ESAP Proceedings

Water and Livestock Development in Ethiopia

Proceedings of the 23rd Annual Conference of the Ethiopian Society of Animal Production (ESAP) Held In Addis Ababa, Ethiopia, August 27-29, 2015

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Ethiopian Society of Animal Production
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Ethiopian Society of Animal Production (ESAP)
P.O.Box: 62863
Addis Ababa
Ethiopia
Tel: 251-115-547-498
Email: esapeth@yahoo.com
Website: www. Esap-ethiopia.org

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Opening Address

H. E Dr. Gebreigziabher G/Yohannes
Sate Minister of Livestock sector Development, Ministery of Agriculture

Honourable Guests,
ESAP members and Participants,
Ladies and Gentlemen**,**
On behalf of the Federal Democratic Republic of Ethiopia, Ministry Agriculture (MoA) and myself, I feel honoured in being amongst you today to officiate the opening of 23rd ESAP Annual conference.

Improvement of water resources has a significant impact on the productivity of the Livestock the livelihood of farmers and pastoralists. The overwhelming majority of livestock products in Ethiopia come from rain-fed areas, which is highly vulnerable to climatic variations. Water availability for livestock is critical in the lowlands. Most of the year, animals have to walk long distances in search of water, and are usually watered once in two to three days. The effect of water stress can be simply stated in the energy loss in long distance walking in search of water and low nutrient intake. Water stress is also pronounced in highland areas of the country especially in areas that receive low rainfall (both in amount and distribution). Water resource management in livestock agriculture is a critical to the economic and social development of Ethiopia. Water is a very scarce commodity for many of the smallholder farmers and pastoralists and their livestock, and the situation is aggravated by seasonal variations in availability of water. On top of this climate change scenarios are aggravating the water shortage. This is more so, given the projections in the Livestock master plan as well as in the GTP II formulation. The expected increase in livestock population and envisaged improvement in productivity (milk, meat, eggs) require more water. Improvements in the modern dairy sector need additional water for milk production and sanitary management. The potential benefits of water economy should be realized in relation to productive parameters, because there would be a trade-off between water saving strategies and production.

Water resource utilization program should therefore consider the current and future demands of livestock and fish production. Selection of appropriate water sources, and the management and protection of these sources are also critical in ensuring that a safe water supply is used for livestock. Research and development initiatives on water, relatedto livestock production and management practices, are limited in scope, and where available the information is not shared widely. In view of these, therefore, the conference will deal with aspects of water in livestock development-research results, development experiences, and considerations on the future demands of water, and efficiency of its use. It is envisaged that the conference will also lay the ground for further research and development priorities. Today we have representatives from different researchers, academia, development practioners, experienced and prominent personalities to share their experiences.

Finally, I wish you all very pleasant and fruitful deliberations and discussion. I declare that the workshop is opened.

Thank you!

Interactions among Water, Livestock, and People on Ethiopia's Borana Plateau: Implications for Rangeland Dynamics and Human Health

D. Layne Coppock, Professor, Dept. of Environment and Society, Utah State University

Summary

Worldwide attention on water resources is increasing. Fresh-water pollution, fresh-water shortages, and negative effects of climate change on ocean chemistry and drought occurrence dominate global concerns. While there has been progress in the development and management of fresh-water resources in wealthy nations, this has occurred relatively recently following major investments in infrastructure, public education, and regulatory institutions. Developing nations have a long road ahead in terms of creating the water systems required to meet the needs of citizens, agricultural systems, and industry.

There have been recent technical reviews that cover water and livestock production in Ethiopia and other developing nations. This paper will not duplicate such work. Rather, the emphasis here is on key interactions among water, livestock, and people in a semiarid Ethiopian environment. The purpose of the perspectives generated is to remind us of the vital roles that water plays and to inspire new scientific ideas. It is forwarded that more research questions in the future should focus on interactions of water, livestock, and people simply because development must promote human well-being.

Ethiopia's Borana Plateau is an important rangeland for eastern Africa. The defining feature of the plateau has been the scarcity of surface water. Despite this constraint, clever Borana pastoralists have created a successful animal-production system here. The lack of drinking water has shaped many basic livestock-production practices as well as the cultural organization of the society. Water scarcity also affects how the people use water in their daily lives. The condition of rangeland vegetation and soils is now in decline across the plateau, however, and a growing number of households are in poverty.

The sustainability of the system has been damaged, in large measure, by chronic over-grazing from livestock. While many factors have contributed to this situation, the fundamental driver has been a gradual increase in livestock water supply in the absence of a socioeconomic transformation for pastoralism. More water has led to more grazing and more grazing has contributed to bush encroachment, soil erosion, and rangeland xerification. The Boran are adjusting to such trends by augmenting their cattle-dominated herds with more browsing camels and goats, but this is insufficient. Additional adaptation should include improvements in grazing management as well as pursuit of livelihood diversification.

It has also been observed that the Boran share drinking-water sources such as ponds and wells with their animals. Animal feces pollute these water sources, and thus debilitating water-borne diseases transferable from animal waste to people (i.e., zoonoses) should be common. Given that the Boran do not treat pond water prior to drinking and there are seemingly no gastrointestinal epidemics, this raises the question as to whether the Boran have become adapted to drinking polluted water. Evidence for this hypothesis will be reviewed.

Compared to the volumes of research conducted on the plateau concerning the socio-ecology of pastoralism, livestock production and health, water resources, and vegetation, the lack of attention to human health as related to water quality or other environmental hazards is, frankly, astonishing. Our priorities as researchers and change agents have somehow become reversed; the plight of livestock producers should be more important to us than the plight of their livestock. It is therefore proposed that a high priority for future integrated studies be the interactions among water, livestock, and people with the main focus on human health and zoonotic disease and how human health can be improved.A framework for uniting livestock, land, water, and human components falls under a "social-ecological systems" or SES approach. This is because livestock production requires feeds, water, human labor, and other inputs to perform optimally. All of these components thus require nurturing attention to yield a sustainable, resilient production system.

Introduction and Objectives

The main purpose of this invited presentation is to highlight issues that pertain to water and livestock agriculture. It seemed most relevant to me that the paper should concern water and livestock agriculture in Ethiopia. Ethiopian scholars have previously reviewed research concerning livestock production and water-use efficiencies (Sileshi et al., n.d.), so I felt there was no need to cover that ground again. Given my long experience working on Ethiopia's Borana Plateau, I decided to summarize key points pertaining to water in the context of the Borana pastoral system.

At first I felt that my colleagues and I had not done much in the way of water research on the Borana Plateau over the past 30 years, but upon further reflection I was wrong—water indeed touched on many of our studies concerning livestock production, livestock population dynamics, rangeland ecology, and socioeconomics. In addition, while working on a recent project in the Yabelo area, water was revealed by participatory needs assessments as a paramount issue for the people living in four neighboring Pastoral Associations (PAs). In addition, casual observations were made concerning the intake of untreated pond water by the pastoralists: water that had been heavily fouled by animals. This raised questions concerning the extent that the local people arewell-adapted to the abundant zoonotic diseases that would be endemic in such situations.

Thus, the main objectives of this paper are to: (1) Review and synthesize water-related research from the Borana Plateau; and (2) identify a way forward for research that considers not only past completed studies, but also incorporates recent observations and hypotheses that connect water to future development tactics and possible interventions that might improve human health. Water issues are also global and timely with respect to the theme of this conference. In recognition of this a third objective was adopted, namely (3) kick-off the paper with a brief overview of world water issues.

Highlights of World Water Issues

Globally, fresh water comprises only2.5 percent of the total water resource, including water in ice sheets and glaciers (Babkin and Klige, 2003). As such, our fresh water supply is indeed precious and worthy of our priority attention as we seek to promote high standards for water quality and quantity in support of

various human uses.Recent allocation for major uses of fresh water worldwide is 65 percent for agriculture, 22 percent for industry, and 7 percent for municipalities (Postel et al., 1996).

And the global demand for fresh water is steadily increasing. Fresh water withdrawals per year have tripled between 1965 and the present day, a function of an increasing human population (with a net growth of 80 million people annually), altered lifestyles and diets attributable to economic development, and changes in how energy is procured and consumed.[1]The result is that the yearly demand for fresh water increases by 64 billion cubic meters.

Most developed nations have made great strides over the past 50 years in improving water quality for their citizens. This has been focused on the aggressive regulation of water pollution and involves coordinated efforts in policy, law enforcement, and public education. While vigilance and active intervention characterizes pollution control and monitoring today, increased attention is now being given to improve water-use efficiency for industry, agriculture, and private household consumption, especially in places where water shortages can occur.[2]

In contrast to developed nations, however, developing nations face a longroad ahead as chronic problems of substandard water quality and inadequate water quantity hinder socioeconomic progress.[3]One case-in-point is illustrated by the fact that over 80 percent of human diseases today are attributable to the consumption of polluted water, and this is concentrated in the poorer nations of the world. Improving this situation requires massive investments in infrastructure for processing sewage as well as water treatment, storage, and distribution. It also requires large capacity-building efforts for regulatory institutions and expansion of public awareness via outreach and educational programs. Some contend, however, that new, more affordable, and less centralized approaches to water development are needed (Gleick, 2003).

Climate change is adding another layer of new challenges to the global water situation, challenges that affect both poor and wealthy nations. Perhaps the most insidious influence is the recently documented role of climate change in increasing oceanic acidity as a result of the oceans absorbing more CO_2. Increasing acidity then impairs the ability of a wide variety of organisms to form calcium-carbonate shells, thereby encouraging their demise and threatening the food webs that sustain fisheries.[4]

Climate change is also affecting precipitation patterns on land; in general, wet regions are anticipated to become wetter while dry regions are expected to become drier (R. Gillies, Utah Climate Center, personal communication). This will translate into more severe flooding regimes and more severe droughts. This bodes ill for poor nations in particular because they lack the risk-management capabilities that can help manage disaster situations or accommodate the movement of “climate-change refugees,” whether they

[1]http://www.worldometers.info/water/

[2]http://www.epa.gov/learn-issues/learn-about-water

[3]http://www.un.org/en/globalissues/water/

[4]http://www3.epa.gov/climatechange/science/indicators/oceans/

originate from drought-stricken regions or inundated coastlines.[5]Wealthy nations are not immune to such problems. Climate change is having well-documented, highly negative effects on the economy of the US state of California, for example. This is largely manifested in the form of prolonged, severe droughts that have crippled agriculture and depleted regional and urban water supplies (Wang et al., 2014).

Indeed, the world faces major challenges in terms of providing humanity with high quality water in adequate quantities in the coming century. The picture, however, is not bleak. The previously mentioned progress made in the developed world has actually occurred relatively recently in historical terms, and this illustrates what can be achieved given a strong dose of political will and adequate financial resources. The political will fostered in the USA during the 1950s, 1960s, and 1970s was fostered by an engaged and alarmed public demanding that political leaders move forward on legislation such as the Clean Water Act (1972) and empowering the Environmental Protection Agency (EPA) in 1970 to enforce new environmental regulations.

Progress is being made in terms of increasing the access of people worldwide to "improved water points" (e.g., those equipped with pipes, spigots, fountains, or pumps), although large gaps in this regard remain for sub-Saharan Africa.[6]Sub-Saharan Africa is also by far the worst continental-scaled region with respect to the poor access that the public has to sanitationin general or potable drinking water.

Economies in the developing world are growing and the voices of their citizens are being increasingly heard with regards to concerns with water pollution and inadequate water supplies. It is likely—although it will take much time and effort—that the trajectory of many developing nations will eventually follow those of developed nations in terms of the growth of an environmentally conscious middle-class that demands efficient socioeconomic development along with concomitant natural-resource protections and improved quantity and quality of fresh water.

From a bird's eye view, the world is actively responding to water challenges in terms of policy development, infrastructural investment, and in the creation and implementation of new water management technologies. Need thus inspires innovation in the case of water. In addition, even the international political sphere exhibits some creativity and flexibility as concerns the management of world water resources. While "water wars" have long been predicted to emerge from competition among nations that share water basins in conflict- and drought-prone regions (Klare, 2001), the reality is that cooperation rules the day. New agreements concerning shared management of international river systems are increasingly common. The process is illustrated, for example, by a growing spirit of collaboration among Ethiopia, Egypt, and Sudan in the management of the Blue Nile.[7]

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[5]http://www.unhcr.org/pages/49e4a5096.html

[6]http://www.cdc.gov/healthywater/global/wash_statistics.html

[7]http://www.bbc.com/news/world-africa-32016763

Water-Use Discrepancies Forged by Economic Development

A huge disparity in household water use between the developed and developing world is fundamentally a measure of stunning differences in living standards. Household water use can be illustrated from surveys(developing world) or billing data(developed world),and it is useful to comparepopulations living under similar environmental circumstances. One case-in-point offers a contrast in household water use in the arid state of Utah (in the western USA) with that for pastoral households in semiarid, southern Ethiopia (i.e., Borana Plateau).

Both places have variable and low annual precipitation and are highly water-limited systems; range livestock production, for example, is a common form of rural land use in both locations. Water-use statistics for Utah are compiled from water billings across hundreds of thousands of households over a wide variety of urban and rural settings; statewide averages still provide meaningful descriptors.[8]Water-use statistics for southern Ethiopia, in contrast, are based on a small sample of pastoral households living under very remote conditions where daily water use by household members was directly surveyed by enumerators (Coppock, 1992; 1994).

Discrepancies in the size and value of dwellings illustrate the basis for differences in water use. For example, the median size of a wooden or brick residential home in Utah is 214 square meters, with a value just over USD $1,000 per square meter.[9] The average size of a wooden- latticed, grass hut with a dirt floor in Borana is about 14 square meters with an unknown (but extremely low) value per unit area (D.L. Coppock, personal observations).Water used by households in Utah is piped directly into homes andassociated lawnsor home gardens. Water used by households in southern Ethiopia, in contrast, is carried by women, donkeys, or camels for several kilometers (at least) to the home village from various central water points.[10]The typical water containers employed are 20-liter,plastic jerry cans (Coppock, 1994).

Utah has experienced massive infrastructural investments in centralized regional and local systems for water capture, storage, and delivery to the tune of many billions of USD over the past 150 years.[11] This is despite that the total population of Utah is only three million people,[12] 90 percent of whom live on about one percent of the total land area of 220,000 square kilometers.[13]While the long-term development of water-related infrastructure is supported by federal and state resources, Utah citizens pay for the delivery

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[8]http://www.water.utah.gov/OtherReports/RWU_Study.pdf

[9]http://www.inman.com/2011/10/27/10-states-with-biggest-houses/

[10]Water points typically are managed by pastoral communities and include ponds, wells, cisterns, or springs (Coppock, 1994).

[11]http://www.uen.org/utah_history_encyclopedia/i/IRRIGATION.html

[12]https://www.google.com/?gws_rd=ssl#q=population+of+utah

[13]http://archive.sltrib.com/story.php?ref=/sltrib/politics/53794385-90/areas-census-concentration-front.html.csp

of a largely safe and reliable water supply to households via local taxes and monthly fees. Contrast this to the Borana Plateau, where today the Oromia state and federal governments are only in the initial stages of developing majorwater-related infrastructure in the northern region near the escarpment of the southern highlands (S. Desta, MARIL, personal communication.) This implies that a region that is home to over two million peoplescatteredacross a 95,000square-kilometerlandscape (Coppock et al., 2011)has no access to anything resembling a modern system for water capture, storage, or distribution.

Data in Table 1 illustrate the tremendous variation in water use between households in the Utah and Ethiopian examples; on average, a Utah household uses 113-times more wateroverall on a weekly basis.Interestingly, large proportions of the household water budget in both situations go to non-human uses; for Utah the vast majority of water in residential settings not used by people is used to irrigate highly manicured, grass lawns that serve ornamental (cultural) purposes. Some of this water in suburbia also supports small gardens that yield vegetables for home consumption or local sale. For Ethiopia, a large proportion of household water is given to pre-weaned calves kept in or near the home as their herded dams graze and consume water at distant locations. Ensuring calf survival via such hand-rearing methods is vital to promote herd growth and animal asset accumulation (Coppock, 1994).

Discrepancies forged by economic development in the remaining household water budgets used by people are further magnified by the fact that Utah households—with about three persons on average[14]—are half the size of Borana households (Coppock et al., 2014a). This suggests greater differences per capita than suggested by Table 1 with respect to households. On a per capita basis, Utahns may use 700-times more water than the Boran for personal washing or hygiene.

[14] https://www.census.gov/newsroom/releases/archives/2010_census/cb11-cn139.html

Table 1. Comparative water-use statistics (liters per week) for average households in the state of Utah, USA, andremote locations on the Borana,Ethiopia.[1]

Category	Average Household in the State of Utah	Average Household on the Borana Plateau
Total water used per household	8,847 (100%)	79 (100%)
Water used for gardens, lawns, or livestock	5,309 (60%)	25 (32%)
Water used for personal washing,hygiene, etc.	2,300 (26%)	7 (9%)
Water used for cooking, drinking,etc.	619 (7%)	34 (43%)
Water used for cleaning the home, utensils, etc.	619 (7%)	13 (16%)

[1]Note that the Utah households are typically located in a highly developed urban settingwith water use averaged throughout a calendar year, whilethe Boranapastoral households represent an extremely undevelopedruralsituationwith water use considered over two months at thepeak of an annual dry season. Developed urbansettings in Ethiopia will show somewhat intermediate figures.Utah data are from 2009 (http://www.water.utah.gov/OtherReports/RWU_Study.pdf) while theEthiopian data are from Coppock (1992;1994).

The massive discrepancies in the access and use of water between citizens in Utah and southern Ethiopia may not be surprising, but they are disturbing nonetheless. They illustrate the urgency needed to doggedly pursue water development in poor nations like Ethiopia, and this is not only in support of improving plant and animal agriculture but to support processes that begin to rectify such enormous concerns to alleviate human suffering. According to Article 25 of the Universal Declaration of Human Rights,[15]*"everyone has the right to a standard of living adequate for…health and well-being…"*; it is posited here that an adequate water supply is a foundation of this premise. Eighty liters of water per household per week is indeed a shameful statistic, and the situation must be improved.

Water, Livestock, and People on the Borana Plateau

Study Area

As previously noted, the Borana Plateau is a 95,000 square kilometer region in southern Ethiopia. It is described in detail by Coppock (1994). The Borana Plateau has a relatively cool, semiarid climate, and this is primarily due to the elevation (i.e., 1,000 to 1,500 meters above sea level). There is a bi-modal pattern of rainfall delivery that ranges between 550to 700 mm per year. Most (60 percent) of the annual precipitation occurs during the long rainy season of March to May, with the remainder occurring during the short rainy season of October to November. The climate is generally semiarid. The intervening dry seasons are referred to as the cool dry season (from June to September) and the warm dry season (from

[15]http://www.un.org/en/universal-declaration-human-rights/

December to February.) The vegetation is dominated by perennial grasses and woody *Acacia s*pecies and hence is a mixed savanna (Coppock, 1994).

The people who live on the plateau are pastoralists representing several ethnic groups. The largest group is the Boran. The Boran are *Oromifa*-speakers who have occupied the region for centuries. These people herd livestock and have traditionally subsisted on animal products (i.e., milk, meat) either for direct consumption or via sales in small towns to purchase non-pastoral foods (i.e., cereal grains, pasta), clothing, or special items such as coffee beans, chewing tobacco, or household items. Households own the livestock. The dominant species has been cattle (specifically, the Boran breed) that are prized for the quantity and quality of their milk production and their tolerance to difficult production conditions (Coppock, 1994). Cattle holdings per household have been traditionally supplemented with a few sheep or goats and a donkey for portage; in recent times camels have increased in importance. The household unit typically consists of about six members with a husband, wife, children, as well as extended family members (Coppock, 1994; Coppock et al., 2014a).

The Boran live in encampments (e.g., *olla)* that traditionally were relocated when livestock were moved in the search of forage and water. The *olla* occur in *madda,* traditional units of resource allocation that include dry-season water points (e.g., deep wells), wet-season water points (e.g., ponds), and forage resources used all year (Coppock, 1994). The Boran have traditionally practiced a semi-nomadic lifestyle where the herds moved frequently and households moved occasionally.

The Borana pastoral system has exhibited considerable change over the past 30 years. The ratio of livestock to people has been declining, mostly as a function of more people on the landscape. The numbers of livestock fluctuate in a boom-and-bust fashion as affected by drought and stocking-rate dynamics (Desta and Coppock, 2002; 2004). Livestock numbers are increasingly limited by the availability of forage and water—hencelivestock numbers cannot keep pace with growth in the human population. Fewer livestock per person are indicative of less milk production and fewer animal assets per person, and hence an increasing risk of poverty and food insecurity.

Synthesis of Review Findings for the Borana Plateau

Water Scarcity Affects the Natural Biota. Inventories of native plants and animals conducted by various investigators on the Borana Plateau were first summarized by Coppock (1994). Perhaps one of the most striking features of the region is the extent that water limitations have shaped the biota. One prominent aspect of water on the plateau proper is simply the relative lack of permanent, natural sources of surface water. Simply put, there are no lakes, rivers, or streams in the central region. Scattered springs are confined to rugged mountainous areas. The ponds and deep wells have been createdby people; the deep wells have existed for centuries while ponds have proliferated more in recent decades as human populations have grown and heavy machinery has become available in support of transport infrastructure projects.

The general aridity and lack of surface water accessible to wildlife has led to an assemblage of animal species that are very tolerant to water deprivation. They maintain relatively low population numbers and obtain much of their water requirements from forage rather than drinking sources. Common examples of

such species on the plateau include the dik dik (*Madoqua* spp.) and guinea fowl (*Numida* and *Acryllium* spp.; Coppock, 1994).

In addition, the dominant plant species are well-adapted to environments where moisture is seasonally limited. Examples for drought-adapted woody plants on the plateau include numerous *Acacia*spp. that exhibit water-harvesting crown morphologiesand *Commiphora* and *Boscia* spp. that often possess waxy leaves to inhibit transpiration. Root morphologies of these plants also can take advantage of either intercepting light precipitation near the soil surface or mining water from very deep in the soil profile (Coppock, 1994).

Water Scarcity Affects Pastoral Social Organization. The Borana people that inhabit the north-central plateau primarily rely on two main water sources for both people and livestock. These include: (1) Ponds that are used during and shortly after the two rainy seasons, and (2) deep wells that are used during the peak of the two dry seasons, but mostly during the height of the warm dry season from December to February. Ponds provide about half of the annual water requirements with the wells providing most of the remainder. Of these two water resources, it is the deep wells that have had the most profound effects on the structure and function of Borana society. Deep wells will thus receive attention in this section, and many points made synthesize points from previous work conducted by Coppock (1994) and Coppock et al. (2014a,b). Ponds will be discussed later in the context of improving rangeland sustainability and human health.

The deep wells.A network of deep *(tula)* wells provides the backbone for the Borana production system. These wells reliably yield water every year for livestock and people at the height of the warm dry season, thus enabling the pastoralists to overcome the fundamental bottleneck that challenges their survival.There are over 500 deep wells distributed among 40 clusters in the region, with an average of about 12 wells per cluster. Each cluster is an epicenter (or co-epicenter) of some 29 traditional *madda*, spatial units of forage and water allocation that incorporate encampments (e.g., villages); *madda* have been introduced previously. Well clusters are located where the soil and rock substratesare sufficiently thin and soft to allow excavation via human labor using hand tools over 500 years ago.There is not a definitive agreement on who originally dug the deep wells, but scholars agree that it was not the Boran (Coppock, 1994).

The structure and function of deep wells was initially reported by Cossins and Upton (1987) and cited in Coppock (1994).Starting from the water source*(madda ella)*, each well consists of a lower basin *(hawa)* adjacent to the source that forms the base of a vertical shaft. The shaft can be up to 40 meters in height and is served by six or more small ledges where people stand and pass small buckets of water upwards. Buckets of water eventually reach a basin at the top *(fechana)*. Water is then raised by hand another one to three meters to long and narrow watering troughs *(naninga)*, and the now-empty buckets are passed back down the chain.The troughs form the border of an open access area where dozens of livestock assemble and crowd shoulder-to-shoulder to drink. The troughs may be located five to ten meters below the surface of the local landscape; thus animals usually must descend to the troughs via five-meter wide ramps that may follow a direct linear path or a curling trajectory. Large earthen berms that define the well proper have been created from the tons of soil excavated when the ramps and trough access areas were created. Thirsty livestock are restrained from a chaotic descentdown the ramp via people who regulate traffic to maintain an orderly process. Herds arrive for watering based on a daily schedule, and the "watering order" can be influenced by traditional rules of access that consider where the herd owner

resides as well as aspects involving local and regional reciprocity of resource use.[16]The "check point" at the ramp entrance is referred to as the "mouth of the well." Dung and other refuse deposited on the ramp or in the trough access area is collected by hand and accumulated in large piles away from the ramp entrance. This is an effort to minimize water contamination by livestock feces that would otherwise easily pollute the *ella* as a consequence of concentrated runoff from local rainfall events.

The main point regarding the deep wells is that their efficient operation requires considerable human labor and organizational acumen. Paragraphs that follow illustrate the societal commitment required by the Boran to effectively and equitably distribute dry-season waterthat reliably emanates from the deep wells. I contend that this situation has helped to foster a high degree of social organization and centralized leadershipamong the Boran (i.e., also evidenced by elements of the *Gaada* and *Gumi Gaayu*) that is highly unusual among pastoralists. In other words, the opportunity to manage dry-season water on the plateau has had profound effects on shaping the structure and function of Borana society and its associated institutions.In contrast to the Boran, other East African pastoral groups such as the Turkana, Afar, or Issa lack the water resources that would compel similar investments in traditional governance. The Turkana, for example, are well known for decentralized leadership, and this instead promotesa high degree of herd owner independence from authority as well as flexible opportunism as herd owners pursue scarce and ephemeral natural resources (Coppock, 1994).

To illustrate the organizational efforts needed to operate the deep wells, it has been estimated that five to 20 laborers are required to operate any given well shaft on any given day, and considering multiple shifts for this arduous work (Coppock, 1994). And this excludes the additional effort needed to regulate the daily flow of thousands of animals and keep the ramps, troughs, basins, and associated structures tidy and in good repair. The deep wells typically are in full operation for three to four months of the year, with longer commitments occurring during drier years. When the labor demands above are extrapolated across the central region, it suggests that on the order of 5,000 laborers are needed on a daily basis simply to pass water buckets.

The need to maintain tightly orchestrated labor schedules among thousands of people requires strong leadership and effective organization. There are designated roles in Borana society to oversee deep-well operations including well councils *(chora ella)*, "well fathers" *(abba ella)*, and "fathers of the herd-watering order"*(abba hirega)*.The labor for any given well cluster comes from the local network of settlements served by the cluster. It has been estimated that up to 60 percent of men and boys aged 10 to 50 from local settlement networks are engaged in well operations; women and girls have also been known to participate, as needed. The settlements are located in the proximity of their respective well cluster, but not too close. Before the recent advent of mobile phones, having settlements near each other and also near the well clusters would facilitate access to wells and assist the need for regular verbal communicationnecessary for coordinating worker cohorts.

With well clusters identifying a geographic center of a *madda*, different concentric zones emanate outwards from the cluster. The innermost zone is called the "well zone,"and this is a sacrifice area subject

[16]Wells are affiliated with one of two Borana clans, and clan affiliation thus matters in the degree of access a herd owner can have to local wells and the associated grazing areas.

to heavy trampling by hundreds of thousands of livestock that may be several kilometers in diameter. The next zone outwards is called the "settlement zone" where most of the encampments or villages are located and where the less-mobile livestock are taken to forage locally*(warra.)*The distance between settlements and the deep wells is thus optimized so that walking distances for people are modest (as above),but human exposure to concentrated environmental impacts by livestock in the well zone is minimized. The outermost and largest zone is the zone where the most-mobile livestock can be taken long distances to forage *(forra)*.

In summary, then, the deep wells indeed affect Borana social organization. It is also evident that the deep wells influence the spatial distributions of people, settlements, and livestock across the landscape. These distributions, in turn, affect patterns of grazing and browsing that shape the structure and function of plant communities and the associated wildlife.

Water Scarcity Affects Pastoral Households. As previously mentioned, water availability greatly varies by season on the Borana Plateau. Rainfall during the long rainy season (i.e., March to May) and short rainy season (i.e., September to October) typically fillsmost of the ponds, at least for short periods. The combination of locally accessible drinking water, fresh green forage, and birth patterns for livestock that coincide with wet periods all lead to relatively abundant supplies of water and milk for people,over a few months in each case. These are times when the labor needed for households to acquire water is lower compared to that for dry periods and when water supplies are less limiting in fulfilling the human needs shown in Table 1.

The warm dry season (i.e., typically covering November to February) is the most stressful period of the year with respect to water. During this season no rainfall may occur, air temperatures rise, vegetation dries out, ponds dry up, and lactation outputs for most livestock species markedly decline. This is the period when human labor output for water procurement dramatically increases; water must be carried to the home from increasingly distant locations (i.e., from the largerponds and the deep wells); in addition, family labor must be contributed to support the operations of the deep wells. While data do not exist with respect to quantifying the use of water by the Boran throughout the year, it is likely that water use by people is highest during the rainy seasons and lowest during the warm dry season. It is also reasonable to expect that the Boran reduce their demand for water during dry seasons, even to the extent of undergoing water deprivation. It is already known that adults, in particular, will reduce their demand for food during dry seasons and drought (Coppock, 1994).

Gender.I have worked on the Borana Plateau for 30 years, although on a discontinuous basis. One truism from my experience is that I have never observed men or boys physically carrying water using their own muscle power. Men or boys, however, may accompany donkeys or camels that are hauling water. Both of these livestock species can be outfitted with a wooden and leather apparatus—strappedon like a "saddle"—which enables up to four 20-liter, plastic jerry cans of water to be carried. Today, most pastoral households in the central plateau region have either a donkey or camel for portage purposes (Coppock et al., 2014a).

While women or girls may also accompany donkeys or camels hauling water, in contrast to males, the females are commonly observed carrying water using their own muscle power. The container most often

used by women is again the 20-literjerry can. This can be transported by either balancing it on their heads or by carrying it on their backs via leather or woven straps over the shoulders and/or across foreheads.

Teenage girls and adult women in Borana are typically lean and slight of build. It is therefore reasonable to assume that their weight varies from 32 to 55 kilograms, respectively (D.L. Coppock, personal observations). Given that a full jerry can of water weighs 21 kilograms including the container, it is possible that a water-carrying journey involves transporting from 65 to 38 percent of their weight. Even if these estimates are twice as high as what actually occurs, the task is onerous indeed. Research (Dufaut, 1988) suggests that carrying water by women over long distances can result in extreme energy depletion over the short-term, which can make them vulnerable to malnutrition, anemia, and other illnesses. Over the long-term, the practice can lead to skeletal problems for the neck, spine, and pelvis.

Married women on the plateau have a wide variety of daily tasks to complete (Coppock, 1994). As the primary custodian of the family domicile, the tasks include childcare, meal preparation, hut maintenance and repair, milking livestock, and providing traditional health interventions for livestock. In support of these tasks are onerous duties that include collecting firewood for cooking and heating the hearth,and hauling water for the purposes shown in Table 1.

There have not been rigorous studies on the plateau concerning the time and effort expended by women and girls to haul water throughout the year. It can be assumed that there is at least one trip to water per household per day, or 365 trips per year. Using interview data,Mulugeta Assefa (1990) estimated that pastoral women spent 30 hours per week hauling water in the warm dry season. If this is accurate, it suggests that hauling water could comprise about 36 percent of a work week totaling 84 hours (i.e., 12hoursof daylight per day x seven days).

Roles of cement cisterns in promoting water access and laborsavings.An experimental study was conducted in the central region of the Borana Plateau during 1990 where enumerators were assigned to watch 64 married Borana women during waking hours over several weeks at the height of the warm dry season (Coppock, 1992).Women were sorted into several experimental groups, but only two concern us here: (1) A control group consisted of 32 women that had access to traditional water points (deep wells); and (2) a treatment group also having 32 women, but in this case they had access to cement cisterns built by CARE-Ethiopia in 1988. The cisterns were about four-meters deep on average, with base dimensions of four by five meters; construction details are found in Coppock (1994).At full capacity the cisterns could hold 90,000 to 150,000 liters of water. Cisterns were positioned below-groundand had wood-latticed roofs at the ground surface that were covered with long, dry grass woven into the lattice work to reduce contamination. The cisterns filled via rainfall surface runoff that entered the spillway after passing over silt traps.The cisterns provided local access to water when compared to the deep wells. Data collection included: (1) Continuous observation of the women over 12-hour periods (with data recorded at 10-minute intervals) for seven consecutive days; and (2) interviews involving 24-hour recall and opinions concerning household water use.

Overall, the walking distance from the control households to the nearest wells was a 14-kilometer round trip that took 2.8 hours. In contrast, the walking distance from the treatment households to the nearest cistern was 0.75 kilometers that took 15 minutes. Therefore, based on one trip to water per household per day, it was expected prior to conducting the research that a control household could spend 19.6 hours per

week collecting water over a cumulative walking distance of 98 kilometers. If one jerry can was transported for each trip, the water volume carried would add to 140 liters. If the women for the treatment households would carry a similar volume of water during a typical week, the time and effort required should markedly decline. We expected, for example, that when compared to the controls, the hours per week hauling water could drop by 90 percent to 1.75 hours and the cumulative distance covered could drop by 95 percent to 5.25 kilometers. It was also expected that the treatment households could use more water than the control households, but this difference could not be precisely estimated.It is logical to expect, for example, that treatment households might have more water for people to drink or for washing. In summary, we anticipated that the cistern intervention could have a wide variety of positive effects on the Boran, namely freeing-up women's time and labor so they could engage in more important or valued pursuits, and increasing basic access to water to improve human welfare.

The results of the study in Coppock (1992) only partially supported the predictions above. Surprisingly, women in the control group spent only 8.3 hours per week hauling and drawing water, while women using the cisterns spent 8.2 hours per week in the same activities. This remarkable result was due to two main factors: (1) We greatly overestimated the time women actually spent fetching water in the traditional system—the women inflated the numbers in prior interviews—whether this was meant to mislead or due to recall bias is unclear; and (2) improved access to cisterns meant that the number of trips to water doubled, from five trips per week for the controls versus 10 trips per week for the treatment group. Having a closer water point meant more trips per week that equalized the overall time commitment between control and treated households.

Access to cisterns, however, strongly affected total water use, but categories of water use markedly differed from expectations. On average, a control household procured 78 liters of water per week, while a treated household procured 134 liters per week—an increase of 72 percent. Interestingly, there was only one category of water use that significantly changed with access to the cisterns, namely water for cattle calves hand-reared in the home.[17] Water for such calves increased from 23 to 75 liters per week, or by 226 percent.

At first glance, the observed results were confusing and paradoxical given that studies elsewhere in Africa have shown reduced labor demand for hauling water and greater water use by families in farming villages when water points have been either developed or upgraded (Cairncross, 1987). Ultimately, however, our results made sense given the severe water restrictions during dry periods on the Borana Plateau as well as the very high economic value of cattle for pastoralists (Coppock, 1992). The cisterns were indeed useful interventions in two main respects. First, despite that total time fetching water was unchanged due to the provision of cisterns, the arduous and stressful nature of carrying water long distances by women was mitigated—thispromotes human welfare. Second,cisterns were used to supply more water to calves, and simply keeping calves alive through the weaning phase is the critical production intervention for this system where pastoralists can exert the most control (Coppock and Sovani, 1999). Adequate water can help promote forage intake and improve nutritional status as young calves make the transition from a milk-based diet to a forage-based diet.

[17] On average, the number of calves hand-reared in the households was three, with no significant differences between control and treatment groups.

But why would the Boran increase water intake for calves, but neglect to enhance water use for themselves—evenby a significant fraction? The answer may lie in how these people view risk and uncertainty in their access to natural resources here. For example, in our view as researchers we see the water in the cisterns as merely a temporary bridge between the warm dry season and the upcoming long rains, and we expect that water-deprived people would certainly increase their water demand during the interim simply to improve their well-being.

In the view of the pastoralists, however, they can't assume with certainty that the long rains will arrive. Indeed, the onset of the rains may be delayed for weeks or even entirely fail this year. This view justifies a very conservative approach in using water during the time frame of the study. If the long rains arrive on time, water then becomes plentiful. If the long rains fail, the cisterns become a longer-term reserve supply of water that can carry the community into an uncertain future (Coppock, 1992).

In summary, water scarcity greatly affects how Borana households collect, use, and manage water. Effects of interventions like cisterns, however, may be counter-intuitive, especially if researchers misperceive how the research subjects actually view resource-use priorities and the role of uncertainty in household decision-making. Water also has a strong gendered component here, especially manifested in labor allocation for fetching water for household use—this seems to almost entirely fall on women and girls and is thus embedded in the male-dominated culture. There are probably long-term consequences of water carrying on the health and vitality of pastoral women, and this merits study. Increased investment in water development and making animals such as donkeys and camels more available here for portage, can help reduce the onerous burdens on women, and this is an important development goal.

Water Scarcity Affects Cattle Productivity. The relatively cool climate of the Borana Plateau is fostered by the high elevation and bimodal rainfall regime. This climate, inconjunction with the previously mentioned scarcity of surface water during dry periods, compelledthe Boran to develop an unusual, multi-phased watering system for cattle. Work by multiple authors on this topic is reviewed in Coppock (1994).

The system is comprised of two distinct phases of cattle management. The first phase occurs during wet seasons with locally abundant forage,when cattle would be watered as frequently as possible—and largely from rain-fed ponds. Such a practice promotes higher rates of forage intake and a boost to milk production that benefitsboth calf growth and human nutrition.The second phase occurs during the peak of the warm dry season, when cattle can be watered once every two or three days, depending on the local availability of forage and water.

The disadvantage of infrequent watering for cattle would be in terms of reduced forage intake and reduced milk yields, although scarcity of forage and low rates of milk production would already characterize the warm dry season. The advantages of infrequent watering, however, could be viewed as more compelling for sustaining the production system given the dominant constraints. The advantages include: (1) Allowing cattle to range further from the centrally located deep wells as they search for adequate forage supplies during dry periods; (2) conserving water in the deep wells; and (3) conserving the human time and labor required to operate the deep wells.

It is the relatively moderate temperatures on the central plateau that allow cattle to tolerate water restriction. Moisture losses due to evaporative cooling are lessened in the Borana case when compared to other situationsin pastoral eastern Africa where hotter temperatures at lower elevations impose a higher incidence of heat stress on livestock. It is also notable that the Boran cattle breed is known to be well-adapted to dry conditions, and this includes phenotypic as well as physiological aspects [see review in Coppock (1994)].

Experimental trials at Abernosa Ranch.Nicholson [1987; summarized in Coppock (1994)] undertook controlled trials at Abernosa Ranch in the central Ethiopian Rift Valley. He wanted to characterize effects of restricted watering on the productivity of Boran cattle that were otherwise managed as an on-station herd. The treatments and highlights of some key statistics for calf growth are shown in Table 2. Overall, the effects of restricted watering on the live-weight dynamics of calves whose mothers were managed under the two watering frequencies shown were modest. The greatest effect between calves reared under the daily watering regime versus those reared under the once-every-third-day watering regime was a decline in calf live weights for the latter of 11 percent at seven months of age. This difference narrowed, however, to only three percent by 24 months of age. These differences in calf growth were probably due to differences in milk production of the mothers, but milk production due to treatment was not

Table 2.Mean live weights (kilograms) for calves at varied ages when their mothers were subjected to different experimental watering regimes atAbernosa Ranch in the Ethiopian Rift Valley.[1]

Treatment	**Calf Age (months)**			
	7	**12**	**18**	**24**
Daily Watering for Dams	140	210	230	313
Every-Third-Day Watering for Dams	125	191	215	306

[1]Based on work performed by Nicholson (1987) and reviewed in Coppock (1994). The sample size for the seven-month results was n=50, while the sample size for the other results were n=25.See referenced work for the statistical results.

directly measured. While it could be argued that 15 kilograms difference in calf weights at seven months may have some financial consequence in a commercialized cow-calf system common in the USA and other developed nations, the live weight variation evident in Table 2 overall is of dubious significance for pastoral systems where animals are sold at advanced ages (Coppock, 1994). The pattern in the Abernosa data is one of gradual convergence between treatments.

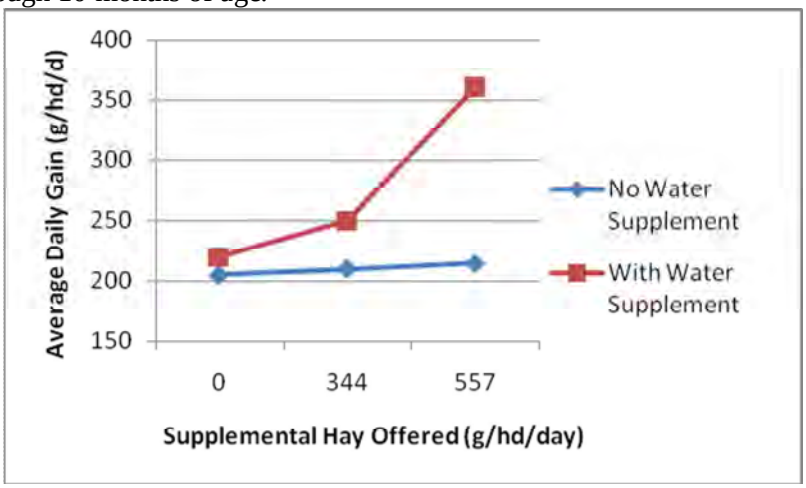
Experimental trials with calf growth on the Borana Plateau.Coppock and Sovani [(1999), with preliminary results reviewed in Coppock (1994)] conducted a four-year experimental trial under near-pastoral conditions at Demballa Wachu Ranch on the Borana Plateau. The research was designed to answer the question whether supplementation with high-quality hay and water could help calves compensate for the loss of roughly half of their mother's milk production that otherwise went to people. The idea was that milk restriction for calves in pastoral systems yielded animals at weaning that were of

low weight, possibly lacking in vigor, and that as heifers would show delayed onset of puberty. This would essentially drag down the overall productivity of the system in terms of calf recruitment. Because the people relied on the foregone milk for their own food supply, strategic supplementation with forage could be the main option for intervention.

The experiment involved a factorial design offering calves one of three levels of alfalfa hay (i.e., 0, 344, and 557 grams per head per day on a dry-matter basis),and one of two levels of supplemental water (i.e., 0 and 3.8 liters per head per day).This was over and above a background regime of simulated pastoral management that included restricted access to milk from the dams plus local grazing in and around a recreated *olla* having dozens of "calf huts." The treatment receiving no hay and no extra water constituted the controls in the factorial design. There was also another control group of calves, however, that received all of the milk from their dams with no access to hay or added water, and this group was for comparative purposes outside of the core factorial design. The mother cows for all calves were managed as per pastoral practices that included local grazing as well as seasonal shifts in access to ponds and deep wells. Calves were evenly split between males and females, with 44 total animals in each of six factorial treatment combinations. After weaning at 10 months of age, the calves were managed in a traditional fashion; live weights were noted thoughout the trial period from birth onwards. At roughly 3.5 years of age the heifers were assessed for pubertal features and pregnancy; this followed exposure to breeding bulls that were added to the experimental herd. Ultimately this design would test the idea whether there was a significant carry-over effect of supplementation on reducing time to pregnancy.

The relevant issue for this paper was the strong effect of supplemental water on cattle productivity. The forage x water interaction is depicted in Figure 1. It was the supplemental water that allowed calves to consume more of the supplemental hay, and the treatment having the high level of hay plus the added water yielded animals having near-identical mean weights at puberty to those of calves in the positive control group that had received all of their mother's milk. Thus, the hypothesis was confirmed that supplementation could compensate calves for

Figure 1. Supplemental hay x water interaction for growth of Boran calves though 10 months of age.[1]



[1]Figure adapted from data in Coppock and Sovani (1999). The factorial interaction was significant (P<0.01).

milk restrictionbut that water was required in addition to the hay. In general, however, both males and females showed trends to converge in live weight between 10 months (e.g., weaning) to 3.5 years of age. Heifers from the high hay plus water treatment also reached puberty from 2.6 to 4.3 months earlier than controls on restricted milk access and no supplements, but it was concluded that this effect was not enough to offset the supplementation effort and costs. Basically, the variable, harsh environment of the rangelands exerts strong control over cattle performance. Water scarcity plays a big role in such processes. The best thing that pastoralists can do is ensure that calves survive until weaning (Coppock and Sovani, 1999). This conclusion is supported by other observations of the high labor investment that the Borana women make in terms of carrying extra water to their homes in support of calf management, as well as the rationale that extra water provided by cisterns be devoted to calves, not people (Coppock, 1992).

In summary, the livestock production system of the Borana pastoralists has been designed to accommodate highly valued cattle in a seasonally water-restricted setting by reducing the frequency of watering. This conserves water, promotes grazing over larger portions of the dry-season landscape, and conserves human labor. The scientific evidence suggests that while water restriction can hinder forage intake and hence growth of young animals, this is not necessarily a situation that leads to outcomes such as permanent stunting. Compensatory growth and a generally harsh, variable environment ultimately act to harmonize animal productivity over time. However, it is fair to say that while researchers have studied the effects of restricted watering on productivity parameters relevant to commercialized systems (i.e., growth, time to puberty), they have not studied parameters of greatest importance to the pastoralists themselves (i.e., milk production). Study of how restricted watering affects milk production would thus best illuminate the true key tradeoffs in the system. Finally, there is little doubt that the prevailing, relatively cool climate on the Borana Plateau has allowed restricted watering for cattle to occur over many generations. Climate change, however, is gradually making the region warmer and drier (Funk et al., 2012).It is therefore logical to expect that climate change will make restricted watering more difficult to implement for cattle without risking even lower levels of productivity or higher rates of dry-season mortality. Climate change and water shortages may compel the Boran to shift their emphasis from cattle dominance to incorporate more drought-tolerant small ruminants and camels in their holdings, a pattern that is already underway for a variety of reasons (Desta and Coppock, 2004).

Alleviating Water Scarcity Can Negatively Affect Pastoral System Dynamics

The material reviewed thus far amply demonstrates that water scarcity affects many aspects of the Borana pastoral system. It is therefore logical that water development makes sense to enhance human welfare and boost livestock productivity. The record, however, shows that poorly planned water development can negatively affect African pastoral systems by undermining traditional grazing controls and accelerating environmental degradation (Coppock, 1994).

In a nutshell, it is common in traditional pastoral systems that access to dry-season grazing is fundamentally controlled by the associated access to nearby water. Livestock can only travel certain distances to feed before they also need to find water; scarcity of surface water thus imposes *de facto* controls on access to local grazing, and this can help conserve forage and keep stocking rates moderate. In

the case of the traditional Boran society, for example, if a herd owner has permission to take his animals to certain deep wells, then this also gives his herd access to the local forage. Such arrangements are often part of regional reciprocity rights within and between clans (Coppock, 1994). But there are instances when water access for a herd owner can be denied, and this is when local management criteria—suchas a shortage of grazing—cancome into play.

The problem with water development occurs when outside entities do the planning and pastoralists are excluded from the process. New water can thus impose a stressor on the system if there are no associated social norms to regulate access. New water can thus lead to higher and uncontrollable stocking rates; the latter then can push foraging to a scale where rangelands are effectively destroyed. This will not happen in every case, but it certainly has been implicated in the gradual deterioration of many pastoral areas (Coppock, 1994).

One irony is that, at least until recently, the Borana Plateau was viewed as a model for sustainable pastoralism (Coppock, 1994). This image was mostly conferred because Borana society had not been subjected to unplanned water development. In addition, the region was traditionally isolated from major urban centers and hence outside interference in natural resource management. Elsewhere in this proceedings volume, Coppock et al. describe a situation on the Borana Plateau as recently studied under the auspices of Project Kalo. The specter of pervasive environmental degradation in the north-central region as well as pervasive food aid testifies to the idea that the Borana pastoral system is now unsustainable (Coppock et al., 2014a,b).

It is theorized here that the widespread prevalence of soil erosion and bush encroachment so evident on the plateau today is due to long-term over-grazing by livestock, and this, in turn, is linked to uncontrolled water development that gradually began over two generations ago.[18] I do not contend that all such water development has been unnecessary; indeed, the leading edge of change occurred with creation of the large, permanent pond (e.g., lake) at the Beke site to the North, and this process was likely inspired by humanitarian needs. These needs grew as the numbers of pastoralists being displaced by population growth in centrally located *madda* expanded andneeded new access to water and grazing somewhere else.Today's environmental degradation on the plateau is simply the sum local cost of a nation not being able to absorb excess numbers of people from rural areas into gainful urban employment and also not being able to invest in government institutions that could assist the Boran in promoting sustainable systems of natural resource use and conservation.[19]Another important contributor has been the lack of alternative investment to livestock. If pastoralists had a rationale to invest in non-pastoral opportunities in addition to livestock, wealth could be better conserved and the rangeland environment would also benefit (Desta and Coppock, 2002).

An overly-simplified depiction of events leading to environmental degradation on the plateau is shown in Figure 2. It is hypothesized that human and livestock populations began to accelerate in the 1950s, 1960s,

[18] The eradication of major livestock diseases such as rinderpest, and improved access of pastoral people to food and medical interventions, have probably also contributed to the described system dynamics.

[19] The Forest Service and the Bureau of Land Management are examples of federal agencies in the USA that have promoted the wise use and conservation of grazing and other natural resources on public lands for many years by working collaboratively with local communities.

and 1970s. Uncontrolled water development for ponds began in the 1960s and accelerated into the 1970s and 1980s. Efforts to increase the capacity of deep wells were observed in the 1990s (D.L. Coppock, personal observation). Bush encroachment was well underway by the 1970s (reviewed in Coppock, 1994). Focus groups conducted with pastoralists under the auspices of Project Kalo indicate that gully erosion began to appear in the 1990s and early 2000s (Coppock et al., 2014a).

Recent Concerns: Water Supplies and Health of the Social-Ecological System (SES)

In previous sections of this paper,highlights have been presented as to how water has profoundly affected several aspects of the Borana pastoral system. The highlights describe outcomes from somewhat disconnected research projects conducted between the early 1980s to the late 1990s. In sum, they collectively point to a need for more water development to promote human welfare on the plateau, but they also underscore the dangers that poorly planned water development can pose for things like accelerated land degradation or the possible unraveling of Borana social institutions.

Figure 2. Conceptual diagram linking a timeline of factors contributing to environmental degradation on the north-central Borana Plateau.

In this section highlights will be presented of recent research (i.e., Project Kalo that was operational from 2012 to 2015). In this project,water management has emerged to assume an extremely important and central role. This gives us a chance to formulate a more unified vision as to how concurrent problems involving water supplies, land degradation—and even human health—could be simultaneously tackled in a comprehensive pastoral research and development effort. Such a unified vision embraces the concept of "social-ecological systems," a relatively recent term in the ecosystems literature that considers an agroecosystem to be an integrated whole having biotic, abiotic, and human components (Folke et al., 2010).[20]

In the vision of a social-ecological system (SES), interventions would preferably involve technical as well as social elements, and these would interact to improve both the biological basis for productivity as well as building resilience in the human society that manages that system. It is likely that the vision developed for the Borana Plateau is probably also relevant to other pastoral and farming systems in Ethiopia. I begin by revisiting a key water resource that has only been briefly touched upon previously—and is the cornerstone of our vision—namelythe large network of pondson the central Borana Plateau.

In acontributed synthesis paper to this proceedings volume, Coppock et al. describe Project Kalo. Project Kalo was created to discover opportunities to promote production enhancements in the Borana pastoral

[20] Socioecological models, however, have long occurred in other fields including health, psychology, etc.

system. We were also responsible to extend new innovations in land or livestock management to the pastoralists in the hope they might be adopted, but we were only given three years to complete this task. Because of this project mandate, we decided to rely on participatory community engagement by using tools such as Participatory Rural Appraisal (PRA; Lelo et al., 2000; Narayanasamy,2009), Participatory Action Research (PAR; Whyte, 1989), and focus groups (Short, 2006). Involving the pastoral community at the start would greatly improve the likelihood that important problems would be identified; it would also improve the chance that new innovations would be adopted. This is unlike conventional research where study tends to be conducted more independently of community needs (Coppock, in press).

Details pertaining to the methods and outcomes for Project Kalo are reviewed elsewhere in this proceedings volume and will not be repeated here. However, one major finding was that the most pressing need for the four pastoral communities analyzed was simply improved water supplies. No other element—forage, livestock health, poverty alleviation, livestock marketing—was even close. Thus, because we wanted Project Kalo to reflect the priorities of our host communities, water problems took center stage.

As previously noted, water resources on the plateau are dominated by deep wells and ponds. Cisterns or other cement structures built by development agencies since the late 1980s can be locally important, but regionally they are very minor in terms of total annual water supply. We focused on ponds for a couple of reasons. First and foremost, because our project was mandated to improve the livestock production system, the water resource we should engage with would ideally connect with forage resources and land use in some direct fashion. Ponds satisfy this requirement, as will be described. Second, while the deep wells also merit research attention, the scope for intervention is on a much greater scale than that for ponds. Ponds tend to be locally managed, and marshalling the resources to improve pond stewardship could involve thousands of USD per pond catchment (see below). The deep wells, in contrast, constitute regionally and politicallyvital resources that receive oversight from clans and the Ethiopian government—a much more complex proposition for effective public engagement by a project having only a three-year lifespan. And the costs to effectively intervene to improve well systems would be manytimes greater than those incurred for ponds. Having a modest project budget therefore also led us away from a focus on the deep wells.

The Importance of Ponds. While the deep wells are the “heart” of the Borana pastoral system, a network of ponds has also proven vital in promoting a more balanced utilization of the southern rangelands environment (Coppock, 1994). There are far more ponds than deep wells in the central region, and when compared to the wells, the ponds collectively promote livestock access to a much larger total foraging area. Ponds are important to the pastoral system for many reasons, but in terms of livestock production they matter because they typically allow livestock to forage far beyond the central region that is supported by the deep wells. Once the ponds gradually begin to dry up, the associated access to local grazing also declines. This process has traditionally provided a mechanism that has helped keep livestock numbers in balance with forage resources. Ponds, like deep wells, are also very important because they provide water for people.

Ponds, as defined here, may include natural depressions or man-made excavations, but the latter greatly predominates. Ponds occur on a wide variety of soil types, and unfortunately some soil types are much worse at holding water than others. Ponds on red soils are most common. The water-holding capacity of

ponds is difficult to assess and is most easily visualized in terms of how long ponds can provide water. Small ponds, for example, may hold water for a few weeks following the end of a rainy season and have a depth of a meter or less with a diameter 50 to 100 meters across. The largest ponds, in contrast, can resemble a lake and may hold water all year. A prominent example of a very large pond is the Beke Pond located north of Yabelo town. Beke Pond has served thousands of pastoralists and their livestock for decades. It was created under the auspices of a water development project funded by the United States Agency for International Development (USAID; Coppock, 1994).

Project Kalo focused on four Pastoral Associations (PAs) within 50 kilometers of Yabello town. Inventories for these PAs indicated an average of 40 ponds in each (Coppock et al., 2014a). Most of these ponds have small to moderate water-holding capacities; they would mostly be dry by September following the end of the long rains in May. If we extrapolate the 40 ponds per PA to all PAs in the central region, this suggests that the total number of ponds there is on the order of 1,600.

Where did all these ponds come from? Traditionally, ponds were excavated by the Boran, whether using their bare hands or rudimentary tools such as picks, shovels, and hoes. Excavated soil was hauled away on animal hides. Things have changed in recent decades given the advent of major road infrastructure projects starting in the 1980s (Coppock, 1994). These projects brought excavation equipment to the southern rangelands, including road graders, bulldozers, and dump trucks. What then happened next probably involved the pastoral leaders convincing equipment operators to assist with pond excavation and maintenance in their spare time. While this is a logical outcome of a local, opportunistic development process to benefit pastoral needs, it can also be argued that the process fostered an uncontrolled proliferation of ponds in the absence of traditional community responsibility for stewardship. In the big picture, this has probably contributed to a destabilization of the pastoral production system, as previously reviewed.

Why do ponds require oversight and stewardship? While the deep wells and their environs can be subject to fecal contamination and other forms of degradation due to overuse by livestock, ponds are actually much worse in this regard. The inner catchment zones for ponds typically have heavily compacted soil surfaces practically denuded of vegetative cover due to heavy grazing and intense trampling. Livestock use is uncontrolled; animals drink from any location along the pond edge and defecate and urinate freely. No troughs or other means of concentrating animal activities are evident. The high rate of pond sedimentation is also a chronic problem. Rainfall events quickly lead to extensive sheet or gully erosion given the unprotected soil surfaces in catchments, and ponds rapidly fill with sediment. More sediment means less water-holding capacity as well as a lower water supply for people and animals. And whether using human labor or machinery, pond de-sedimentation is a very expensive problem to correct (Coppock et al., 2015).

The large watershed serving Beke Pond has also been badly damaged by years of excessive livestock trampling, over-grazing, and general mismanagement by pastoralists. This watershed is currently being rehabilitated as part of a multi-million dollar project. Whether large or small, the impression is that ponds are a very poorly managed water resource when compared to the deep wells. This is due to the much more poorly defined rights and responsibilities associated with pond stewardship. Ponds, in contrast to the wells, are seemingly accessible to anyone and yet actively managed by no one.

Improving Pond Stewardship and Water Quantity. As reviewed elsewhere in this proceedings volume, Project Kalo used participatory processes to identify four model pond catchments for intervention, with one for each of four PAs. These catchments were essentially donated to the project by each community for pilot demonstration and research purposes. The process began by having communities erect bush fencing around the inner catchment zonefor each pond; the area so protected varied from two to 20 hectares in size, but some expansion of the protected areas occurred later. Livestock were only allowed to enter the inner catchment zone for each pond via one or more corridorswhere their impacts could be controlled and concentrated. Animals would be herded, often in single file, along the corridors to the pond edge to drink and then taken out the way they came in. They were not allowed to feed or loiter. In some cases the walls of corridors were bush-linedto ensure resource protection (Coppock et al., 2015).

Effects of pond catchment protection.After only a few weeks of protection coincident with a long rainy season, herbaceous vegetation in the innermost catchment zones began to quickly recover from livestock protection (Norton et al., 2015). In large measure this was due to the fact that inner catchment zones are resource sinks; water and nutrients flow across the landscape towards the ponds and thus become concentrated, providing excellent conditions for plant growth the closer one gets to the pond edge. After roughly 14 months of subsequent protection that included two long rainy periods and one short rainy period, the ultimate recovery of the herbaceous vegetation was dramatic. Total plant cover in the inner catchment zones improved from nine percent to a median value of 36 percent, a 400 percent increase. In contrast, cover for control plots located just outside of the protective bush-fencing typically remained low overall (i.e., typically less than 10 percent.) The number of herbaceous species also increased in the protected zones from 13 initially to 23 after one year. Many grass species that showed considerable recovery are high-value, indigenous species with exceptional nutritional value for livestock (Norton et al., 2015).

In addition to the perimeter bush fencing, efforts were made to undertake gully repairs in the catchments using trenches, sieve dams, check dams, and bench terraces. These options are described in Tadele et al. (2015).On average, each catchment required the implementation of 13 trenches, 57 sieve dams, eight check dams, and four bench terraces (Coppock et al., 2015). Gully repairs were needed because gully erosion was probably the greatest source of direct sediment flow into the four ponds. The perimeter fencing was essentially a means to arrest sheet erosion and gully formation via recovery of the herbaceous vegetation, while the gully repairs were a means to arrest gully erosion. It is our assessment that the local people can indeed build these erosion-control structures without further outside assistance.

Towards the end of the project, effort was made to remove all accumulated sediment from each of the ponds. This was done via human labor, with 70 percent freely provided by community volunteers and the balance paid for by the project (Coppock et al., 2015). De-sedimentation greatly improved the water holding capacity per pond, leading to improved water supplies in each of the four cases. This fulfilled one of the main goals of the project.

At this writing, all four protected pond catchments are being sustained by their communities, although there have been a couple cases where the bush fencing has been breached by livestock. These events have occurred surreptitiously and purposefully by herd owners who have violated the new community rules governing the stewardship of these sites. Despite such incidents, the fact that the pond catchment protection system has been adopted by the four communities fulfills another goal of the project.

The ultimate test of the sustainability of this intervention, however, is whether the catchment protections and gully control measures can be continued during droughts. During droughts, forage resources are often stripped bare in communally grazed (e.g., unprotected) locations. The abundant standing vegetation in protected pond catchments during dry periods thus provides a great temptation for hungry livestock and greedy herd owners. Such temptations must be controlled by improved or expanded pastoral governance. One compromise measure could be to use the standing vegetation in protected catchments on a cut-and-carry basis during droughts, which would be far less destructive than having them grazed.

The benefits of pond-catchment protection include having the recovered herbaceous vegetationin the inner catchment zones slow the rate of pond sedimentation by filtering overland water flows, and thus capturing sediment before it enters the pond. Although we were unable to conduct research to confirm the extent that pond sedimentation was reduced by the improved herbaceous cover, pastoralists in each location quickly noticed that reduced rates of pond sedimentation were a major benefit of the intervention.

Overall, we estimated that the average cost to rehabilitate each of the four ponds was 283,045 Ethiopian Birr, or the equivalent of USD 14,152. The cost breakdown was 87 percent for de-sedimentation, nine percent for gully repairs, and four percent for the bush fencing (Coppock et al., 2015). The high cost for de-sedimentation illustrates that poor pond stewardship has important consequences for this pastoral system. Simply engaging in more lower-cost, preventative measures such as pond catchment protection via bush fencing would yield high returns in terms of reducing the annual outlay otherwise needed for de-siltation, whether this occurs by human labor or mechanized means (Coppock et al., 2015).

Implications of Improved Pond Stewardship for Water Quality and Human Health. As previously noted, the pastoralists perceived that lower rates of pond sedimentation resulted in a higher water-holding capacity for each pond, and this yielded higher quantities of water for people and animals. The pastoralists also perceived that less sediment in the water improved water quality for human consumption. While water quantity—not quality—was the major focus of Project Kalo, some review is warranted here regarding poor water quality and its implications for human welfare and, to a lesser extent, livestock production. By incorporating water quality and human health into our discussion,a more unified or integrated vision of intervening in this social-ecological system can be realized.

Water quality has received very little research attention on the Borana Plateau. Some water samples from the deep wells were analyzed in the context of unpublished reports prepared in the 1970s and 1980s and, in general,on the basis of such work, the well water was deemed potable for humans and suitable for livestock. Wells ondifferent substrates were noted to vary in terms of mineral content. There is considerable “local knowledge,” however, concerning the presence of overly saline wells and other water points, especially in the vicinity of Soda Crater near Mega town (D.L. Coppock, personal observations).It is thought that the salt content of water in some wells is high enough to discourage water consumption by cattle, small ruminants, and equines, but it can be tolerated by camels.[21]

[21] A comprehensive study of water quality in the Ethiopian Rift Valley that emphasized mineral content is reported by Reimann et al. (2003). Their work analyzed 138 samples for 70 parameters. They found 86 percent of all wells

The focus of pastoral development, understandably, has always been centered on water quantity given the constraints that insufficient water supplies pose for the development of rangeland systems. Drilling bore holes, digging wells, and creating irrigation systems has been a major emphasis in the African rangelands since the 1960s (Sandford, 1983; Coppock, 1994). Despite this orientation on quantity, it is still amazing that water quality for human consumption in pastoral areas has received so little attention.

Have the Boran Adapted to Drinking Polluted Water?During the implementation of Project Kalo, we haveobserved the Boran scooping water directly from ponds with their hands and promptly drinking it. We have also commonly observed the pastoralists collectingpond water with plastic jerry cans; this water is carried short distances back to *olla* for people to use. Expert opinions (Mr. Seyoum Tezera, MARIL, personal communication; Mr. Jaldesa Doyo, OARI, personal communication) indicate that water taken to the*olla* remains untreated in the home prior to human consumption, whether such treatment might involve water boiling or other interventions. The water container may sit for a while, however, so at least sediment can settle before water is consumed.

Such observations of the Boran routinely consuming pond water may seem unremarkable to many readers of this paper. However, it is argued that this is indeed remarkable for several reasons. First, pond water has been observed to be extremely polluted due to extensive fouling via livestock urination and defecation, high levels of sedimentation, and the presence of other environmental contaminants—i.e., ponds provide habitat for amphibians and are places where aquatic plants decay (D.L. Coppock, personal observations).Second, if members of the Project Kalo research team—people who live in modern urban locales in Ethiopia and abroad—wereto drink such water it is virtually certain they would be incapacitated and probably require hospitalization to promote recovery.[22]Third, the Boranin the field appear to "carry-on with daily life" despite their routine reliance on putrid water. For example, one does not come upon villages full of incapacitated residents—people, rather, are typically "out and about."After integrating these observationsit can be hypothesizedthat the pastoralists have become physiologically adapted to drinking highly polluted water.

There are a couple "weak links" in this argument, however. One is the assumption that research team members would indeed be fully unable to tolerate polluted water, while the other is the assumption that the Boran are not significantly impaired by same. The first could be tested empirically with team members, but it is doubtful anyone would volunteer! The second assumption could be investigated by interviewing and giving routine physical examinations to a sample of pastoralists to assess the types and incidences of morbidity, and then making a link from morbidity to the consumption of fouled water. This approach, however,is far from perfectbecause human morbidity is common hereand assessing single-factor causes would be difficult. Besides foul water, the population is routinely challenged by malnutrition, malaria, gastro-intestinal parasites, etc. Morbidity would commonly result from interactions among multiple factors.

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failed to pass international quality standards for human consumption, with the biggest problem being low concentrations of fluoride.

[22] The author required medical intervention as a young man to treat a painful episode of *Giardiasis* after briefly drinking seemingly clean, but untreated, city water from a garden hose in Fort Collins, Colorado, USA.

Water-qualityresearch from elsewhere.Luckily, the literature documenting similar situations elsewhere illuminates various aspects of the general situation that occurs in Borana. Other studies confirm that rural populations and their livestock are often exposed to polluted drinking water and that such water poses significant health risks for both people and animals. Evidence that people can physiologically adapt to consuming fouled water, however, is largely circumstantial. And there are no comprehensive studies where all elements are combined. Thus, the overall picture must be pieced together.

For example, research by Shivoga and Coppock (2003) investigated claims by Rendille pastoralists in the town of Kargi, northern Kenya, that water-borne factors were negatively affecting human healthand occasionally killing livestock. Water samples were collected from various wells and one earthen dam around the town and assessed for several physiochemical and bacteriological characteristics. The biggest problems were found in the water from the oldest wells, which were far below water-quality guidelines for human consumption. The samples were high in mineral content, low in dissolved oxygen, and also showed the presence of toxic bacteria such as *Salmonella* spp. and *Eschericha coli*. The combination of *Salmonella* spp. with low oxygen levels,in particular, could promote production of lethal gases such as hydrogen sulfide, and hence this could be asource of livestock mortality. In contrast to samples from the older wells, water samples from the younger wells and the earthen dam were more suitable in terms of general water-quality parameters, but they showed evidence of fecal contamination (Shivoga and Coppock, 2003).

Work by Musa et al. (1999) demonstrated that fecal coliform bacteria were commonly detected in water samples collected within nomadic pastoral as well as peri-urban community settings in an arid region of Sudan. The highest values were found at the end of rainy seasons, and this also coincided with a temporal peak in the incidence of diarrhea in local populations. Another important finding was that when compared to point-source values for fecal coliform, values increased in water that was subsequently stored in various containers for future use. This suggested that if water is inoculated prior to storage, bacterial populations in the stored water will continue to increase over time.

Clasen et al. (2009) reviewed global literature that testified to the critical linkage between water contamination and human health—most notably the connection between sewage pollution and diarrhea—worldwide.[23]Their meta-analysis of dozens of studies revealed that mitigating the incidence of diarrhea in developing nations can be achieved by undertaking water purification or disinfection measures at both community water points and in households at the point-of-use. Household interventions were noted to be most effective overall (Clasen et al., 2009).

The linkages between livestock and people as mediated by water quality underscore avenues for zoonotic disease transmission, a subject that has received increasing attention in recent years. Ethiopia is one of world's hotspots for zoonoses.[24] Livestock waste contains many pathogenic micro-organisms including bacteria, viruses, and protozoans (Fong and Lipp, 2005; Mawdsley et al., 1995.) A review of the literature

[23] Statistics from the Oromia Regional Health Bureau confirm the importance of water-borne disease and diarrhea in Ethiopia (http://www.moh.gov.et/web/Pages/factsheets).
[24]http://www.ilri.org/ilrinews/index.php/archives/9172

yielded three major types of zoonotic contaminants of global concern that are transmitted in standing water (Table 3)

Table 3. Three major zoonotic contaminantsin aquatic environments and associated symptomsafter transmission to humans.[1]

Type	Symptoms in Humans
Fecal coliform and *E. coli* (both bacteria, some harmless)	Highly varied symptoms—mild to fatal—include bloody diarrhea, stomach cramps, nausea, vomiting, dehydration, headaches, anemia, and kidney failure
Cryptosporidium parvum (protozoan)	Highly varied symptoms—mild to rarely fatal—includewatery diarrhea, stomach cramps, dehydration, nausea, vomiting, fever, weight loss; some individuals are carriers who can pass infections onwards but never exhibit symptoms themselves
Giardia spp. (protozoan)	Highly varied effects include diarrhea, stomach cramps, fatigue, vomiting, weight loss; some individuals are carriers who may pass infections onwards but never exhibit symptoms themselves

[1]Tabulated symptoms are simplified from reviews given in Andrew-Thompson (2000), Ishii and Sadowsky(2008), Savioli et al. (2006), and the Centers for Disease Control and Prevention(CDC; www.cd.gov).Adults, or especially children, already compromised by other diseases ormalnutrition may have increased vulnerability to these afflictions.

Human adaptation to drinking polluted water.The literature concerning how people can physiologically adjust or adapt to drinking fouled water over the long-term is surprisingly elusive. I use the term "surprisingly" because international travel advisories often note that while the residents of developing nations can be adapted to drink (unclean) local water, tourists new to an area are not adapted—often with negative consequences.[25]The fact that vaccines have been recently developed for travelers to take as precautionary measures when visiting developing nations points to immunological response as a key protective factor. Oral vaccines, for example, can offer several months of (albeit incomplete) protection against bacteria such as enterotoxigenic *E. coli*as well as *Vibrio cholerae.*[26]The basic process of peopledeveloping the ability to cope with recurrent challenges from microbial pathogens may involve a combination of innate(i.e., broadly based) as well as adaptive(i.e., selective) immunological responses, and this is an area of active research in general (Iwasaki and Medzhitov, 2010).

While it is evident that adaptation of local communities to drinking unclean water in the developing world is in the realm of "common knowledge" among travel agents, it appears to be woefully understudied as to the physiological and health-related details, especially given its importance to humanity. And the

[25]http://www.independenttraveler.com/travel-tips/safety-and-health/drinking-water-safety
[26]http://www.cdc.gov/cholera/vaccines.html

"required adaptation" of locals in developing-world tourist destinationsis probably a far cry from the scope of "required adaptation" needed for people like the Borana pastoralists. The Boran must be able to detoxify an astonishing daily flood of pathogens from the excessively polluted water found in ponds.

And even if we assume that a remarkable level of such adaptation has indeed occurred among the Boran, there are metabolic tradeoffs that probably further compromise the health and vitality of the population. For example, in his review,Muehlenbein (2010) noted that immunological activation in response to toxic challenges in people can have very significant energetic costs that can ultimately contribute to morbidity and excessive weight loss in their own right. This means that large amounts of metabolic energy devoted to the constant warfare with pond pathogens is energy otherwise lost for competitive, productive purposes; this would be an especially worrisome trade-off in the case of growing children.

Further research should clarify the extent that the Borana population is indeed compromised by poor water quality; it is amazing that such work has not already been conducted simply to characterize public health issues. If significant health problems are confirmedas caused by polluted water, the next question is whether or not to intervene. This may appear to be an odd argument, but if interventions (see below) are deemed too difficult to sustain we might ask ourselves if they might make the situation worse? Namely, if water quality improves for some people for some period of time, could this lead to a mitigation of their protective adaptation, thus increasing their subsequent vulnerability when they return to consuming fouled water?

There are several avenues to intervene to improve water quality here at least over the short-term, but none offer an easy solution. Because firewood is abundant, it could be argued that informal education is the key to promote more water boiling in the home. Other constraints—labor, culture, etc.—may loom large, however. There arealso water filters based on slow sand filtration that can be made from localmaterials,[27] but challenges of meeting potential demand for such units are probably daunting.Finally, simply excluding livestock from wading and relieving themselves in ponds could also help, but you would almost need 100 percent compliance to achieve a community-level effect. The scale of implementing such changes is vast given the sheer numbers of poorly managed pond catchments. Clasen et al. (2009) advocated on behalf of the effectiveness of household-level interventions. It could be argued, for example, that if infants or other young children are considered most at risk from drinking fouled water, targeted attention to improve their water supplies in the home via boiling or filtering might be pursued.

Conclusions and the Way Forward

This review illustrates, not surprisingly, that water profoundly affects virtually all aspects of the Borana pastoral system. Water development is badly needed here and in similar places, first and foremost, to enhance human welfare. This includes relief of human health concerns from water-borne illness as well as addressing water supply for proper hydration, food preparation, and hygiene as well as mitigating the onerous labor burdens imposed on women and girls. A secondary goal would be to provide better support for livestock production. The current situation on the Borana plateau, where pastoralists have access to such woefully inadequate water in terms of both quantity and quality, is unacceptable.

[27] http://www.who.int/water_sanitation_health/publications/ssf9241540370.pdf

Such water development, however, must not be done haphazardly but rather very carefully. And there must be associated efforts to build the capacity of local and regional institutions—both formal (i.e., government or private sector) and informal (i.e., traditional or customary)—so they can collaborate to better manage water andthe associated natural resources (i.e., grazing) compared to what has occurred in the recent past. Unfortunately, there will be significant competition for limited funds available for waterdevelopmentacross Ethiopia. It may take many years before suitable improvements in water resources become a reality for most residents of the Borana Plateau.

What does this review reveal in terms of clarifying a way forward for researchers and development agents interested in improving Ethiopian livestock systems? First, it is clear that applied researchers and development agents need to embrace more collaborative, team-oriented, and action-based approaches. Such investigations need to rely more on authentic participatory methods with communities to identify key problems, chart pathways for sustainable problem solutions, and promote community buy-in to better problem-solve and increase the chance that technical or management innovations will be adopted. It is likely that if community participatory methods are more commonly used, problems concerning water quantity and quality will rise to the top of local concerns as rural populations grow, awareness of human health issues increases, and climate change exerts more influence, especially in the drier parts of the country. Because rural communities will typically see water development as vitally important, community members will be more willing to be active, rather than passive, players in rural development projects. Improvements to water resources can provide compelling incentives for community participation. This is well illustrated by Project Kalo, where the focus on water development was enthusiastically endorsed by the pastoralists and led to land management innovations that were locally adoptedby four communities within three years.

Second, water provides an excellent “currency” that helps researchers integrate people, livestock, forage, and other elements in asocial-ecological system (SES) framework.A focus on water makes it easier for research teams to be interdisciplinary, holistic, and address multiple problems at once. Efficient livestock production requires inputs of water, forage, human labor, and other factors. A truly interdisciplinary approach would address problems in ways that alleviate system constraints in a stepwise manner. The experience of Project Kalo is again illustrative of this point; the focus on ponds led to a rich interplay of ideas concerning connections among water quantity, water quality, soil erosion, forage production, human welfare, livestock production, and rangeland management.

Third, there is still a role for basic field research in addressing practical livestock development problems. For Project Kalo, for example, basic research is needed to investigate the extent that poor quality drinking water affects the health and vitality of the pastoral population. The zoonotic issues involved still require study. If the pastoralists have indeed “adapted” to fouled water, how has this adaption occurred, how labile is the response, and what are the consequences? Then the applied questions could include whether water-quality intervention is worth the effort or not, especially if such intervention is currently unsustainable? Finally, applied questions could be asked concerning how improvements in human welfare—asmediated by enhancements in water quality or quantity—might boostthe overall efficiency or output of the livestock production system.

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Enhancing Market-oriented Small Ruminant Production in Ethiopia: Implications for Natural Resource Management

Berhanu Gebremedhin[1], Dirk Hoekstra[1], Azage Tegegne[1], Kaleb Shiferaw[1] and Aklilu Bogale[1]*
[1] International Livestock Research Institute (ILRI), P. O. Box 5689, Addis Ababa, Ethiopia
Email: b.gebremedhin@cgair.org

Abstract

Small ruminants, which account for more than half of the domesticated ruminants in the world, are an important component of the farming systems in most developing countries. Despite their economic and social importance, socio-economic and marketing research on small ruminants has so far been limited, a fact which also holds strongly true in Ethiopia. This study, based on survey data of 5004 Ethiopian smallholder households, uses analysis of descriptive information and econometric analysis to analyze the determinants of household market participation in small ruminants and the resultant implications to natural resource management. Results indicate that small ruminant flock size is a major determinant of household market participation. We find optimal flock size of 41 heads of animals after which probability of participation as seller declines and an optimal flock size of 21 heads of animals after which probability of participation as buyer declines. An increase in flock size by one animal, increases probability of participation in the market as seller by only 4.2%, showing that the current average flock size of 7.8 heads per household is way below the optimal size for market orientation. Our results imply that an effective package of interventions to promote market oriented small ruminant production will need to include efficient animal reproduction and management, proper animal health care, development of livestock market infrastructure and market institutions, and improved access to extension and credit use. However, interventions aimed at improving small ruminant ownership across all producers is likely to put tremendous pressure on the natural resource base through increased demands for food and water. Hence, interventions to promote market-oriented small ruminant production should be targeted at those households who are more likely to develop as market-oriented small ruminant producers in rather specialized way.

Key Words*:* *Small ruminants, probit, ordinal probit, flock size, Ethiopia*

Introduction

Small ruminants, which account for more than half of the domesticated ruminants in the world, are an important component of the farming systems in most developing countries (Tedeschi et al., 2011; Kosgey, 2004). Between 1961 and 2006, the global population of small ruminants increased from 1.35 billion to 1.94 billion (Tedeschi et al., 2011). Since they require less investment compared to large ruminants, small ruminants are more suitable livelihood strategies for resource poor households, and particularly for women who are often the most vulnerable members of society in the developing world. In the crop-livestock mixed farming systems small ruminants are considered as diversification strategy to cushion market and climatic risks and optimize the use of available resources (Oluwatayo and Oluwatayo, 2012).

Sheep and goats have high adaptive capacities to survive and produce in difficult environments (Gizaw, et al., 2010). For the rural part of most developing countries that are characterized by widespread poverty, inadequate access to financial markets, with ever decreasing land holding and recurring natural shocks, small ruminant production offers an alternative livelihood option. The short reproductive cycle of small

ruminants allows quick stock recovery after losses due to droughts or diseases. Moreover, small ruminants can be more appropriate component in the face of climate change and adaptation strategies for smallholder farmers (Gizaw, et al. 2010). Despite their low productivity mainly due to under-feeding, poor management and diseases, small ruminants are major sources of cash income to rural households who rear them. Because of the ease to liquidate small ruminants at times of household cash needs, small ruminants are sometimes dubbed as 'village banks'. The benefits to small holders from small ruminant production would be enhanced with increased market participation. However, production and marketing research on small ruminants remains limited (Tedeschi et al., 2011). Ethiopia is one of the African countries with the largest small ruminant population in the continent (Abebe et al, 2013). Recent estimate indicates that there are about 27.35 million sheep and 28.16 million goats in the country (CSA, 2014). Almost all of the small ruminant population is comprised of local breeds. The CSA data further indicate that of those who own sheep or goat about 64% and 58% own less than five heads of sheep and goats, respectively. Gezahegn et al (2006) posit that small ruminants play a major role in the livelihoods of smallholders in the mixed crop-livestock systems of the highlands of Ethiopia.

Like in many other developing countries, the traditional small ruminant production technologies and practices in Ethiopia render the productivity of the sub-sector low (Gizaw, 2010). This means considerable increase in animal productivity and production can be achieved with improved technology and management practices. Improvements in feeding and disease control can ameliorate the genetic potential of endogenous breeds.

Promoting market orientation in small ruminant production requires an understanding of why farmers opt to stay out of markets and the constraints they face in market participation28. Market orientation is likely to facilitate the adoption of improved technologies and practices, thus helping households to increase marketable surplus, with the resultant expected higher level market participation (von Braun et al, 1994; Gebremedhin et al, 2006; Barret, 2008). Hence, analysis of household market participation is fundamental to transforming small ruminant production in developing countries. Such an analysis is particularly important in Ethiopia due to the large population size of the animals. This paper is aimed at analyzing the determinants of market participation behavior of small ruminant producers in the crop-livestock mixed systems of the Ethiopian highlands. Based on analysis of descriptive information, and econometric analysis of the determinants of household participation in selling and buying small ruminants and market position of households (net seller, autarkic and net buyers), the paper attempts to draw implication to enhance market orientation and participation of small ruminant producers and the resultant implications to the natural resource base.

The paper is organized as follows. The following section presents the conceptual framework of the study, followed in section three by methods of the study. Section four discusses results of descriptive and econometric analysis. The last section concludes the paper and draws implications.

[28] We define market orientation as agricultural production systems where most of the produce is targeted for sales and production decisions are based on market signals. Market participation refers to the actual involvement of producers as sellers in the output market.

Conceptual framework

The conceptual framework followed in this paper is based on the theoretical framework developed by Barret (2008) and Boughton et al. (2007). The key features of the models are that access to markets are not uniform across households because of differential transaction costs as conditioned by household and farm specific characteristics, as well as meso-level factors affecting transportation and other marketing costs and the competitiveness of markets. Hence, the core issues in the models are the effects of asset endowments and access to physical and institutional infrastructure. Policy interventions that are required to lift smallholders in developing countries out of the semi-subsistence poverty trap that perpetuates itself through the vicious circle of poverty and low productivity have been major preoccupations of the agricultural and rural development policy research in these countries (Barret, 2008). Underlying this broad policy issue is the subsidiary question of how to improve smallholder market participation and facilitate their transformation from semi-subsistence into market orientation (Gebremedhin and Jaleta, 2012). Market participation can lift smallholders from the semi-subsistence poverty trap due to welfare gains that could be realized from specialization and comparative advantages and continuous engagement in market exchange of goods and services. Market participation also has the potential to promote scale economies that would otherwise be difficult to achieve due to non-trivial fixed and sunk costs of production and marketing (Romer, 1994). The low level equilibrium poverty trap that characterizes many farm households in developing countries is closely associated with semi-subsistence production based on traditional technologies that limit potential for marketable surplus. Farm households' production capacity and active engagement in markets is also constrained by limited productive assets and weak access to physical and institutional infrastructure, resulting in low participation of smallholders in profitable markets (Barret, 2008).

Hence, access to adequate assets and improved technologies that enhance productivity, and access to infrastructural and institutional services that reduce production and marketing costs are needed for smallholder's active engagement in markets. While competitive markets (or "getting prices right") may be necessary condition for broad-based welfare enhancing market participation of farm households, interventions at household or market level that improve productivity and production, reduce transaction costs and enhance demand are needed to generate behavioral or welfare effects (Barret, 2008). Since increasing livestock ownership would result in higher demand for feed, water and livestock services, it is important to consider the implications to the natural resource base of enhanced market orientation in small ruminant production. The focus of this analysis is, therefore, on flock size and flock structure (crucial asset bases for market participation in small ruminants), and access to physical and institutional infrastructure. We have not been able to control for variations in technologies since production technologies in small ruminants are basically traditional and uniform throughout the study area. The study then attempts to draw implications of the results to natural resource management.

Empirical Models and Methods

Empirical model

Our specification of empirical models is based on the conceptual framework described in the previous section and is divided into two (1) the determinants of market participation of households as sellers and buyers of small ruminants, and (2) the determinants of market position of households (net sellers,

autarkic, and net buyers). The focus of our analysis is on the effect of flock size and flock structure, and access to institutional and infrastructural services. In order to minimize the bias in estimating the marginal effect of these variables, we also control for several household and community level variables. Hence, each of our dependent variables of interest is modeled as a function of household characteristics ((age (age_i), sex (sex_i), education of household head (edu_i), household size ($hshds_i$), labor supply ($labsup_i$), and household total dependency ratio ($deprat_i$));, household assets ((land ($land_i$), physical assets excluding small and large ruminants ($phasst_i$), non-farm cash income ($cash_i$), and ownership of mobile ($celphn_i$)); flock characteristics ((flock size ($flksz_i$), squared value of flock size ($flkszsq_i$), large ruminant herd size ($hrdsz_i$), proportion of female animals in the flock ($propfml_i$), and number of dead animals in the year ($deadanm_i$)); access to physical infrastructure ((distance from household homestead to nearest livestock market ($distmrkt_i$), and all weather road ($distrd_i$), household access to extension and credit services (distance from household homestead to farmer training center or development agent post ($distDA_i$), whether household received extension advice/training on improved livestock production the previous year ($lvstkext_i$), and whether household had obtained credit during the previous year ($crdt_i$)); and community level variable (population density ($popdens_i$) (equations 1 & 2).

$$markpart_i = f(age_i, sex_i, edu_i, hshds_i, deprat_i, land_i, labsup_i, phasst_i, cash_i, celphn_i, flksz_i, flkszsq_i, hrdsz_i, propfml_i, deadanm_i, distmrkt_i, distrd_i, distDA_i, lvstkext_i, crdt_i, popdens_i, u_{mar}) \quad (1)$$

$$markpos_i = f(age_i, sex_i, edu_i, hslds_i, deprat_i, land_i, labsup_i, phasst_i, cash_i, celphn_i, flksz_i, flkszsq_i, hrdsz_i, propfml_i, deadanm_i, distmrkt_i, distrd_i, distDA_i, lvstkext_i, crdt_i, popdens_i, u_{mar}) \quad (2)$$

Materials and Methods

Data sources

Results are based on analysis of data from a survey 5004 smallholder households and 497 rural *kebeles*[29] in the four highland regions of Ethiopia (Tigray; Amhara; Oromia; and Southern Nations, Nationalities and Peoples (SNNP) regions). Data were collected from ten zones which are project intervention zones of the Livestock and Irrigation Value Chains for Ethiopian Smallholders (LIVES)[30] project. The study area accounts for about 13.6% of the national area, 30% of the national[31] sheep population, and 22.5% of the national goat population. For sampling purposes, the study districts were stratified into 10 agro-ecologies, and farm households were selected randomly based on proportional to size sampling technique. Data were collected on household characteristics; household asset ownership; farm characteristics including land

[29] A *Kebele* is the lowest administrative unit in Ethiopia and comprises of 4-5 villages.
[30] LIVES is an action research value chain development project implemented by the International Livestock Research Institute (ILRI) in the highlands of Ethiopia.
[31] The national figures used to compute these percentages exclude the lowland non-sedentary zones of the Afar and Somali regions.

holding, herd size and structure; access to physical and institutional infrastructure; and cash earning of household. Survey was conducted in 2014 and referred to the 2012/2013 production season.

Econometric approach

The econometric models used depend on the nature of the dependent variables. The dependent variables used in this analysis are household participation in small ruminant markets as seller and as buyer (bivariate outcome) and household market participation position as net seller, autarkic and net buyer (ordinal outcome) during the study year. Descriptive analysis of the buying and selling data show that only about 5% of households that participated in the small ruminant market participated both as buyers and sellers. We used univariate probit models to analyze the determinants of household participation in selling and buying small ruminants. We also estimated ordered probit model to analyze the determinants of household market participation position since the outcomes are ordinal. Involvement in extension and use of credit are potentially endogenous variables, since they can be related systematically to household or farm characteristics. To control for these potential endogeneity, we use lagged value of these variables.

Results

Analysis of descriptive information

Small ruminant ownership

Table 1 presents small ruminant ownership structure. Among the surveyed households, 52.6% of them rear ruminants, with an average ownership size of 7.8 heads, split into 4.7 heads of sheep and 3.1 heads of goats. The sheep flock structure shows that about 48.9% of the flock is accounted for by ewes, followed by lambs which account for 34.1%. Mature male sheep (rams and castrated sheep) account for only 17%. The goat flock structure also shows that about 48.4% of the goat flock is accounted for by does, followed by goat kids which account for 32.2%. Mature male goats account for only 19.4%. These results show that the flock structures of both sheep and goat are dominated by female reproductive animals and kids or lambs.

Table 1. Ownership structure across those who own small ruminants (N=2634)

Type of animal	Mean ownership (SE)	% of flock (by sheep and goats)	% of flock (by total)
Mature male sheep	0.8 (0.03011)	17.0	10.3
Ewe	2.3 (0.05969)	48.9	29.5
Lamb	1.6 (0.04943)	34.1	20.5
Mature male goats	0.6 (0.02742)	19.4	7.7
Doe	1.5 (0.05850)	48.4	19.2
Goat kid	1.0 (0.04552)	32.2	12.8

About 57.8% of small ruminant producers' rear sheep without goats, and about 28.1% rear goats without sheep. Just about 14% of producers rear both sheep and goats. Because of the highland nature of the study area, sheep appear to be owned by a higher percentage of households than goats. The results also show that sheep and goat production are, in most parts, separate enterprises. Moreover, 52.5% of small

ruminant producers rear sheep only with cattle, while 26.3% rear goats only with cattle. Almost all the households who own both sheep and goat also produce cattle. Only 5.3% of small ruminant owners rear only sheep (without cattle or goats) and 1.8% rear only goats (without cattle and sheep). These results indicate that small ruminant production is conducted jointly with cattle rearing.

The proportion of small ruminant producers who own the types of animals is given in Table 2. About 66.2% of small ruminant producers own ewes, 36.1% own does, while 45% own lambs. About 39% of small ruminant owners own doe. Mature male sheep (castrated and un-castrated) are owned by 38% of the producers, while mature male goats are owned by 23.7% of small ruminant producers. These flock structures mirror the primary reproduction objective of producers.

Table 2. Proportion of households who own the type of animal (%) (N=2634)

Type of animal	%
Ewe	66.2
Doe	39.0
Mature male sheep	38.0
Lamb	45.0
Mature male goats	23.7
Goat kid	26.8

Among the sheep producers, only 7.8% did not have ewes in the stock, while among goat producers, only 7.4% did not have does, reinforcing the result that reproductive female animals are essential components of the small ruminant flock. On the other hand, among sheep producers about 47.1% of them did not have rams, and among goat producers about 43.6% did not have bucks, suggesting that significant number of small ruminant producers depend on other household's stock for mating their animals. This issue is likely to be of a more serious concern with the declining availability of communal grazing lands

Off-takes and inflows

We found a total gross off-take rate of 34.3% constituted by commercial off-take of 18.9%, slaughter of 4.5%, death of 10.1%, given out as gift of 0.3% and loss due to theft of 0.3% (Table 3). We also found gross inflow rate of 22.5% constituted by inflow due to birth of 18.4%, purchase of 3.9% and obtained as gift of 0.2%. These results show that births are the most important sources of inflow and that there was a decrease in the stock of small ruminants by 11.8% during the year. Negassa and Jabbar (2008) also found that there was 27% and 13% reduction in sheep and goats stock within one year in their study areas in Ethiopia. We computed lambing and kidding rates of 66.6% and 67.4%, respectively.

Table 3. Commercial off-take rates and death rates by type of animal

Type of off-take or inflow	Rate (%)
Small ruminant gross commercial off-take rate	19.0
Small ruminant net commercial off-take rate	15.1
Sheep gross commercial off-take rate	20.9
Sheep net commercial off-take rate	16.3
Goat gross commercial off-take rate	16.0
Goat net commercial off-take rate	13.3
Small ruminant death rate	10.1
Sheep death rate	10.5
Mature male sheep death rate	6.1
Ewe death rate	11.2
Lamb death rate	11.7
Goat death rate	9.6
Mature male goats death rate	5.4
Doe death rate	9.7
Goat-kid death rate	12.0

We also computed the ratio between the number of animals sold and the number of animals slaughter for household consumption of 4.35 for sheep and 3.85 for goats, suggesting that small ruminants are kept primarily as source of cash for the household rather than for own consumption. These results belie the traditionally held view that small ruminant production is subsistence oriented primarily aimed at home consumption.

Market participation

More than 51% of small ruminant owning households sold small ruminants during the study period, while just about 13% bought the animals. About 7.5% of owners bought the animals to build a new stock in the year. Hence, only 5.5% of households were purchasers who also had own stock at the beginning of the study period. Analysis of the market participation regime of households also shows that about 40% of owners remained non-seller non-buyer during the study period, while about 46% and 8% of owners were sellers only and buyers only, respectively. Only about 5% of owners were involved in both buying and selling. Similarly, just above 50% of owners were net sellers during the year, while about 41% and 9% of owners were autarkic and net buyers, respectively. Among those who purchased small ruminants, the average purchase was 2.3 heads, while among those who sold the animals, the average sale was 2.9 heads. Among the sold animals, about 31% were mature male sheep, followed by ewes (18%), does (16.6%), and mature male goats (11.4%).

Mean t-tests of characteristics of small ruminant owners who participated in the market (either as seller or buyer) and those who did not participate at all shows that participants have higher proportion of households who slaughter small ruminants for home consumption and slaughter higher proportion of their stock, use more purchased feed, have larger flock size, and earn more income from non-farm activities than non-participants. On the other hand, non-participants have higher land-labor ratio, higher land per capita, and are farther away from livestock markets. We find no difference in asset wealth between the

two. These results show that non-market participants have better return opportunities from land-based agricultural activities, while participants don't seem to have these opportunities because of smaller land holding. Small ruminant production appears to provide comparative advantage for households with smaller land size. Only about 5% of small ruminant owners are involved in small ruminant fattening business. These fatteners have been in the business for an average of 3.5 years. The average fattening cycle is 5 months. We found that the three major constraints faced by fatteners in their fattening business are feed shortage, diseases and market problem in that order.

Reasons of selling and buying

Households reported meeting planned household expenses, meeting emergency household expenses, removal of animal because of low productivity, removal of animal because of sickness, and trading (buying and selling for profit) as reasons for selling small ruminants. More than 79% of sellers cited meeting planned household expenses as a reason, followed by about 12% of households who cited meeting emergency household expenses (Table 4). Similarly, about 74% of sales were made to meet planned expenses, and about 11% of sales were made to meet emergency expenses (Table 4). These results show that households do in fact plan ahead of time on their sales of small ruminants to meet required household expenses, belying the widely held belief that small ruminants are sold to meet emergency cash needs. Trading was cited by only about 3% of sellers.

Table 4: Descriptive values of variables included in the regression models (N= 2246)4.2. Econometric analysis results

Dependent variables		%
Market position	Net buyer	9.38
	Autarkic	40.51
	Net seller	50.11
	None seller nor buyer	40.39
Market participation	Seller only	46.39
	Buyer only	8.16
	Seller and buyer	5.05

	Mean	Min	Max
Sell or not	0.51	0	1
Buy or not	0.13	0	1
Explanatory variables			
Age of household head *(year)*	45.50	18	120
Sex of household head *(male=1, female=0)*	0.85	0	1
Family size *(no.)*	6.23	1	22
Dependency ratio	1.06	0	6
Available family labor *(15-64 age)*	3.31	0	13
Year of schooling of Household head *(year)*	2.47	0	14
Land owned *(ha.)*	1.51	0	18
Household wealth *(1000 Birr)* (value of assets excluding large and small ruminant)	21.15	0	822
Non-farm cash income *(1000 Birr)*	3.83	0	208
Availability of cell phone *(yes=1, no=0)*	0.61	0	1
Small ruminant herd size *(no.)*	7.85	0	81
Small ruminant herd size square *(no.)*	116.27	0	6561
Large ruminant herd size *(no.)*	5.03	0	80
Proportion of female animals *(%)*	0.72	0	1
Number of dead animals	0.80	0	41
Distance to nearest livestock market *(walking minutes)*	90.35	0	600
Distance to all weather road *(walking minutes)*	49.28	0	650
Distance to DA post *(walking minutes)*	31.81	0	240
Involvement in extension program *(yes=1, no=0)*	0.40	0	1
Credit use *(yes=1, no=0)*	0.21	0	1
Population density *(persons/ha.)*	2.81	0.46	28.90

In this section we present and discuss econometric results of the estimation of determinants of household participation in small ruminant markets as seller and as buyer and the market participation position of households as net seller, autarkic and net buyer. We discuss the results of econometric analysis of these models below. Descriptive statistics of the variables included in the regression models are given in Table 5.

Table 5. Probit regression results for selling and buying

Explanatory variables	Probit Regression - Coef. (Std. Err.)	
	Sell or not	**Buy or not**
Age of household head *(year)*	-0.00013 (0.00274)	0.00040 (0.00435)
Sex of household head *(male=1, female=0)*	-0.03723 (0.08647)	0.01118 (0.13255)
Family size *(no.)*	-0.04626 (0.03435)	-0.02161 (0.05220)
Dependency ratio	0.13006 (0.08091)	0.01463 (0.12360)
Available family labor *(15-64 age)*	0.08709 (0.05726)	0.00582 (0.08727)
Year of schooling of Household head *(year)*	-0.00021 (0.00998)	0.01151 (0.01475)
Land owned *(ha.)*	-0.07310 (0.02351)***	-0.04987 (0.03651)
Household wealth *(1000 Birr)*	-0.00012 (0.00051)	0.00100 (0.00060)*
Non-farm cash income *(1000 Birr)*	0.00009 (0.00330)	-0.00462 (0.00573)
Availability of cell phone *(yes=1, no=0)*	-0.04296 (0.06323)	-0.01717 (0.09797)
Small ruminant herd size *(no.)*	0.10550 (0.00943)***	0.06611 (0.01774)***
Small ruminant herd size square *(no.)*	-0.00130 (0.00023)***	-0.00158 (0.00054)***
Large ruminant herd size *(no.)*	-0.01841 (0.00750)**	0.01792 (0.00975)*
Proportion of female animals *(%)*	-0.95574 (0.12146)***	0.03787 (0.20146)
Number of dead animals	-0.07609 (0.01526)***	0.00754 (0.02095)
Distance to nearest livestock market *(walking minutes)*	-0.00160 (0.00047)***	-0.00065 (0.00069)
Distance to all weather road *(walking minutes)*	0.00038 (0.00040)	-0.00061 (0.00067)
Distance to DA post *(walking minutes)*	-0.00011 (0.00096)	-0.00180 (0.00162)
Involvement in extension program *(yes=1, no=0)*	0.16102 (0.05793)***	0.22237 (0.08556)***
Credit use *(yes=1, no=0)*	0.17866 (0.07056)**	0.19900 (0.09760)**
Population density *(persons/ha.)*	0.00929 (0.01146)	-0.02870 (0.02496)
Constant	0.32135 (0.20439)	-1.84126 (0.33202)***
Number of observation	2246	
Wald $chi^2(40)$	347.70	
Prob > chi^2	0.0000	

Probit regression results

Table 6 presents the results of the maximum likelihood probit estimates of the models explaining the probability of household participation in small ruminant markets as seller and as buyer.

Determinants of selling

The results show that small ruminant flock size, participation in livestock extension service, and use of credit services increase the probability of market participation as seller, all with expected signs. Small ruminant flock size has significant non-linear effect on probability of selling, with an optimal small ruminant flock size of 41 animals, beyond which probability of participation as seller starts to decline. Flock size increases participation as seller because of the possibility to produce surplus to market, result that is consistent with the findings of Negassa and Jabbar (2008) in the highlands of Ethiopia, and Bellemare and Barret (2007) for the pastoral regions of northern Kenya and Southern Ethiopia. The livestock development extension program increases the probability of selling consistent with its core objectives of promoting household's involvement in market oriented livestock production. Use of credit facilities increases selling since the imperfect or missing credit markets is a major constraint of investment in livestock in the highlands of Ethiopia.

Large ruminant herd size, proportion of female animals in the flock, number of dead animals in the year, land size, household wealth, and distance to nearest livestock market decrease the probability of market participation as seller, also all with expected signs. Large ruminants may be serving as alternative cash sources for households, thus detracting from selling small ruminants. The number of dead animals reduces probability of selling, consistent with and reinforcing the effect of larger flock size increasing the probability of selling. Female animals in the herd are usually preferably kept for breeding purposes and in a small herd size such as shown by the average stock size of sample households, the higher proportion of female animals is likely to decrease selling at the margin because households retain female animals to sustain their stock. Multivariate econometric results obtained by Barret et al. (2006) for pastoralists showed no significant effect of proportion of female animals on livestock marketing behavior of herders.

Households with larger land size are more likely to depend on crop production and so the lower likelihood for them to participate in the small ruminant markets as sellers. Such households may have higher opportunity costs for involvement in market oriented small ruminant production. Desta (1999) posits that in a local economy offering limited alternative livelihood strategies, livestock are the most attractive assets available and a best option to meet future food security for the household. Barret et al. (2006) also reported that the low market participation sites in their study areas were the areas which had the best alternative livelihoods. The farther the household resides from the nearest livestock market, the less likely it will be involved in selling due to both fixed and variable marketing costs. Distant markets can be source of fixed costs in the form of transport and lodging for the participant, as well as variable costs. Barret et al. (2006) also found that reduced costs to market participation for Ethiopian pastoralists stimulate livestock marketing at the margin.

Table 6: Marginal effects of the probit regression equations

Explanatory variables	Marginal effects after Bivariate Probit Regression dy/dx (Std. Err.)	
	Sell or not	Buy or not
Age of household head *(year)*	-0.00005 (0.00108)	0.00005 (0.00050)
Sex of household head *(male=1, female=0)*	-0.01466 (0.03397)	0.00127 (0.01498)
Family size *(no.)*	-0.01825 (0.01355)	-0.00247 (0.00597)
Dependency ratio	0.05131 (0.03192)	0.00167 (0.01414)
Available family labor *(15-64 age)*	0.03436 (0.02259)	0.00067 (0.00998)
Year of schooling of Household head *(year)*	-0.00008 (0.00394)	0.00132 (0.00169)
Land owned *(ha.)*	-0.02884 (0.00928)***	-0.00571 (0.00417)
Household wealth *(1000 Birr)*	-0.00005 (0.00020)	0.00011 (0.00007)*
Non-farm cash income *(1000 Birr)*	0.00004 (0.00130)	-0.00053 (0.00065)
Availability of cell phone *(yes=1, no=0)*	-0.01693 (0.02490)	-0.00197 (0.01128)
Small ruminant herd size *(no.)*	0.04162 (0.00372)***	0.00756 (0.00197)***
Small ruminant herd size square *(no.)*	-0.00051 (0.00009)***	-0.00018 (0.00006)***
Large ruminant herd size *(no.)*	-0.00726 (0.00296)**	0.00205 (0.00111)*
Proportion of female animals *(%)*	-0.37704 (0.04796)***	0.00433 (0.02305)
Number of dead animals	-0.03002 (0.00602)***	0.00086 (0.00240)
Distance to nearest livestock market *(walking minutes)*	-0.00063 (0.00019)***	-0.00007 (0.00008)
Distance to all weather road *(walking minutes)*	0.00015 (0.00016)	-0.00007 (0.00008)
Distance to DA post *(walking minutes)*	-0.00004 (0.00038)	-0.00021 (0.00019)
Involvement in extension program *(yes=1, no=0)*	0.06332 (0.02268)***	0.02627 (0.01039)**
Credit use *(yes=1, no=0)*	0.06975 (0.02718)***	0.02497 (0.01336)*
Population density *(persons/ha.)*	0.00366 (0.00452)	-0.00328 (0.00284)

Marginal effect coefficients of the probit model are given in Table (7). Marginal effect results show that involvements in extension and use of credit have higher marginal effects. Involvement in livestock extension and use of credit increase the probability of a seller by about 6% and 7%, respectively, while one more animal in the flock increases probability of participation as a seller by 4.2%. The small effect of an increase of one head of animal to the flock on the probability of market participation shows that the average flock size is too small to promote market orientation and significant effort is needed to raise the flock size to an optimal level of 41 heads of animals.

Table 7: Ordered probit regression results for market position of households

Explanatory variables	Ordered Probit Regression Market position Coef. (Std. Err.)
Age of household head *(year)*	-0.00054 (0.00255)
Sex of household head *(male=1, female=0)*	-0.05848 (0.08049)
Family size *(no.)*	-0.04030 (0.03162)
Dependency ratio	0.14552 (0.07558)*
Available family labor *(15-64 age)*	0.08535 (0.05309)
Year of schooling of Household head *(year)*	-0.00241 (0.00933)
Land owned *(ha.)*	-0.03547 (0.02151)*
Household wealth *(1000 Birr)*	-0.00039 (0.00046)
Non-farm cash income *(1000 Birr)*	0.00212 (0.00322)
Availability of cell phone *(yes=1, no=0)*	-0.03441 (0.05898)
Small ruminant herd size *(no.)*	0.08642 (0.00890)***
Small ruminant herd size square *(no.)*	-0.00100 (0.00022)***
Large ruminant herd size *(no.)*	-0.02225 (0.00661)***
Proportion of female animals *(%)*	-0.87961 (0.11450)***
Number of dead animals	-0.08064 (0.01406)***
Distance to nearest livestock market *(walking minutes)*	-0.00156 (0.00043)***
Distance to all weather road *(walking minutes)*	0.00046 (0.00037)
Distance to DA post *(walking minutes)*	0.00041 (0.00089)
Involvement in extension program *(yes=1, no=0)*	0.06357 (0.05410)
Credit use *(yes=1, no=0)*	0.11207 (0.06605)*
Population density *(persons/ha.)*	0.01156 (0.01068)
Number of observation	2246
LR $chi^2(20)$	271.85
Prob > chi^2	0.0000
Pseudo R^2	0.0748

The effect of proportion of female animals in the flock is also important: ten percent increase in the proportion of female animal decreases probability of a selling by almost 4%, and death of one animal decreases probability of selling by about 3%. A reduction of two hours walking distance to livestock market increases the probability of participation as seller by about 7.2%. Improved livestock health service, development of livestock market places, improvement of access to road and transport infrastructure and collective action to sell small ruminants may be potential option to explore to reduce marketing costs.

The combined effect of the significant variables on market participation as seller could guide the development of small ruminant extension package. An increase of flock size by 10 animals combined with involvement in extension and credit, and reduction of distance to livestock market by 2 hours increases the probability of market participation as a seller by more than 62%. These results show that the development of livestock markets, market institutions and transportation infrastructure should be combined with improved production, health care, and access to extension and credit services for highest impact to promote market oriented small ruminant production. However, the increase in flock size to the optimal level of 41 heads per household is likely to put tremendous pressure on the natural resource base through demand for feed and water. Hence, in an effort to enhance market-oriented small ruminant production, interventions should be targeted at farm households who are more likely to stand out as more market-oriented small ruminant producers.

Determinants of buying

The results also show that household wealth (value of physical assets excluding small and large ruminants), herd size, involvement in livestock extension, and use of credit services increase the probability of buying, all with expected signs. Small ruminant flock size has a significant quadratic effect on probability of selling, with an optimal size of 21 animals, beyond which probability of buying starts to decline, suggesting that herd size of 21 animals can be adequately self-sustaining in the highlands. Descriptive analysis results show that most of the purchases made by households were meant for reproduction purposes. Hence, flock size, not only encourages selling, but also buying apparently in order to build stock and produce marketable surplus. This effect of herd size on the probability of selling and buying suggests that building herd size is crucial for market oriented small ruminant production. Interestingly, we also find that large ruminants herd size increases probability of buying, perhaps because income from large ruminants may be used to finance purchase of small ruminants.

The livestock extension service increases probability of buying, in addition to its positive effect on the probability of selling. The livestock extension package seems to have started showing effect in promoting market oriented small ruminant production. Access and use of credit facilities also increase probability of buying and selling, suggesting that livestock credit facilities are important to promote market oriented livestock production. Marginal effect results show that one more small ruminant to the flock increases probability of buying by about 7%, while an additional large ruminant increases the probability by about 2%. Involvement in extension and use of credit increase the probability of buying by about 2% each.

Ordered probit regression results

Table 8 presents the results of the maximum likelihood ordered probit equation explaining the probability of household positions in the market. Results of the ordered probit reinforce the findings in the probit estimations. Results show that household total dependency ratio, small ruminant flock size, and use of credit increase the probability of a household being a net seller, all with expected signs. Higher dependency ratio increases household cash requirements to cover miscellaneous expenses related with dependents, and raises the probability of a household being net seller than autarkic or net buyer. As flock size increases, household is more likely to be net seller than to be autarkic or net buyer because of the effect to have surplus for sale, other things held constant. Credit, by easing the liquidity constraints to invest in livestock, increases the probability of being net seller. On the other hand, land size, large ruminant herd size, proportion of female animals, number of dead animals, and distance to livestock market decrease the probability of net selling. These same variables, except dependency ratio, also reduce the probability of household participation as seller.

Table 8: Marginal effect results for market position of households

Explanatory variables	Marginal effects after Ordered Probit Regression – Market position dy/dx (Std. Err.)		
	Net Buyer	**Autarchic**	**Net Seller**
Age of household head *(year)*	0.00003 (0.00014)	0.00018 (0.00087)	-0.00021 (0.00101)
Sex of household head *(male=1, female=0)*	0.00314 (0.00416)	0.01996 (0.02756)	-0.02311 (0.03170)
Family size *(no.)*	0.00225 (0.00178)	0.01371 (0.01077)	-0.01597 (0.01253)
Dependency ratio	-0.00814 (0.00429)*	-0.04952 (0.02576)*	0.05766 (0.02995)*
Available family labor *(15-64 age)*	-0.00478 (0.00300)	-0.02904 (0.01808)	0.03382 (0.02104)
Year of schooling of Household head *(year)*	0.00013 (0.00052)	0.00082 (0.00318)	-0.00095 (0.00370)
Land owned *(ha.)*	0.00198 (0.00122)	0.01207 (0.00732)*	-0.01406 (0.00852)*
Household wealth *(1000 Birr)*	0.00002 (0.00003)	0.00013 (0.00016)	-0.00016 (0.00018)
Non-farm cash income *(1000 Birr)*	-0.00012 (0.00018)	-0.00072 (0.00110)	0.00084 (0.00128)
Availability of cell phone *(yes=1, no=0)*	0.00191 (0.00325)	0.01172 (0.02010)	-0.01363 (0.02334)
Small ruminant herd size *(no.)*	-0.00484 (0.00067)***	-0.02941 (0.00313)***	0.03424 (0.00352)***
Small ruminant herd size square *(no.)*	0.00006 (0.00001)***	0.00034 (0.00008)***	-0.00040 (0.00009)***
Large ruminant herd size *(no.)*	0.00125 (0.00039)***	0.00757 (0.00226)***	-0.00882 (0.00262)***
Proportion of female animals *(%)*	0.04922 (0.00781)***	0.29931 (0.03990)***	-0.34853 (0.04538)***
Number of dead animals	0.00451 (0.00089)***	0.02744 (0.00485)***	-0.03195 (0.00557)***
Distance to nearest livestock market *(walking minutes)*	0.00009 (0.00003)***	0.00053 (0.00015)***	-0.00062 (0.00017)***
Distance to all weather road *(walking minutes)*	-0.00003 (0.00002)	-0.00016 (0.00013)	0.00018 (0.00015)
Distance to DA post *(walking minutes)*	-0.00002 (0.00005)	-0.00014 (0.00030)	0.00016 (0.00035)
Involvement in extension program *(yes=1, no=0)*	-0.00352 (0.00299)	-0.02165 (0.01843)	0.02517 (0.02140)
Credit use *(yes=1, no=0)*	-0.00588 (0.00330)*	-0.03831 (0.02266)*	0.04419 (0.02589)*
Population density *(persons/ha.)*	-0.00065 (0.00060)	-0.00393 (0.00363)	0.00458 (0.00423)

Net Selling

Marginal effect results (Table 9) show that a unit increase in dependency ratio increases the probability of being net seller by 5.7%, while an addition of one head of animal to the flock increases probability of being a net seller by about 3.4%. Use of credit increases the likelihood of net selling by about 4.4%. The fact that credit use affects positively both the probability of selling and buying, as well as the probability of being net seller strengthens the point that that livestock credit is essential to promote market oriented small ruminant production in the study area. A ten percent increase in the proportion of female animals decreases the likelihood of net selling by 3.5%. The negative effects of the proportion of female animals on selling and net selling can be reduced by increasing the reproductive efficiency of small ruminants. A death of one animal also reduces probability of net selling by about 3.2%, consistent with the effect of herd size. A reduction of 2 hours of walking distance to nearest livestock market increases the probability of net selling by about 7.2%, strengthening the result of the probit model.

Net Buying

The marginal effect results also identified significant variables that affect probability of net buying (Table 12). Large ruminant herd size, proportion of females in the flock, number of dead animals and distance to livestock market increase the probability of net buying, while dependency ratio, small ruminant flock size, and credit use decrease the probability of net buying. Large ruminant herd size increase probability of net buying perhaps because of its role as alternative cash sources. It is not clear why higher proportion of female animals in the herd increase the probability of net buying. It could be that households with higher proportion of female animals are induced to buy bucks or rams for reproductive purposes, other factors held constant. However, this is a tentative hypothesis to explain an unexpected result and requires further testing. The effect is also significant: a ten percent increase in the proportion of female animals in the herd increases the probability of net buying by about 5%. Similarly, it is interesting to see that distance to livestock market increases the probability of net buying, while it decreases the probability of net selling, although the marginal effect is very small. It is not clear why distance to livestock market increase probability of net buying and further study is required to explain the result. The marginal effects of dependency ration and small ruminant herd size are also small.

Autarky

The marginal effects for autarkic position show that land size, large ruminant herd size, proportion of female animals, number of dead animals, and distance to livestock market increase the probability of being autarkic. These same variables, except land size, also increase the probability of net buying, suggesting households with these characteristics are likely to be either autarchic or net buying. The marginal effects of the significant variables on probability of being autarkic are all small.

Conclusions and Recommendation

Small ruminants, which account for more than half of the domesticated ruminants in the world, are an important component of the farming systems in most developing countries. Despite their economic and social importance, socioeconomic and marketing research on small ruminants has so far been limited, a

fact which also holds strongly true in Ethiopia. This study is aimed at analyzing household marketing behavior in small ruminants in the highlands of Ethiopia and the resultant implications on the natural resource base through demands on feed and water.

Just over half of the surveyed households rear small ruminants with an average flock size of 7.8 animals. Breeding stock dominate the herd structure, consistent with the primary producers' objective of reproduction. Because of the highland nature of the study area, sheep dominate the small ruminant herds. We find that sheep and goat production are, for the most part, separate enterprises, as only 14% of small ruminant producers rear both sheep and goat. However, about 92.8% of small ruminant producers also keep cattle showing that small ruminant production is done together with cattle rearing.

Just about half of the small ruminant producers participated in the market as sellers, while only about 13% participated as buyers, and 40% did not participate in the market either way. Producers participate in the market mostly either as seller only or as buyer only, with only 5% of market participants participating both as sellers and buyers. Mature male sheep are the most sold type of animals. Almost all those who participate in the market as sellers are net sellers. Only 9% of owners are net buyers.

Econometric results identified important variables that affect market participation behavior of small ruminant producers. Flock size increases the probability of selling and buying, and being net seller suggesting that flock size is a crucial factor for market participation, consistent with the findings that established the importance of asset ownership for market participation (Barret, 2008; Negassa and Jabbar, 2008; Bellemare and Barret, 2006). The fact that flock size not only promotes selling but also buying indicates that larger flock size is needed to transform the small ruminant production into market orientation. Methods of increasing flock size could include promoting improved production and specialized small ruminant producers, combined with availing credit for small ruminant production. The significant quadratic effects of small ruminant herd size on the various indicators of market participation behavior of households also indicates that there is an optimal herd size beyond which market participation may decline. We find that a herd size of about 41 heads of small ruminants is optimal for market participation as seller and a herd size of 21 is optimal for market participation as buyer.

Distance to livestock market is another important variable that affects market behavior of households. Distance from homestead to nearest livestock market decreases the probability of selling and being net seller and increases the probability of being net buyer and autarkic. These results suggest that improvement in livestock market access should be an important consideration in promoting market oriented small ruminant production. It could take the form of developing market infrastructure such as building market places and/or developing and improving road infrastructure to reduce transportation costs. Moreover, promoting collective action for marketing small ruminants could be explored as an option.

The effects of the two institutional factors of involvement in extension and credit use are found to be strong. Involvement in livestock extension programs increases the probability of selling and buying. The effect of credit use is similar. Credit use increases the probability of selling, buying and being net seller while it decreases the probability of net buying and being autarchic. These results suggest that strengthening the livestock extension program supplemented by credit facilities can play important role in

promoting market oriented small ruminant production. In particular, the promotion of market oriented livestock extension service needs to be given due attention.

Our results highlight an important implication of the promotion of market-oriented small ruminant production on the natural resource base. The current average flock size is way below the optimal flock size computed in this analysis, implying that increasing the flock size is a crucial factor for market-oriented small ruminant production. However, interventions aimed at improving small ruminant ownership across all producers are likely to put tremendous pressure on the natural resource base through increased demands for food and water. Hence, interventions to promote market-oriented small ruminant production should be targeted at those households who are more likely to develop as market-oriented small ruminant producers in rather specialized way.

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Sustainable Pastoralism on the Borana Plateau: Research Highlights from Participatory Processes, Economics, and Rangeland Management

D. Layne Coppock,[1] Seyoum Tezera[2] Bedasa Eba[3] Jaldesa Doyo[3] Demisachew Tadele[3] DeeVon Bailey[1] Brien E. Norton[1] Solomon Desta[2] Tesfaye Alemu[3] Ajebush Defar[3] Derege Teshome,[3] Getachew Gebru,[2] Aliye Hussen,[3] Brigham Forrest,[1] Medhat Ibrahim,[1] Ruby Ward,[1] Elliott Dennis[1] Nizam Hussein[3] and Mieso Guru[3]
[1]Utah State University, [2]MARIL PLC, [3]OARI

Abstract

A research project, funded under the auspices of USAID, was initiated in late 2012 on the north-central Borana Plateau. The project had a combined research and outreach mandate. For research, the main objective was to discover opportunities that could increase the productivity of forage resources and livestock. For outreach, the objective was to implement productivity-boosting interventions within three years that would be adopted by the Borana pastoral community. We based our overall approach on Participatory Rural Appraisal (PRA) methods implemented among the residents of four Pastoral Associations (PAs). We wanted to identify major problems quickly and increase the chance that communities would readily accept intervention concepts. We used focus group studies, social surveys, economic modeling, vegetation cover assessments, and erosion control trials as our primary research methods. In this paper we offer brief highlights of the multidisciplinary work that was undertaken.

The major problems recognized by the four communities included: (1) Lack of drinking water for people and livestock; (2) low forage productivity combined with bush encroachment; (3) lack of public services; and (4) poverty. We tackled the rehabilitation of pond catchments as the primary field emphasis of our program because ponds link water with forage, people, and livestock. Companion studies included the economics of bush control, feasibility of establishing rotational grazing systems, and the behavior of the wealthiest herd owners with respect to animal asset diversification.

Key situational findings included: (1) The Boran view their livelihood status as precarious a poor class of pastoralists is growing and they clearly recognize that their society is unsustainable, with greater numbers of people and animals trying to survive on a declining base of natural resources; (2) although the pastoralists are clever in accommodating the diverse grazing needs of herd owners each year, they are unable to control the rate of forage utilization hence the fact that most of the consumable forage is removed and the exposed soil is eroding badly in many locations; and (3) the wealthy minority that own vast numbers of livestock remain traditionally minded and prefer to invest in livestock over non-livestock assets, but camels are an increasingly preferred animal asset relative to cattle.

Key intervention findings include: (1) Modeling work has revealed that reducing bushland by 30 percent can increase the human carrying capacity to a similar degree via improvements in grass production and cow milk yields, but communities would need external resources to provide an endowment of cleared bushland to begin a sustainable process of land management; (2) the PAs readily created their own rotational grazing management systems on paper based on principles provided by the project, but the

"political economy" of herd reduction is the main barrier that prevents the implementation of new grazing systems; and (3) a pilot program whereby the catchments of four badly degraded ponds were protected with bush fencingbut still allowing animal access via a single, secured corridor gave very positive results in a short period of time in terms of improved plant cover and reduced rates of pond siltation. Evidence to-date indicates that the Boran will adopt the pond-catchment protection program, but external resources are probably required to launch a major effort given that hundreds of ponds require rehabilitation.

Outcomes from a project-sponsored pastoral conference revealed that the Borana leadership is well aware of the economic and environmental challenges faced by the society. They stated that their people must commit themselves to managing the rangelands in a more responsible fashion, but that the keys to this process include the need for government and non-government players to improve livestock marketing` so that animalofftake rates can be increased. There is also a need for the process of livelihood diversification to be facilitated in ways that allow more pastoralists to invest in nonlivestock assets. The latter process can be assisted via education and policies that improve access to urban real estate, banking, and other opportunities. The conference attendees also felt that having more such meetings with a diversity of stakeholders is also extremely important.

Finally, we aspired to create an "Innovation System" involving multiple partners to most effectively carry out this project. This goal was not realized, however. This was primarily because project resources including money and time were insufficient to compel other organizations to join our effort. We also lacked the ability on the ground to provide a level of inter-institutional coordination that was required.

Introduction

Dynamics of a Pastoral System

The Borana Plateau is a 95,000 km^2 region in southern Ethiopia. It is described in detail by Coppock (1994). The Borana Plateau has a relatively cool, semiarid climate, and this is primarily due to the elevation (i.e., 1,000 to 1,500 masl). There is a bi-modal pattern of rainfall delivery that ranges between 550 to 700 mm per year. Most (60 percent) of the annual precipitation occurs during the long rainy season of March to May, with the remainder occurring during the short rainy season of October to November. The climate is generally semiarid. The vegetation is dominated by perennial grasses and woody *Acacia* species, and hence is a mixed savanna (Coppock, 1994).

The people who live on the plateau are pastoralists representing several ethnic groups. The largest group is the Borana. The Borana are *Oromifa*-speakers who have occupied the region for centuries. These people herd livestock and have traditionally subsisted on animal products (i.e., milk, meat) either for direct consumption or via sales in small towns to purchase non-pastoral foods (i.e., cereal grains, pasta), clothing, or special items such as coffee beans, chewing tobacco, or household items. Households own the livestock. The dominant species has been cattle (specifically, the Boran breed) that are prized for the quantity and quality of their milk production and their tolerance to difficult production conditions (Coppock, 1994). Cattle holdings per household have been traditionally supplemented with a few sheep or goats and a donkey for portage. The household unit typically consists of six or more members with a husband, wife, children, as well as the possibility of extended family members.

The Borana live in encampments (e.g., *olla)* that traditionally were relocated when livestock were herded in search of forage and water. The *olla* occur in *madda*, traditional units of resource allocation that include dry-season water points (e.g., deep wells), wet-season water points (e.g., ponds), and forage resources used all year (Coppock, 1994). The Boran have traditionally practiced a semi-nomadic lifestyle where the herds moved frequently and households moved occasionally.

The Borana pastoral system has exhibited considerable change over the past 30 years. The ratio of livestock to people has been declining, mostly as a function of more people on the landscape. The numbers of livestock fluctuate in a boom-and-bust fashion as affected by drought and stocking-rate dynamics (Desta and Coppock, 2002; 2004). Livestock numbers are increasingly limited by the availability of forage and water, hence livestock numbers cannot keep pace with growth in the human population. Fewer livestock per person are indicative of less milk production and fewer animal assets per person, and hence an increasing risk of poverty and food insecurity.

More people and animals means less land per capita. There is thus more land competition for grazing, non-irrigated maize farming, and the establishment of fodder banks (Desta and Coppock, 2004). The surging human population has spilled over into formerly unoccupied grazing reserves that were once used only during droughts; one outcome today is that when a drought occurs, the lack of fodder reserves means that animals die quickly from starvation and the people must then survive on food relief. More people and animals have also led the population to become more sedentary simply because there are fewer unoccupied places to move to. Other contributors to sedentarization have included the establishment of large, permanent water points (i.e., Beke Pond) as well as the lure of towns and large villages as market centers and places where a few public services can be accessed. When herds become more sedentary they become more vulnerable to feed shortages and disease; this also leads to foraging areas being repeatedly grazed to an extent that the grass cover is removed and noxious bush species can invade. Bush then further reduces grazing capacity by suppressing grass production; most of the noxious bush species do not even provide much in the way of suitable browse forage for camels or goats (Coppock, 1994).
More water points and more animals also lead to a general increase in livestock impacts on the landscape. These include soil compaction associated with excessive trampling and denudation of pond catchments. Denudation of pond catchments then leads to high rates of pond siltation and poor water quality due to sedimentation. Alteration of rangeland hydrology occurs as a result of water being transpired from deep soil layers by noxious bush species and via a lowering of water tables from processes such as gully erosion. These contribute to a xerification or drying of the environment. Xerification alone can further reduce forage yields for livestock. When climate change is added in, the specter of a downward spiral increases. The scenarios for southern Ethiopia suggest that the region will become warmer and drier in the coming decades, particularly to the east (Funk et al., 2012).

Creation of "Project Kalo"

During mid-2012 a USAID-sponsored, collaborative research support program entitled *"Adapting Livestock Systems to Climate Change"* sent out a request for proposals that targeted the Borana Plateau for study. The area of investigation was not climate change per se, but rather work that would address the declining status of forage and livestock productivity. Were there technologies or management practices that might mitigate the declines? Then a second major challenge was included, namely that if a technology or management practice was identified that could improve productivity, the successful project

should strive to have the innovation(s) adopted by the pastoral community by the end of the three-year project.

We therefore accepted these challenges. We realized that in order to quickly assess problems that might generate practical, adoptable solutions, we needed to use participatory approaches with the pastoral communities. We focused our winning proposal on a wide array of possible rangeland improvement pathways. For example, for livestock we were thinking that herd diversification from cattle-dominated to camel-dominated holdings made sense given the increase in woody plants and the projected warming and drying of the environment. For herbaceous forage we were thinking that enhancements of the existing fodder bank (e.g., *kalo*) system made sense; there were reports that the numbers and sizes of dry-season fodder banks were increasing, and we already knew that the practice of bush fencing, deferred grazing, and a lowered grazing intensity that were employed in *kalo* management resulted in a recovery of key grass species and enhancement of grass standing crops when compared to unprotected, adjacent sites (Coppock, 1994). For people we were thinking that livelihood diversification and improved livestock marketing could be fostered by investment in building human and social capital as per the prior success with pastoral women on the USAID-supported PARIMA project (Coppock et al., 2011).

Finally, given the complexity of making sustainable improvements in either the livestock, forage, or human components of the system, we knew that partnerships with other groups from government, non-government organizations, or civil society would be necessary. Different partners bring varied skills and resources to the table, and an assemblage of dozens of partners was vital to the success of the women's groups in PARIMA. An informal, dynamic association of partners devoted to tackling a core problem and achieving shared learning from the experience is referred to as an "Innovation System" (Rölling, 2009); hence we expected that an "Innovation System" would need to be forged in this project to have sustained success.

The formal name of the project at the time of inception was "*Sustainable Pastoralism on the Borana Plateau: An Innovation Systems Approach.*" After the Utah team members had completed their first field trip to Borana early in 2013, we thought we needed to create a less formal, shorter name for the project. We decided on "*Project Kalo*" with the recognition that *kalo* represents both indigenous innovation as well as forage and livestock resources combined.

The proposal was led by Utah State University (USU), and two local partners were selected. The partners included the Ethiopian consulting firm Managing Risk for Improved Livelihoods (MARIL) PLC, Addis Ababa, and the Oromia Agricultural Research Institute (OARI). The OARI had representation on the project from several units including the main OARI headquarters in Addis Ababa, a regional station located in Borana Zone called the Yabelo Pastoral & Dryland Agricultural Research Center (YPDARC), and the Adami Tulu Agricultural Research Center (ATARC) center at Ziway.

Study Area

With a limited budget and a restricted capacity for local transportation, we selected four Pastoral Associations (PAs) to collectively serve as the study area. They needed to be easily accessible to our project partners. These were Dikale, Harweyu, Denbala Bedana, and Medecho. These four PAs are

largely adjacent to each other in the north-central region of the plateau. Dikale, Harweyu, and Denbala Bedana occur within the Yabelo District while Medecho occurs within the Dire District.

Statistics concerning the human and livestock populations are shown in Table 1. The four PAs vary markedly with respect to population density and natural resources, despite that they are within 50 km of each other. Dikale to the northeast has a landscape and level of precipitation that is most conducive to non-irrigated cultivation; it also has the largest numbers of people and livestock. Dikale is also notable because the livestock there can rely on large, permanent ponds rather than deep wells for their dry-season water; this has altered the dry-season labor demands for the people because they need not work lifting water in the deep wells. The landscape and soils in Dikale also appear to be more conducive to extensive gullying that has been accelerating in the past decade according to oral histories (Coppock et al., 2014a). The gullying has resulted from a combination of intense trampling and grazing impacts from livestock over several decades, and in combination with occasional flooding

Harweyu PA to the northwest has the greatest extent of bush encroachment again an attribute of this particular landscape and soil type interacting with chronic grazing pressure and reduced fire frequency. There is little cultivation at Harweyu in contrast to Dikale. Denbala Bedana and Medecho PAs to the southwest and southeast, respectively, have lower densities of people and livestock than Dikale and Harweyu (Table 1). Denbala Bedana hosts a large number of deep wells that attract herds from across the region during the dry season, and this has intensified grazing pressure in this PA[32]

[32] *Variation in human and livestock numbers largely reflect local variation in ecological site potential. The maximum distance separating these pastoral associations is 90 km^2 (between Dikale and Medecho). Higher or lower cattle numbers for Dikale and Harweyu, for example, reflect (in part) a higher degree of bush encroachment and less herbaceous forage production in the latter. Each pastoral association provides most of the water and forage for resident herds in most years; during drought years all livestock species may seek forage and water away from the home pastoral association.*

Table 1. Population and land statistics covering four Pastoral Associations (PAs) on the north-central Borana Plateau, 2013 (source: Adapted from Coppock et al. 2014a)[33].

Pastoral Association	Area (km^2)	Human Population	Cattle	Camels	Sheep and Goats	Humans (per km^2)	Cattle (per km^2)
Dikale	315	4,409	25,420	671	22,460	14.0	81
Harweyu	567	3,067	8,700	900	11,400	5.4	15
Medecho	392	3,763	12,484	594	16,480	9.6	32
D. Bedana	767	4,229	6,245	671	23,740	5.5	8
Average	510	3,867	13,212	709	18,520	8.6	34

Research context and objectives

Stage 1: Research Objectives

The project was designed to be managed in an adaptive fashion. In other words, the specific (detailed) research objectives were not identified in the initial proposal but rather were clarified after the pastoral population was engaged and their priority problems revealed. This is best depicted as a two-stage process. The Stage 1 research objectives were thus:

- Determine the priority problems of the pastoralists in the study area; and
- Facilitate creation of community action plans to address priority problems.

As will be described, we identified lack of drinking water for people and livestock, low forage yields, lack of public services, and poverty as key priority problems to be tackled. The community action plans emphasized multiple water sources for development attention (i.e., ponds, deep wells, cisterns, springs, etc.) while the low forage yields were attributed to general degradation of the land from over-grazing, drought, and bush encroachment. Because the problems of water and forage were deemed as most aligned with the general thrust of our proposal, those topics were prioritized in our subsequent work.

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Context for Pond Catchment Rehabilitation

For water we decided to focus on pond rehabilitation. Ponds are a vital resource during the months of March to August for all Boran, with larger ponds providing water for longer periods of time. There are hundreds of ponds in the north-central region. Ponds are also a focal point that link forage, livestock, and people; hence we felt that by giving attention to ponds we could address multiple project goals at the same time.

We are aware that the deep wells are the critical water source for the majority of people and herds during dry seasons in the central region (Coppock, 1994). We are also aware that the areas around the entrances to the deep wells are ecologically degraded. Given the choice between a focus on ponds or wells, we felt that the scale of the pond problem was a better match for our project given we had limited financial resources. In addition, while each of the four PAs selected for study had similar management issues concerning ponds, they showed more variation with respect to the deep wells. For example, although Denbala Bedana serves as an epicenter for deep wells in the region, the people in Dikale do not have access to deep wells because they rely on very large permanent ponds for dry-season water.

Our initial reconnaissance activities confirmed that pond catchments were badly degraded from uncontrolled use by livestock. Ponds and pond water are community resources. Livestock approach ponds to drink from all angles and are unrestrained by herders. The trampling and grazing activities over decades have resulted in near barren surfaces in the catchments that are very susceptible to soil erosion following rainfall events. Eroding soil then rapidly fills the ponds with sediment. As sediment increases the water holding capacity of a pond decreases; high sediment loads also reduce water quality for consumption by people and animals. Ultimately, ponds must be desilted, and the most common approach has been to use community volunteer laborers who lift sediment with decrepit shovels or their bare hands. Unless a donor is found to help pay for the work, the labor must be freely provided by the community, and this can be a very difficult task, with many hundreds of man-days required for larger ponds. In some cases if a pond catchment is near a road, communities have been known to convince operators of heavy machinery (i.e., bulldozers, graders, etc.) to spend a couple of hours to desilt a pond.

It had been previously noted that vegetation recovery in *kalo* can be very impressive, and this is indicative that the vegetation is resilient in the face of intensive use by livestock. In other words, given a pause in grazing pressure, the forage can quickly recover. We therefore decided to transfer elements of the *kalo* approach to pond catchment rehabilitation.

We invited each PA to nominate one pond catchment for rehabilitation as a demonstration. Once the ponds were identified, the project paid for community laborers to encircle the perimeter of each catchment with thorn-bush fencing; the areas fenced varied from four to 20 hectares in size. Assuming the fenced areas constituted a circular shape, the length of perimeter fencing would have varied from about 0.7 to 1.6 kilometers.

Livestock would not be allowed to breach the fencing, but access to water would be granted via one low-impact corridor. Animals would be confined to the corridor and not allowed to wander around the catchment. We therefore planned to monitor vegetation recovery in the protected catchments over time.

In addition to protection from grazing, pond catchments and neighboring sites were often damaged by gully erosion. Some gullies were over two meters deep. We therefore wanted to make some efforts at gully repair to assess what the best practices might be in this environment. We wanted to emphasize the use of local labor and local materials such as combining rock with the boles and branches of noxious tree species. The types of structures created included sieve dams, check dams, and trenches.

Context for Assessing the Effects of Bush Encroachment

Our initial insights into the effects of bush encroachment on understory vegetation came from direct observations the team made near the end of the long rainy season at Harweyu PA during May 2013. Some sites had been cleared of dense bush a few months earlier by local pastoralists wielding pangas and hand axes; this allowed us to make a visual contrast of the understory vegetation between adjacent sites with or without bush, and following a long rainy season that had "near normal" levels of precipitation.
Some images of the two site types are shown in Forrest et al. (2014), and they are dramatic. While the understory vegetation in the shaded, bush-encroached sites was sparse and dominated by a low standing crop of unpalatable forbs and annual grasses, the understory vegetation in sites cleared of bush was completely different. Lush stands of high-quality perennial grasses such as *Cenchrus*, *Andropogon*, *Themeda*, and other species occurred at a total biomass level visually estimated at over 10-times that of the bush-encroached sites (on a fresh-weight basis).

This clearly demonstrated the great potential that bush clearing could have on improving the forage resources for grazing cattle, and to a lesser extent for sheep and goats. It was obvious why the pastoralists had spent time manually clearing the area of bush, despite the very hard work this entailed. We therefore wanted to undertake a comprehensive assessment of the implications of bush clearing by using economics to integrate various benefits and costs of the process.

There were several questions we wanted to answer concerning bush management. First, is bushclearing economic in other words, do the returns merit the costs? Given the current resource trends and productive attributes of the livestock, are browsing camels really a viable alternative to grazing cattle in a place like Harweyu? What could be the effect of bush clearing on reducing food aid to the human population, given that bush reduces grass, and less grass means less milk from the dominant species, cattle? If *kalo* are erected around bush-cleared sites, does this further enhance the economic returns from bush clearing?

Context for Assessing Grazing Management

It was apparent, whether considering pond-catchment rehabilitation or bush encroachment, that we needed to better understand how livestock foraging was controlled in the pastoral system overall. Unless we understood grazing management in particular, the chance that any improvements we recommended would be sustainable would be in question. Our impression was that seemingly uncontrolled grazing was the major contributor to most of the environmental ills we observed. We therefore decided to include an exploratory study as to how grazing is managed in the four PAs.

Context for Assessing Asset Diversification among Wealthy Pastoralists

The PRA results revealed that all four pastoral communities were concerned about a trend towards increasing wealth stratification. Overall, fewer herd owners own a larger percentage of the livestock with many hundreds of animals per household while there is a growing number of very poor households that may own just a few animals. This trend has many implications for resource management and equity in the society. It is important to begin to understand how the very wealthy behave and what the implications are for everyone else. We therefore decided to make a preliminary study of some of the very wealthy pastoralists. Our goal was to assess their life backgrounds, management philosophies, and attitudes towards asset diversification. This diversification of assets was approached in two ways, namely in relation to different livestock species and in relation to pastoral versus non-pastoral investments. In this case traditional pastoral investments would focus on livestock, while non-pastoral investments could include houses built in local towns to rent, creating small business ventures, or simply putting funds in bank savings accounts.

Stage 2 Research Objectives

The Stage 2 research objectives were aligned more closely with results emphasized in this paper. They included the determination of:

- The effects of protection from livestock on the recovery of herbaceous vegetation in pond catchments;
- The utility of various methods of gully repair;
- The economic net benefit of pond catchment rehabilitation;
- The economic net benefit of bush clearing;
- The basic elements of grazing management as practiced at the PA level;
- Patterns of asset diversification for wealthy pastoralists; and
- The extent that the Boran leadership perceives major economic and environmental problems facing the society, as well as clarification of their ideas regarding the help they need to move forward.

Why No Direct Project Attention to Camels, Goats, Kalo, or Collective Action?

Given that the project mandate was to investigate ways to boost forage and livestock productivity, it is noteworthy that the project did not directly address issues pertaining to browsing camels or goats as herd-diversification options or to the *kalo* forage enclosures. Camels, goats, and *kalo* were indirectly analyzed, however, in the context of assessing the economic net benefit of bush clearing (above).

In our original proposal the issue of herd diversification from cattle-dominated holdings to camel-dominated holdings was prominent, as were questions of upgrading the local goats via cross-breeding. We also noted the key issue of *kalo* expansion and whether the project could build on this trend or try to improve forage resources inside *kalo*. It was apparent that *kalo* were increasing in both number and average size in the region (Napier and Desta, 2011).

These were speculative ideas based on literature review and previous experience in the area, however, and were not based on current community needs-assessments.

Most importantly, the team decided to primarily focus on the issues that were prioritized by the pastoral communities in the PRA exercises in the first phase of the project, irrespective of what had been promoted in the proposal. Water and bush encroachment thus emerged as the top priorities for intervention in the eyes of the people. We therefore emphasized these issues because we were also charged with the challenge of identifying interventions that would be adopted by the pastoralists within a short period of time. Unless the interventions dealt with felt needs of the people, we concluded there would be little hope of rapid adoption success.

Camels, goats, or *kalo* did not emerge as priorities in the PRAs and thus were not emphasized by the project. Cattle clearly remain as the dominant livestock species in the system. Cattle comprise over 80 percent of the livestock biomass and provide the vast majority of the milk supply. Male cattle are readily sold to both domestic and export markets. Camels, however, are increasingly important to the Boran because they are exceedingly mobile during drought, can utilize otherwise unusable browse forage, provide milk during most of the year, and are now a high-value commodity for export markets, in particular. Camels are increasing relative to cattle in the north central region of the plateau [a conclusion founded on unpublished calculations in Coppock (2013) from data in Coppock (1994) and Pastoral Association official 2011 figures]. Camel biomass in local herds has grown from three percent in the 1980s to 16 percent by 2011; cattle biomass has declined from 90 to 77 percent over the same period. Small ruminants and equines have remained steady. The trend towards more camels has been recently confirmed in the published literature (Boru et al., 2014). In sum, camels do matter here, but the Borana already seem successful at pursuing herd diversification with camels.

Our resistance to working directly with *kalo* stems from concerns of the lack of transparency of *kalo* ownership and use in recent years. Napier and Desta (2011) noted that wealthy, influential pastoralists were increasingly annexing land from the communal rangelands to serve as private *kalo*. Napier and Desta (2011) advocated that policy makers act to disallow the establishment of private *kalo* in favor of traditional, community-based *kalo*. We therefore decided to defer any direct work with *kalo* until this land use policy was clarified. In particular, we did not want to dwell on interventions for *kalo* that might end up only benefitting a wealthy minority in the system.

Finally, there has been success on the plateau in terms of diversifying pastoral livelihoods as a risk-management intervention. The means to do this has involved inspiring collective action and entrepreneurial behavior among pastoral women. This project has been described in Coppock et al. (2011). Poverty alleviation did emerge as a priority in the PRAs, and we initially planned to pursue some activities that could facilitate collective action and cooperative development in the four study sites. We were unable to pursue these plans aggressively, however, because the pond rehabilitation and bush clearing assessments quickly dominated our time and financial resources. This was unfortunate, however, because poverty and poor access to education and other public services were commonly mentioned as major concerns of the pastoralists.

Methods

Research and public engagement methods are listed below in the order of the Stage 1 and Stage 2 Research Objectives that have been previously noted. The major methods have included:

- Participatory Rural Appraisals (PRAs) followed the procedures in Lelo et al. (2000). There were about 50 participants for each PRA in the four PAs. The participants were volunteers who well-represented a diversity of wealth classes, age groupings, and gender.
  Each PRA took three to five days to complete. The PRA toolbox includes a variety of step-wise activities such as community sketch maps, wealth rankings of households, historical timelines, institutional analyses, problem analyses, and development of community action plans. The details of these procedures as pertaining to the four study sites are described in Coppock et al. (2014a). The four PAs had been selected from eight candidate PAs based on a rapid rural appraisal and interviews of PA leaders (Coppock et al., 2014a).

- Follow-up or companion studies to the PRAs primarily concerned the descriptions and problems associated with the management of water resources or the management of grazing at the four PAs. These methods used focus group procedures (Short, 2006) with about eight to 12 members per group who were knowledgeable in the issues at hand. For grazing management, the discussions were augmented with hand drawn depictions of PAs where the residents indicated major community features (i.e., landscapes, villages, roads, farm fields, etc.) and then superimposed a hypothetical framework of paddocks that could be used in a rest-rotational grazing system.

- We were interested in making an economic assessment of the value of bush clearing in relation to multi-species livestock production. The approach is described more fully in Forrest (2014) and Forrest et al. (2014). Our analysis focused on Harweyu PA because almost all of the landscape is covered by bushland that has expanded to cover an otherwise mixed savanna. A linear program (LP) was used to conduct the economic analysis. The LP assumes that members of the community maximize income from selling crops and livestock products (milk and older animals) and subtracts the cost of raising crops and livestock, household expenses (including schooling and medical), buying food, clearing bush, and developing *kalo*. Resource constraints in the model included the need to meet minimum nutritional needs of the human population (calories per day), the number of livestock, the land available to the community, and the labor available to the community. Very large data sets were used to build the model; these data came from the literature, key informant interviews, or official PA statistics. In addition to seasons, years of average rainfall and drought years were considered. The data sets included the human population numbers, family composition by age and gender, the diets and energy requirements of all people in the community, the patterns of household expenses, and how family labor is allocated. For the rangelands, data concerning forage production, wastage losses, and consumption by livestock were incorporated. This considered the grass component, the herb (forb) component, and the browse component. For the livestock, data sets included numbers, age and sex classes for each species, body sizes, and demand for feeds according to feeding habits and lactation. Market prices

for local commodities and the costs of labor were also in the analysis. Drought was simulated by reducing grass, forbs, and browse production by 75, 50, and 20 percent, respectively, compared to an average rainfall year. A variety of model scenarios were used in the LP exercises. These included scenarios based on whether: (1) Rainfall is normal or a drought is occurring; (2) the livestock herd is in a rebuilding phase following a previous drought or is at full carrying capacity; (3) a certain amount of land has already been cleared or not (this is considered as a "sunk cost" creating a cleared land endowment); and (4) *kalo* have been developed earlier or not (another "sunk cost" providing a *kalo* endowment). The endowments of cleared land and *kalo* were considered to have only minimal maintenance costs and labor requirements. Consequently, the LP selected the number of hectares of cleared land and *kalo* necessary to maintain livestock numbers when these endowments were present. For drought scenarios, human caloric intake for the community is assumed to be 10 percent less than normal, assuming that a certain level of fewer calories could sustain the human population before food aid would be required.

- We wanted to assess the risk management behavior and investment strategies of the wealthiest cohort of Borana pastoralists. This is because although they are few in number, the wealthiest pastoralists control more and more of the livestock and are important players in terms of resource use and the local economy (Coppock et al., 2014a). A key component of supply-driven economic growth is investment in infrastructure, capital, and new or expanded commercial enterprises. The linkages among investment, economic growth, and economic opportunity are important because jobs and incomes typically rely on such activities. Besides helping to generate economic activity and growth, investment also plays an important role in helping poor, rural communities adapt to environmental changes such as those occurring from climate change. For example, clearing bush can make pastoral communities more resilient to climate change because more herbaceous forage resources are created, but bush-clearing requires time and money. Beyond investing in drought-mitigation strategies, general investment in small communities and towns in the form of retail shops, hotels, restaurants, and homes could have significant positive economic impacts. Understanding what drives investment decisions in poor, rural areas of the developing world can assist economic development efforts as well as support community resilience. Face-to-face interviews with 12 wealthy pastoralists were undertaken during January and February 2015. The respondents provided information about their livestock and non-livestock holdings as well as perceptions of how discretionary income should be invested. The risks of alternative investment (both livestock and non-livestock assets) were also estimated by simulating average returns for the investment portfolio of each respondent over a 10-year period. This provided a measure of the risk as measured by the standard deviation of average returns (meanvariance approach).
- The assessment of vegetation recovery in fenced pond catchments relied on the measurement of plant cover and presence of species in permanent 1.0 m^2 plots (quadrats). Understory vegetation tends to be thicker nearer to the pond proper where sediment accumulates and the soil is naturally more fertile and moist. The sampling plots were therefore grouped into two zones based on distance from the pond edge; one closer than the other. In June 2014, 72 plots were installed in the four protected pond catchments, including some control plots located outside the bush fences for comparative purposes. The permanent plot locations were marked with wooden pegs and large nails driven into the corners, plus GPS coordinates. An electronic metal detector was used to find the corner nail markers, thus facilitating accurate relocation of plots.

- Recording of information on the basal cover and species occurrence in each plot was facilitated by using a grid created with nylon strands stretched every 10 cm from both sides of the sampling frame. This created a grid of 100 cells with each cell having an area of 10 x 10 cm. Cover and species occurrence were noted on a per cell basis and summed across each frame placement. Many quadrats were photographed with the quadrat frame in place. Data on plant cover and records of species presence and species dominance were collected following the rainy seasons in June 2014, November 2014, and June 2015.

- The sandy and loamy soils of the Borana plateau erode easily. Gullies leading into ponds are the principal pathways for sediment input. Gully treatments were introduced to reduce sediment loads during storm run-off. The concept is not to create solid dam barriers but rather to slow down water flow so that suspended sediment particles are deposited in the gullies before they reach the pond. This approach was proven in the rehabilitation of a deep gully in the Kobo Watershed where sieve structures were implanted in March 2014. In the four protected pond catchments, sieve structures were placed at regular intervals (five to 20 m apart) across gullies and embedded into the gully walls. Tree-stem posts were firmly inserted into the gully floor in two parallel rows to form the foundation of the sieve, from 50 to 150 cm in height. The spaces of 30 to 50 cm between the rows of posts were packed with branches from thorny *Acacia* trees positioned horizontally. Wherever possible, stubs of woody *Commiphora* stems were used for the posts; sprigs of *Aloe* sp. were also planted among these posts. Both the *Commiphora* and *Aloe* materials were expected to sprout and grow to form a living sieve structure. Within a year of establishment, other species such as the local grass *Cynodon dactylon* were expected to grow into the sieve structures to reinforce the effect. A scoring system ranging from 1.0 (poor performance) to 5.0 (excellent performance) was used to monitor the effectiveness of the sieve structures for gully rehabilitation over time.

Highlights of Findings

Participatory Rural Appraisals

The PRA results are discussed in detail elsewhere (Coppock et al., 2014a,b), but a few summary points are mentioned here. The participants from all four communities perceived that the human and livestock populations are still growing. They also noted that, in general, the environmental conditions seem to be getting worse. This includes more over-grazing, bush encroachment, and soil erosion. The people also mentioned that the climate is changing as the region is becoming warmer and drier. An assessment of wealth classes revealed that the numbers of poor households are growing. A small number of households are becoming extremely wealthy, and they control more and more of the livestock. Nearly half of all households own just a few head of livestock each, and thus human food needs are regularly met by food aid.

The rankings of priority problems were somewhat irregular across the four PRA communities, but the same six issues tended to be mentioned repeatedly. The top-ranked problem overall was a general shortage of drinking water for both people and livestock. Most water-supply problems were attributed to high rates of pond siltation due to widespread denudation and erosion of catchments. In addition, cement

cisterns, hand pumps, and infrastructure for the deep wells had fallen into disrepair. Another priority problem was a general lack of forage (bundled together as feed shortages, bush encroachment, and poor natural resource management). There was also a pronounced need for poverty alleviation, improvement in human health, enhanced access to education, and improvement in livestock health. Other, unranked challenges included unreliable livestock markets, new livestock diseases, and the need to better manage resource-based social conflicts. Customary institutions have been weakened and require strengthening. Livestock mobility has been reduced. Some positive trends, however, were also noted for the region. These included improved access to formal education, expanded human and animal health services, growing livestock markets, more non-pastoral investment options, and improved communication with mobile phones. Pastoralists have also been showing more interest in rangeland rehabilitation, grazing management, and watershed protections.

In the process of conducting PRAs and reporting the results at meetings, local GOs and NGOs were invited to participate. We were unable, however, to inspire the formation of an Innovation System whereby multiple partners were compelled to join our effort. This is unlike the PARIMA project where dozens of partners facilitated the sustained interventions necessary to promote collective action among pastoral women (Coppock et al., 2011). The primary project partners, OARI, MARIL, and USU, remained as such throughout the three years of project life.

Economics of Bush Control

The LP results indicated that the community of Harweyu PA is self-sufficient, overall, during years of average rainfall because income (the value of the LP objective function) is positive for all scenarios assuming normal rainfall. However, during a drought year, milk production decreases dramatically, crops fail, grain prices increase, and there is insufficient forage to support livestock numbers all of which result in dramatic decreases in income levels and dramatic increases in food aid needed during droughts to sustain the human population.

Drought scenarios with no bush clearing or *kalo* endowments suggest that a severe drought will result in a loss of approximately 70 percent of the cattle in the system either through offtake or death loss. This seems reasonable given past research about drought effects here. Normal rainfall scenarios were the only ones selecting small ruminants (sheep and goats) to be in the system. The reason for this is that during droughts, grass and forbs production is greatly reduced and remaining herbaceous production is used for cattle. This places small ruminants in direct competition with camels for browse that occurs lower in the woody canopy, and the LP selects camels over small ruminants when this happens because camels produce more milk (especially during dry periods) than small ruminants and are more valuable on a per head basis when they are sold. This result suggests the increasing number of camels in the Borana Plateau is a rational response in the face of frequent droughts. While there is pressure to supplant small ruminants with camels as a response to drought, small ruminants remain important. Sheep and goats can easily be sold to meet short-term household needs requiring relatively small amounts of cash. Sheep also have traditional value in rituals but are more susceptible to disease than goats. This suggests that sheep and goats will continue to be an important part of the livestock mix but that the number of camels will continue to grow.

The LP suggests a very large amount of resources would need to be devoted by the community to clear the bushland. Between 13,000 to 18,700 hectares of bush would need to be cleared to provide enough grass to reliably support the cattle needed for the 3,057 residents. Less land would need to be cleared if *kalo* were developed for the cleared areas because the forage in *kalo* is conserved to be used in the long dry season, the time when forage is least available. Once land is cleared, however, only a small amount of labor and other resources would be needed to keep the land bush-free. The analysis suggests the community could bear the costs of maintaining cleared land and *kalo* if there was an "endowment" of cleared land and the upfront resources needed to create this endowment were not borne by the community.

Even clearing bush and establishing *kalo* will not eliminate the need for food aid during droughts, however. Food aid could be reduced by almost 30 percent if large-scale bush clearing is undertaken. However, our calculation of the costs to clear enough bush and establish enough *kalo* to support livestock numbers at full capacity is over US $1,600 per person in the community per year for five years, while food aid costs per recipient are estimated not to exceed US $500 per person during a drought. This suggests that the cost of bush clearing and/or *kalo* development cannot be justified solely by the savings in food-aid costs.

Further simulation of conditions (income) for the community over a 10-year period revealed that the introduction of bush clearing and *kalo* development increase average community income and reduce the standard deviation of income compared to a scenario where no large-scale bush clearing and/or *kalo* development is undertaken. This suggests that clearing bush and/or developing *kalo* is an effective method to increase the resiliency of the community. However, costs for clearing bush and developing *kalo* are high and may not allow for the large-scale implementation of such an intervention.

Asset Diversification and Investment Strategies of Wealthy Pastoralists

The livestock holdings of the 12 survey respondents are much larger than those of the average pastoralist in the study area. For example, the average wealthy pastoralist reportedly owns 379 cattle, 33 camels, and 368 sheep or goats (Ibrahim, 2015). Figures in Table 1 suggest that the average pastoralist household owns 24 cattle, 1 camel, and 34 small ruminants if it is assumed that each household has seven members. The growing numbers of poor households, however, own significantly fewer animals than this (Coppock, 2014a).

The interviewees currently diversify their investments across both livestock and non-livestock assets, although approximately two-thirds are in livestock. The average investment portfolio consisted of bank accounts (12.9 percent), cattle (35.3 percent), camels (21.9 percent), goats (3.8 percent), sheep (3.8 percent), real estate (22.2 percent; this tended to be investments in small shops or rental residences), and maize plus Haricot bean cultivation (0.2 percent). Investments within the livestock component are also fairly well diversified. Using cost and returns information from Forrest (2014), a simulation over a 10-year period was performed assuming four years of normal rainfall followed by two years of drought followed by four years of rebuilding livestock herds. Information on how the simulation was conducted is provided in Ibrahim (2015).

Correlations between the estimated mean and variance (standard deviation) of annual returns for the 12 portfolios and the percentages of the portfolio held by survey participants in different livestock and non-livestock assets were calculated. There is a large and positive (+0.85) correlation between mean return and the percentage of cattle held in the portfolio, suggesting that a higher percentage of cattle in a portfolio corresponded with higher average or mean return to the portfolio. Conversely, there is a relatively large, negative correlation (-0.85) between mean return and the percentage of the portfolio held in a bank account, suggesting that survey respondents with a large proportion of their assets held in a bank account also tend to have lower mean returns than those with small amounts or no assets held in a bank account.

The correlations also indicate that although holding a high proportion of cattle in the portfolio is positively correlated to a higher mean return, it is also highly and positively correlated with a higher risk (standard deviation). This implies that cattle are a relatively lucrative, but risky, investment compared to the alternatives. Holding a large proportion of the total investment portfolio in non-livestock investments such as bank accounts and real estate reduces both expected returns and risk (negative correlation). The proportion of the portfolio held as camels is negatively correlated with both real estate holdings and bank accounts, suggesting that camels are viewed by participants as substitutes for the non-pastoral investments. That is, survey respondents with camels representing a relatively large percentage of their portfolio tended to have smaller percentages of their portfolio in real estate and bank accounts, and vice versa. This suggests that some participants prefer to reduce risk with a livestock investment (more camels and fewer cattle) while others prefer non-pastoral investments (bank accounts and real estate) to reduce risk rather than investing more in camels. The proportion of the portfolio held as a bank account is positively correlated with the proportion held in real estate investments, suggesting that these are complementary investments. Or, in other words, participants holding bank accounts also tended to hold real estate investments.

When survey respondents were asked how they would spread 100 hypothetical units of investment across new livestock investments, cattle and camels remained the primary livestock investment that would be made. However, when the hypothetical investments could be made across a range of livestock and non-livestock assets, real estate (almost 50 units on average) and investing in family (education, housing, etc.; 12.5 units on average) were by far the most preferred investments selected by the participants. The hypothetical choices are very different than the current, mostly livestock, investment portfolios held by interviewees. This implies the participants would be expected to continue to move toward non-livestock investments and away from livestock. To illustrate, although the current proportion of the total investment portfolio is about 65 percent in livestock, this falls to about eight percent in the hypothetical portfolio (Ibrahim, 2015).

Pond Catchment Rehabilitation

Protection from livestock grazing led to substantial increases in plant cover (Table 2). Within the four pond enclosures, plant cover steadily increased at each sampling period. Mean plant cover was 9 percent in June, 2014, 17.6 percent in November 2014, and 37.6 percent in June, 2015. Cover more than doubled from one post-rainy season sample to the next, but increased nearly four-fold over 12 months from June, 2014, to June, 2015. When the data are broken down according to zones within the enclosures, the zone closest to the pond recorded a plant cover trend of 15.6, 34.7 and 59.9 percent over the three sampling

periods. In contrast, the zone furthest from the pond where vegetation was initially less dense exhibited plant cover values of 5.2, 14.2 and 22.4 percent across the same three sampling dates.

The data from control plots are more ambiguous. Bare ground dominated the control plots with only 3.1 percent mean cover at the June, 2014, sampling date. The bush fencing for the Dikale and Denbala Bedana sites was extended outwards by the communities in August 2014, complicating our design. The fenced extensions annexed the original control plot locations in these sites. By November, 2014, the cover on the former "control" plots at Dikale jumped from 0.7 percent to 4.3 percent, and then up to 14.4 percent by June, 2015.

Table 2. Average plant cover (%) for 1.0-m^2 plots located within four protected pond catchments at four Pastoral Associations (PAs) on the north-central Borana Plateau, during 2014 and 2015 (source: Norton et al., unpublished data).[1]

Pastoral Association	2014				2015			
	Number of Plots	% Cover (Jun 14)	% Cover (Nov 14)	% Change (Jun 14 to Nov 14)	Number of Plots	% Cover (June 15)	% Change (Nov 14 to Jun 15)	% Change (Jun 14 to Jun 15)
Dikale	18	11	26	+ 142	16	37	+ 45	+ 252
Harweyu	15	4	8	+ 103	15	27	+245	+ 600
Medecho	7	6	18	+ 175	7	36	+105	+464
D. Bedana	12	15	36	+ 138	12	51	+39	+230
Average	--	9	18	+141	--	38	+109	+387

[1]*See the text for details on data collection methods. June in both years corresponds to the period just after the long rains have ended. November corresponds to the period just after the short rains have ended. Data were rounded to the nearest whole percentage for this presentation. In most cases vegetation was allowed to grow in the absence of grazing. In some cases, however, unauthorized grazing occurred.*

Similarly, the former "control" plots at Denbala Bedana had a mean cover of 6.3 percent in June, 2014, before the bush-fence extension, and then showed a value of 29.3 percent in November, 2014, after having been protected during the preceding short rainy season. A value of 35 percent cover was recorded in June, 2015.

A general observation from these data is that protection from livestock grazing can cause dramatic increases in vegetation cover within a relatively short time namely just one rainy season. Second, the trend of increasing plant cover under protection has not yet reached its potential after 12 months over two rainy seasons. Third, even areas that initially had very low plant cover can experience massive increases in vegetation. For example, the interior zone at Harweyu began with 3.4 percent cover in June 2014 and finished with 37.2 percent cover 12 months later; cover in the interior zone at Medecho jumped from 2 percent in June 2014 to 46.7 percent by June 2015. The exterior zone showed similarly large increases in cover. For example, mean cover in the exterior zone at Dikale was 3 percent in June 2014 and 23.8 percent at the final sampling in June 2015. Finally, of the 15 plots that were completely bare in June 2014, just seven remained bare in November 2014, with only four by June 2015.

Dominant species within the protected pond catchments were mainly perennial grasses such as *Cynodon dactylon, Sporobolus pellucidus, Pennisetum mezianum,* and *Cenchrus ciliaris.* Dominance by individual species varied according to soil type and distance from the pond edge. The drier Medecho site exhibited higher species diversity with an average of 7.4 species per square meter, while plots at Harweyu recorded only 3.6 species per square meter, on average. A surprising amount of dynamism occurred in plot floristics over the three sampling times. This is partly due to the cumulative effects of an absence of grazing, and partly to seasonal differences in floristics from the long rainy season to the short rainy season. More annual species appeared in November (following the short rains) compared to June (following the long rains).

Gulley Repair

More than 30 sieve structures have been placed in gullies in the Dikale pond enclosure, beginning with an initial set implanted in May 2014. Sieve-structure design and construction improved by the second generation of structures that were established in October 2014. These structures were monitored in February 2015 and most of them received a score of 2.5 on a rating system of 1.0 to 5.0. A score of 2.5 indicated that they appeared to be effective, but their effectiveness needed to be tested in heavy rainstorm events occurring during the long rainy season.

The impact of heavy gully flows from rainstorms in during the long rains of March to May 2015 was mixed. Sieve structures placed in small gullies <1m wide in May 2014 were generally effective in slowing down gully flows and capturing sediment. Where the October 2015 structures spanned gullies up to 1m deep and with catchment watersheds of less than 1 km^2, they remained intact during the long rainy season. However, sieve structures were washed away in the largest Dikale gully that is fed by an extensive catchment of many square kilometers. In the future, gully erosion treatments must begin at the head of large gullies with sieve interventions inserted at regular intervals down the direction of flow.

Low levels of effectiveness in rainstorms also occurred where a sieve structure was constructed across a broad, shallow depression, but failed to have secure attachments at the edges on either side of the depression. Sieve structures at Denbala Bedana and Medecho survived the long rains, but those in the largest gully at Harweyu were washed away. The local OARI Soil and Water Conservation Team has learned much from the experiences of gully repair successes and failures over the past two years. The work so far has demonstrated proof of concept, but the approach and procedures need to revised to deal with the problem of very large gullies that are the main source of sediment movement into ponds, thereby reducing their water-holding capacity.

Grazing Management

The current grazing practices on Borana landscapes allow livestock to have continuous access to any areas that are not demarcated by bush fences. The latter are called *kalo*, and they are a distinctive feature of livestock and land management on the Borana Plateau. *Kalo* tend to be relatively small areas of five to 50 hectares in size, and altogether comprise a very small percentage of the total landscape. Village leaders

regulate their use and families are given responsibility for monitoring compliance. *Kalo* are generally reserved for old and sick animals and for lactating cows with young calves. They also provide emergency fodder banks during warm dry seasons. More recently, *kalo* forage has been used to prepare animals for market, especially by wealthy herd owners who establish *de facto* private *kalo* that have been annexed from communal resources.

The value of *kalo* for increasing forage available in the warm dry season was evident from observations in February 2015 concerning a breach of the bush fence surrounding the Dikale pond catchment. The catchment was supposed to be protected from livestock grazing by communal agreement of the PA, but at least one herd owner found the increased forage inside the enclosure to be very attractive almost irresistible. In February 2015, dozens of sheep, goats, and cattle were foraging inside the protected catchment. The bush fence had been broken down in several places to provide easy access. By daring to trespass inside the enclosure, the herd owner inadvertently demonstrated the value of short-term protection from grazing to enhance forage resources, particularly in the dry season. This is the principle underlying a grazing management strategy to achieve three goals: Recovery of vegetation across the landscape, reduction of soil erosion, and increased livestock carrying capacity. The project has shown that the accomplishment of these objectives is technically feasible. All that is lacking is implementation of a rotational grazing plan by collaborative community action.

The four PAs where the project has worked held focus group discussions during August 2014. They prepared sustainable grazing management plans on hand-drawn maps of each PA. They recognized that the traditional *fora* and *wara* grazing system of herd movements (Coppock, 1994) no longer applies, and cannot be enforced. They also see that their rangelands are degraded and the deterioration continues. They have observed the greater forage productivity in protected *kalo* and pond catchments, and accept the need for temporary rest from livestock as the foundation of sustainable grazing management. They argued that in order for improved grazing management to succeed, livestock numbers would need to be reduced. This last point may be the main stumbling block to adopting a rotational grazing plan. However, if the greater forage production observed in kalo or the protected catchments can be extended progressively across the landscape, the resultant higher carrying capacity may obviate the need to lower animal numbers. Overall stocking rate should not be increased, however, until the resource potential has been realized.

The rotational grazing plans developed by members of the PA focus groups began with a map of wet season and dry season areas in management zones. These were further divided into “paddocks” that would be grazed sequentially. Paddock boundaries followed roads, tracks, and natural features in the landscape. Herds would be restricted to paddock areas by herders, not fences. The essence of a sustainable rotational grazing plan is to provide each area with rest from livestock during at least one rainy season, preferably two. While one area is being rested, other parts of the landscape are being grazed until their turn for a rest period arrives.

This initiation of a grazing system is rotational rest rather than rotational grazing. The goal is to work towards a situation where only one paddock is being grazed by the entire herd while all the remaining paddocks are rested; this becomes rotational grazing that ensures a combination of short but intense

grazing followed by long rest intervals for every part of the PA. It will achieve sustainable improvements in available forage, livestock productivity, community water quantity and quality, human welfare and household viability.

Perceptions of the Boran Leadership and Other Stakeholders

A pastoral conference was held on December 15-16, 2014, at the Yabelo Pastoral & Dryland Agriculture Research Center. Seventy-one people attended. A summary is provided by Tezera et al. (2015) and by Tezera et al. (submitted), but a few main points are presented here. The main purpose of the conference was to facilitate an exchange of ideas among stakeholders about the best way forward on the Borana Plateau. A variety of speakers were featured including the leader *(Abagada)* of the Boran people, a member of the federal parliament, pastoralists, researchers, and a private-sector representative. The audience included pastoralists as well as staff of GOs and NGOs in the area. The plenary talks were followed by break-out group discussions. The meeting was conducted in the *Oromifa* language.

Following the opening remarks, OARI scientists spoke about the technical results of the project with an emphasis on pond-catchment rehabilitation and the principles and practices of sound grazing management. A scientist from the USAID-sponsored CHAINS project emphasized the problems of livestock marketing with a focus on the need for pastoralists to be more proactive about selling animals as well as the gap in informal credit. A member of parliament spoke about the importance of livestock development and the challenges of livestock marketing and disease. The manager of the Yabelo branch of the Commercial Bank of Ethiopia (CBE) explained the structure of CBE and services provided. He described outreach now underway to raise awareness about banking and the value of savings mobilization. Pastoralists can use banks as a means to start a livelihood diversification process.

A local pastoralist leader described his livelihood transformation. He said that Boran society well-understands the problems and that finding solutions is the responsibility of the people. He began to diversify his livelihood years ago by using some of his livestock capital to build rental properties in town. His cash flow has increased greatly because of this diversified approach.

The current *Abagada* of the Boran people echoed the points made so far and said the society is at a turning point. He also emphasized the challenge of climate change; the future is grim. The Boran must be smarter about how they use livestock wealth, and they must improve rangeland management and restore the environment. To succeed, however, the Boran need reliable opportunities to sell animals.
The chairman of the Oromia Pastoralist Association reflected on the problems of the area. He noted that the people have high anxiety about the future. The society must take action now and not rely on GOs or NGOs to assist.

Various people spoke about the positive role of non-livestock investments and the importance of livelihood diversification for traditional pastoralists. Contrasts were drawn between the towns of Hagere Mariam and Yabelo in one case. Hagere Mariam, located 100 km north of Yabelo on the main tarmac highway, has recently witnessed more investment flow from wealthier locals than what is currently

observed in Yabelo. Government leaders in the region are currently pursuing plans to better link private investors with urban development opportunities.

Four discussion groups were formed to review (1) Grazing management and (2) livestock marketing. Some major points made for each topic are noted below:

- Proper grazing management including new ideas for forage utilization should be implemented at the *Reera* and *Dheeda* spatial scales. This process should be led by customary institutions, and GOs can assist with implementation. Other challenges include the need for herd mobility, the weakening of traditional governance, the unfavorable location of some settlements, the expansion of cultivation and private enclosures *(kalo)*, the violation of grazing bylaws by some herd owners, the high numbers of livestock, bush encroachment, and gullying. Stocking rates should be reduced by selling more animals. Stocking rates must be better matched with the condition of the land. The wealthy must maintain their herd sizes at socially acceptable levels. Cultivated areas must not occupy valuable grazing land. The opportunities for change include the large rangeland area, the ability and willingness to strengthen customary institutions, the ideas to optimize how settlements are distributed, and the high demand among consumers in Ethiopia and elsewhere for milk and meat. Strengthening of customary institutions can occur by making new bylaws and improving the ability to take action. Customary institutions can be complemented by government structures; formal government institutions can help enforce rules created by traditional means. Paddock systems with rotational grazing can be adopted by communities; these are important for fodder conservation and proper land management. Grazing enclosures *(kalo)* should be for community members to share and not for private ownership. Construction of new ponds can only go forward after approval by communities, GOs, and NGO actors.

- Livestock marketing is another priority that must be dealt with. The ability to sell animals is important for regulating the stocking rate. Livestock markets are not very predictable, and this hinders planning. Challenges include the lack of market information, poor choices by pastoralists in when they sell animals, and there are too few direct linkages between buyers and sellers. The availability of informal credit is poor and diseased animals cannot be sold. Persistence of traditional social values that compel some herd owners to accumulate too many animal numbers is a problem. The other major problems are the general lack of entrepreneurial skills, livestock marketing skills, and knowledge about alternative investment in the population. Some types of animals have no market at all one example is cows. The GOs and NGOs need to focus on strengthening and diversifying livestock markets and also can help educate pastoralists about best practices for selling animals. The GOs and NGOs can also facilitate improving credit availability and promoting best practices for livestock trading. Finally, the GOs and NGOs should put more emphasis on educating pastoralists about entrepreneurism, small business management, and the value of sending their children to school.

Conclusions

Participatory processes worked well for this project. Their proper use confirms the value that community input can have in helping target applied research. If a project hopes that research will lead to the adoption

of new technologies or ideas, the target population must be involved from the start to build trust and create collaborative synergisms; this is best conducted via broad-based participation. Approaches such as PRA can lead to new discoveries as well as practical insights for research; PRA, therefore, must not be viewed as only useful for development organizations.

The project failed to create a true Innovation System comprised of organizational partners and other stakeholders. An Innovation System with openly shared resources could have been especially useful with respect to pond-catchment rehabilitation or bush-clearing trials, both of which are very expensive to undertake. The failure to create an Innovation System occurred for several reasons. In general, the project was field active for about two years overall and lacked sufficient time and financial resources to generate the necessary interactions with other institutions. We also could have benefitted by having a senior team member permanently based in Yabelo who could coordinate activities of collaborating institutions. There was also a bit of bad luck involved; some potential partners had either recently phased out complementary work in the region or they were mandated to work in locations other than where Project *Kalo* worked. Despite that operating as part of an Innovation System could have led to a project with greater impacts, our feeling is that Project *Kalo* was very successful, regardless.

Our economics research revealed several important findings. First, while bush clearing has important implications for reducing food aid and improving drought resilience among cattlekeeping pastoralists, the great expense of bush clearing is a complicating factor. Bush clearing via manual labor or use of technologies like hand-operated chainsaws needs to be combined with widespread dry-season fodder conservation (for fuel loading) and prescribed fire to reclaim landscapes in the most economically efficient manner. Because of the high expense of bush clearing, outside assistance is required to provide an initial endowment of bush-cleared land. The expectation then becomes that the communities themselves would cover the ongoing maintenance costs. Overall, communities would need to be empowered to undertake a landscapemanagement approach complete with new grazing management provisions if widespread bush-clearing is to be economic and sustainable.

The study of the risk-management motivations of wealthy pastoralists was illuminating. In general, a portfolio with a blend of livestock and non-livestock assets is best in terms of balancing returns and risks. Camels are increasingly viewed as an important element of the livestock investment for the wealthy. Wealthy pastoralists want more non-livestock investment options than currently exist.

The most remarkable observation from the range ecology work was the high degree of resilience exhibited by the perennial grass community in response to bush clearing or short-term protection from grazing. This suggests that despite decades of poor management by the pastoralists, the potential for future range recovery under improved management systems is bright. The main situation where this would not hold true, however, is where massive topsoil losses have occurred as a result of sheet or gulley erosion.

Permanent reduction of forage-production potential is all but assured in parts of Dikale, for example, where soil erosion has been nearing catastrophic levels over the past decade. The only way to arrest the situation in Dikale is via new, strong community commitments to better regulate grazing and animal trailing as well as having residents engage in gully repair using locally available materials. The fact that the level of forage utilization has not been a factor in traditional grazing management decisions explains

why range condition has deteriorated despite the apparent attentiveness that the leadership gives to the allocation of grazing areas to herd owners. Having animals removed from locations when forage utilization has exceeded a mutually agreed, environmentally damaging threshold is the key for change. The willingness of the PA leadership to consider implementation of rest-rotational grazing systems is another positive finding. The people appear to recognize the difficult situation they are in; namely, a downward trending environmental condition in combination with ineffective or ill-adapted governance structures that do not allow easy implementation of resource management solutions. In most of the dialogue conducted by the project, the need for the traditional leadership to work with government to jointly solve problems was repeatedly noted. There was also concern that the traditions of common access to grazing posed barriers to regulation. The emergence of very wealthy herd owners was also seen as a constraint, because they would need to buy into any changes in the status quo. These issues fall under the domain of "political economy."

The pilot program for pond-catchment rehabilitation was a success for our project. As noted above, recovery of the herbaceous vegetation in protected sites was rapid and impressive; this process was facilitated by the fact that catchments are sinks for the accumulation of water and nutrients. The benefits of pond-catchment protection include a dramatic slowing of pond siltation rates and improved water quality for people and animals. Slowing down the rate of pond siltation then reduces the manual labor required for de-siltation. The key in sustaining this intervention is to compel all herd owners to respect the intervention and not breach the bush-fenced perimeter in a quest to provide forage for hungry livestock. The pressure to graze-out protected catchments would be intense during dry seasons and droughts when forage supplies elsewhere are meager. The vegetation in protected catchments can still yield forage, but on a less-destructive, and more easily monitored, cut-and-carry basis.

Finally, the pastoral conference was clear in terms of the major insights and outcomes. The Boran are fully aware of their resource management problems and the solution pathways. They lack the governance institutions to effectively intervene. External forces also affect the system that the Borana society has little control over. These include the constraints that limit an increasing and reliable marketed offtake of livestock. This could be the bottleneck for positive change for the entire system at this point; if more de-stocking could routinely occur, and if options for alternative investments to livestock could be made more available, a rationale for improved grazing management and pond-catchment management would be set in motion.

Recommendations

The project has led to a number of important insights and conclusions. Our recommendations are as follows:

- Whenever possible, applied researchers and other change agents should adopt the use of PRA and associated methods in their work. If professionals and their institutions desire positive impact from their efforts on the ground, there is no substitute for engaging the target beneficiaries when projects are in the design phase;

- Donors should actively encourage both research and development change agents to work together with communities and share knowledge, manpower, and other resources. The right incentives from donors can promote the creation of Innovation Systems founded on principles of participation, partnership, and process. Collaborators can "learn by doing," improve development practice, and build a critical mass for achieving broader-scaled development impacts. The development environment should be based on cooperation, not competition;

- The Borana pastoralists need to be empowered to begin a process of rangeland restoration, wealth conservation, and poverty mitigation. This requires effective leadership at various levels. The process also involves several dimensions, and it would require a renewed commitment by GO and NGO change agents and the communities themselves—to enable positive change to occur. The process would be founded on transparent building of partnerships and goal setting primarily involving the monitoring, evaluation, and betterment of natural resources, improved pastoral governance, and a stronger push for economic development via enhanced livestock marketing and pastoral livelihood diversification. What is first desired as an end-point is a situation where the Boran can more readily sell animals to simultaneously satisfy their personal needs, community goals, and requirements for improved management of natural resources;

- Efforts to better educate pastoralists concerning this development model should be the core priority of all change agents and their institutions. It is typical that research and development projects are focused on improvements to the physical or natural capital such as repairing wells, increasing forage yields, clearing bush, or vaccinating livestock. Investment in human and social capital, however, now needs to be the top priority to promote success.

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Impact of Grazing Around a Watering Point on Botanical Composition of a Semi-Arid Rangeland in the Southern Afar Region of Ethiopia

Kidane Gebremeskel[1]
[1]*Werer Research Center, Ethiopian Agricultural Research Organization,*
P.O. Box 2003, Addis Ababa, Ethiopia
Email: kidgeb@yahoo.com

Abstract

The botanical composition along a stratified grazing gradient around a watering point in a semi-arid rangeland in northeastern Ethiopia was investigated by means of the wheel point method for two growing seasons. Annual grasses and unpalatable forbs, which are indicators of degradation, characterized the severely degraded area in both seasons. In moderately and lightly degraded areas increase in abundance of perennial species was observed and were more preferred by the pastoral community as animal feed. In both seasons, the most frequently occurring perennial species were Chrysopogon plumulosus, Paspalidium desertorum and Panicum coloratum. Thus the study confirmed that there were differences in botanical composition at increasing distances from the watering point.

Key words: *Botanical composition; Degradation; Grazing gradient; Species ordination; watering point*

Introduction

The Allaidege rangeland of Ethiopia is one of the prominent grazing areas of the pastoral community of the Afar Regional State. In the past, the rangeland was known to be the best traditional wet season grazing area before the intervention of commercial agriculture in the region. Degradation of the rangeland gradually took place with the development of a watering point causing grazing pressure in the area. This was also accompanied with the failure of exercising the developed grazing utilization scheme in the community (MCE, 2000). This failure and lack of knowledge in the community compelled the pastoral people to persevere with grazing systems practiced in the past. This mode of grazing effected complete local extinction of palatable perennial species, a fact that is now widely acknowledged by the community (Personal communication with clan leaders and elders, 2004).

Up to now, there was no study to quantify the herbaceous compositional change of the range. Beruk (2000) in a survey assessment report of the Afar rangeland emphasized the very limited identification studies on the major indigenous grasses of the area and recommended a comprehensive study on species composition of the range.

Various researchers have reported grazing pressure, rainfall, edaphic condition and grazing history to influence botanical composition of a range (Milchunas and Lauenroth, 1993; O'Connor and Roux, 1995; Turner, 1999). Other researchers (Boudet, 1975; Stoddart et al., 1975; Pratt and Gwynne, 1977) have explicitly indicated that livestock grazing pressure in dry land regions of Africa due to traditional range management caused changes in vegetation composition of the range. Amsalu and Baars (2002) have also reported that the communally grazed agro-pastoral range areas showed poor botanical composition due to grazing pressure. Thus livestock grazing can have a profound impact on vegetation composition. The

general pattern of grazing induced botanical composition change is well documented by Kirkman (1995), Owen-Smith and Danckwerts (1997) and Amsalu and Baars (2002). The heavy utilization by livestock of forage plants around watering points compared to areas further away is confirmed by Friedel (1988) and Hart et al. (1993). To this effect it is known that less palatable or undesirable plants increase at the expense of desirable plants. The decrease of palatable plants was confirmed by Tainton (1972) and Noy-Meir, Gutman and Kaplan (1989) to be attributed to the impact of selective livestock grazing inducing a shift in botanical composition (Morris and Tainton, 1993). Hence this study evaluates the long-term effects of grazing impact around watering point on vegetation dynamics of the range.

The objective of the study was to assess the unrestricted grazing effect on the botanical composition of the range around a watering point. The following hypothesis was tested: there is no difference in botanical composition at increasing distances from the watering point.

Materials and Methods

Study area

The experiment was conducted for two seasons in a communal grazing land around a watering point. Individuals from the community group were involved in the field layout to stratify the grazing land into different grazing gradients. In cognizance of the vegetation cover the grazing area was quantitatively stratified into four grazing categories: severely degraded (SD), moderately to severely degraded (MSD), moderately degraded (MD) and lightly degraded (LD) areas. Coordinates were taken by GPS to map and calculate the area. The distance of each stratified grazing field from a watering point was also recorded as 1 500 m, 3 600 m, 5 150 m and 6 250 m for SD, MS, MD and LD, respectively.

Study design

A 1.2 km transect was laid out perpendicular to the direction of the grazing gradient, more or less in the middle of each of the grazed categories. This consideration was to avoid border effects on both sides of the different grazing gradient categories. On each transect, five 30 m x 30 m sample plots were laid out at 300 m intervals, resulting in a total of 20 plots in the experimental field. In each of the sampling plots, proportional species composition is determined using the nearest plant approach at 250 points (Bosch and Janse Van Rensburg, 1987; Bosch and Kellner, 1991; Hardy and Walker, 1991), using the wheel point method of Tidmarsh and Havenga (1955) for two seasons. The sampling was done when majority of the pasture plants were at flowering stage. The abundance of species in the sample site is expressed as a proportion of the total number of observations made for the sample site. For some species not identified in the field a representative plant was pressed, labeled and transported to the National Herbarium of Addis Ababa University (AAU) for identification.

Statistical analysis

Descriptive statistics with frequency counts and percentages were calculated for each species and life form was identified. Correspondence analysis was done to graphically show the occurrences of species and life forms with in the grazing gradients (SD, MSD, MD & LD areas). To compare all life forms with all grazing gradient a Chi-square test was performed. Then to determine more specifically where

differences occurred, all combinations of 2x2 tables were analyzed with Chi-square tests, applying Bonferroni multiple testing. Compositional difference along the years was determined using classification tree analysis.

Results

Species frequency in year 1

The rangeland consisted of a matrix of perennial grasses, annual grasses and herbaceous forbs (Table 1). In the SD grazing area, perennial grasses were not prominent in the composition and represented about 4% of the total herbage composition. Annual grasses and unpalatable herbaceous forbs dominated the grazing area. Both groups (annual grasses and unpalatable herbaceous forbs) comprised about 80% of the total composition of the grazing area (Table 1). Perennial grasses that occurred in this grazing area (albeit in low numbers) were *Sporobolus ioclados*, *Paspalidium desertorum*, *Cynodon dactylon* and *Digitaria rivae* (Table 1).

In the MSD area, perennial grasses, annual grasses and others (non grass species) comprised 16%, 63% and 21% of the botanical composition respectively. The annual grass, *Setaria verticillata*, predominantly covers this grazing area, which was also abundant in the SD area (Table 1).

The botanical composition of the MD grazing area consisted of 40% perennial grasses. *P. desertorum, S. ioclados* and *Panicum coloratum* contributed 8%, 5% and 4% respectively to the total species composition. *Chrysopogon plumulosus* was more abundant, contributing 21% of the total species composition in the area. *S. verticillata* and other herbaceous forbs have however contributed almost 60% to the plant composition in the area (Table 1).

In the LD area perennial grassess contributed 47% to the composition. The perennial grasses *C. plumulosus, S. ioclados* and *P. coloratum* contributed 16%, 17%, and 10% to the composition respectively. Other perennial grasses that contributed less than 2% to the composition were also present. Similar to the more degraded grazing areas, *S. verticillata* and other herbaceous forbs were present contributing 24% and 27% to the composition respectively, but were less prominent compared to the other grazing gradients (Table 1).

Ordination of the species in year 1

In this study the species ordination was done by giving emphasis to species with frequency of occurrence above 1 %, which also limits the number of species. It was evident that most unpalatable forb species (others) appear dominantly in the SD area.

Table 1. Species composition (%) in each grazing gradient in year 1 (SD = severely degraded area, MSD = moderately to severely degraded area, MD = moderately degraded area and LD = lightly degraded area)

			Percent composition			
Species Name	**Afar vernacular name**	**Life form**	***SD***	***MSD***	***MD***	***LD***
Perennial Grasses			%	%	%	%
Chrysopogon plumulosus Hochst	Durfu	Perennial	0	0.24	20.96	16.4
Sporobolus ioclados	Denekto	Perennial	1.84	11.52	4.8	16.6
Panicum coloratum	Denekto(p)	Perennial	0	3.6	3.6	9.6
Paspalidium desertorum	Bohale	perennial	0.88	0.32	7.92	2.16
Bothriochloa radicans (Lehm)	As ayso	perennial	0	0	2.88	
Cynodon dactylon Pers	Rareta	perennial	1.04	0	0	0
Cenchrus ciliaris	Serdoyta	perennial	0	0	0	0.4
Lintonia nutans Stapf	Afara mole	perennial	0	0	0	0.16
Sporobolus pellucidus Hoehst	Sosokete	perennial	0	0	0.16	1.28
Digitaria rivae (choir) stapf	Forele/ Hamanto	perennial	0.16	0	0.08	0
Total percentage (%)			**3.92**	**15.46**	**40.42**	**46.6**
Annual Grasses						
Setaria verticillata (L.) P.Beauv	Delayta	annual	40	62.64	33.28	23.6
Tetrapogon tenellus(Roxb)choir	Aytodyta	annual	0	0	0.24	0.32
Sporobolus panicoides A. Ruch	Gewita/Bekelayso	annual	0	0.24	0.72	2.16
Total percentage (%)			**40**	**62.88**	**34.24**	**26.1**
Edible annual forbs						
Ipomoea sinensis	Halal	annual	15.4	2.24	7.68	1.76
Other edible forbs						
Blepharis persica	Yamarukta	annual	0	0	4.88	8.16
Legume annual forbs						
Rhynchosia melacophylla (spreng,Boj)	Haro	annual	0.56	2.64	3.44	2.48
Total percentage (%)			**15.9**	**4.88**	**16**	**12.4**
Others						
Phyllanthus maderaspa tensis L.	Akelekelmi	annual	14.7	6.24	0.8	8.64
Leucas nubica Benth	Ergufuma	annual	14.2	0	0	0
Amaranthus spp.	Bunkete	annual	0.8	0	0	0.08
Orthosiphon pallidus Royle	Hebeke	annual	1.76	0.88	0	0.24
Unidentified	Alelus	annual	0.56	0	0	0

Portulaca quadrifiola L.	Halihara	annual	0.08	2.56	0.48	2.24
Unidentified	Ashara	annual	2	0	0	0
Abutilon fruticosum	Hanbukto	annual	4.8	0.8	0.64	0.64
Unidentified	Aburi	annual	1.28	0	0	0
Koheutia caespitosa	Baroberbere	annual	0	6.08	5.92	3.04
Unidentified	Mituki	annual	0	0	1.52	0.08
Total percentage (%)			**40.2**	**16.56**	**9.36**	**15**
Grand total percentage (%)			100%	100%	100%	100%

The annual grass *S. verticillata* was present in all areas but was relatively prominent in abundance in the MSD area. Similarly the analysis implicated that perennial grasses such as *P. desertorum* and *C. plumulosus* were present in MD and LD areas but more abundant in the MD area. *P. coloratum*, which is closely plotted to the LD area, is more abundant in this particular area than in the MD area (Fig 1).

The MSD, MD and LD areas did share common species such as *S. verticillata*, *S. ioclados* and *Rhynchosia melacophylla* but a higher abundance was revealed in the MSD area for the first two species alone. *R. melacophylla* maintained an equal frequency distribution in the three degradation areas (Fig. 1). The life form ordination also identified similar species ordination for *S. verticilata* (Annual grass) and *R. melacophylla* (Legume annual forb) (Fig. 2). Blepharis spp. is the only annual strictly limited to the MD and LD areas (Fig. 1).

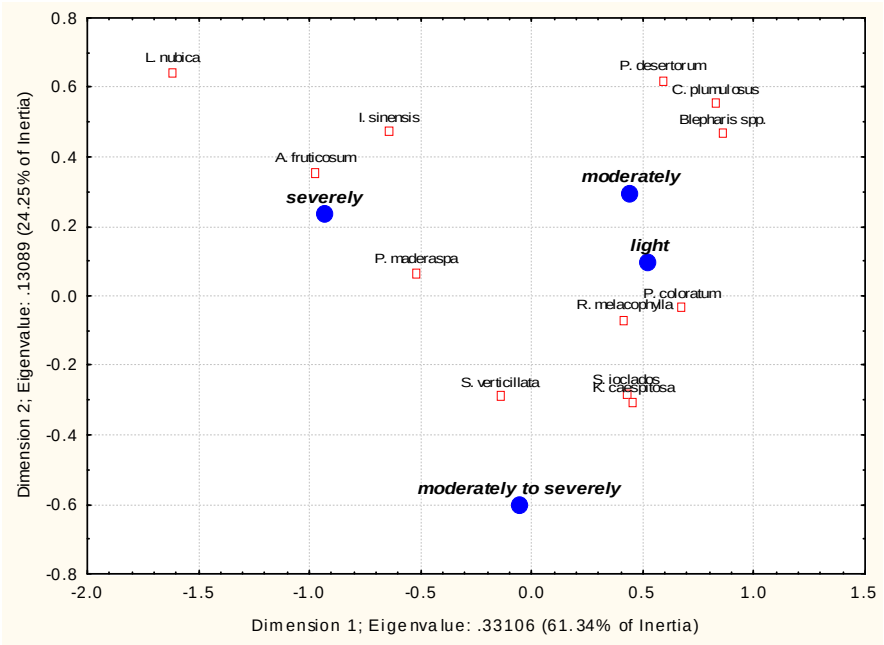

Figure 1. Ordination of the most abundant species in the rangeland according to degradation areas in year 1 (SD = severely degraded area, MSD = moderately to severely degraded area, MD = moderately degraded area and LD = lightly degraded area).

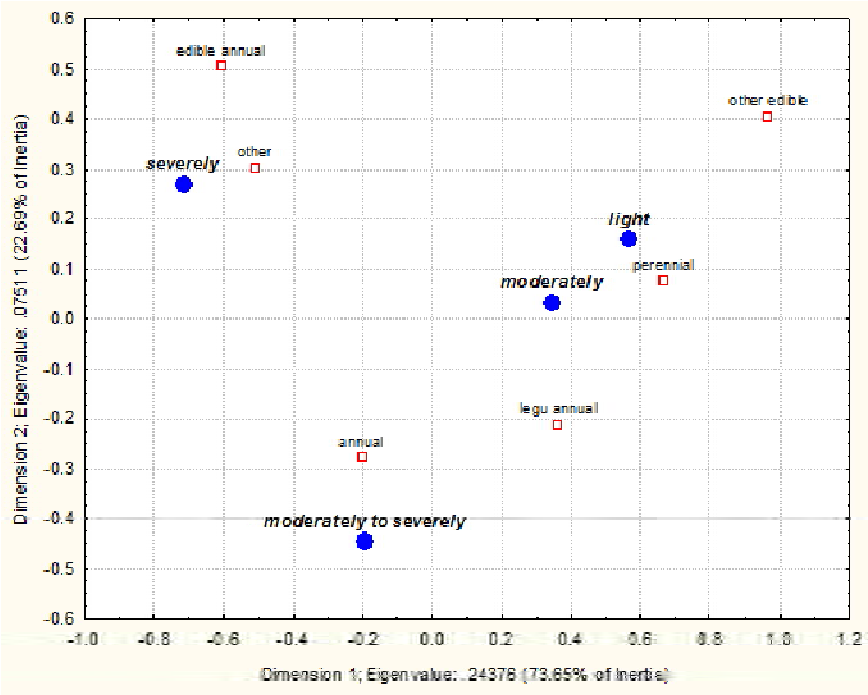

Figure 2. Ordination of life form groups in the rangeland according to degradation areas in year 1 (SD = severely degraded area, MSD = moderately to severely degraded area, MD = moderately degraded area and LD = lightly degraded area).

The species percentage distribution across the grazing gradient was identified using Classification Tree Analysis (CTA). The perennial grass species, other edible and legume annual forbs (*Blepharis* spp.and *R. melacophylla*) had a high frequency of occurrence in the MD and LD areas (37% and 42% respectively) compared to a low frequency of occurrence of 2% and 18% in the SD and MSD areas respectively (Fig.3). In contrast, the unpalatable species (*Phyllanthus maderaspa*, *Leucas nubica* & *Abutilon fruticosum*) relatively high in frequency and edible annual (*I. sinensis*) which are pioneers were found to have a total frequency of occurrence of 62% in the SD area and a consistent 12-14% frequency of occurrence in the other areas (Fig.3). A frequency of occurrence of 25% and 39% was recorded for annual grass *S. verticillata* in the SD and MSD areas respectively. The percentages for the MD and LD areas were 21% and 15% respectively (Fig. 3).

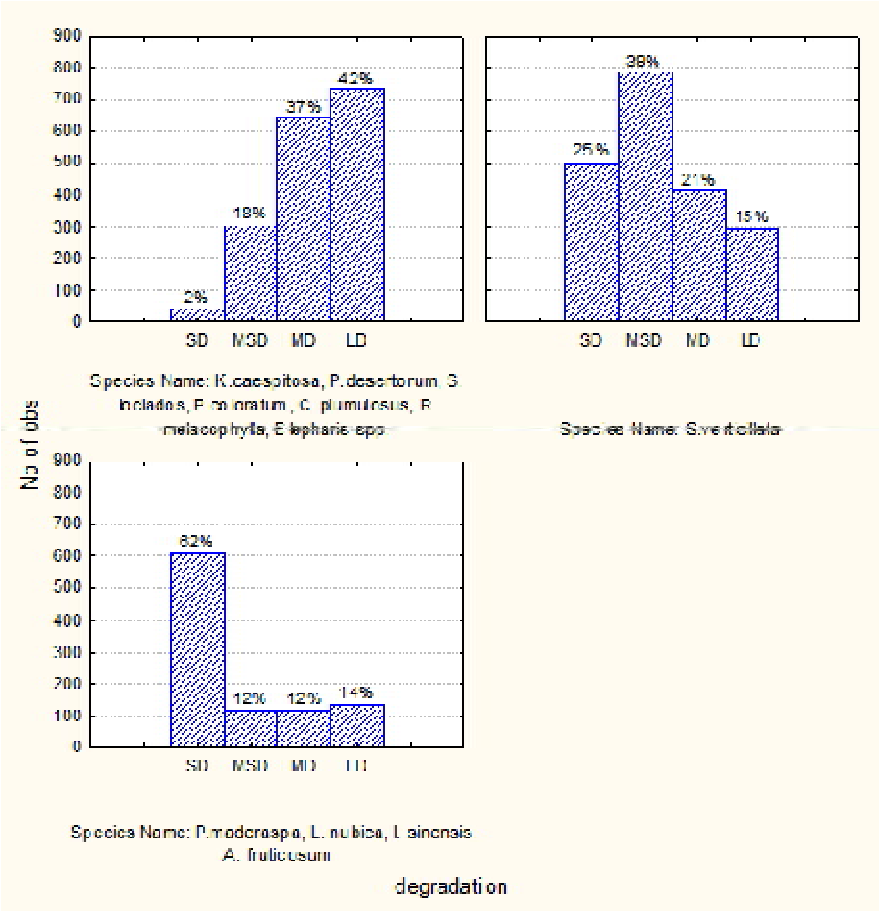

Figure 3. Frequency of occurrence of different species in the degradation areas (SD = severely degraded area, MSD = moderately to severely degraded area, MD = moderately degraded area and LD = lightly degraded area).

Species frequency in year 2

The botanical composition of the rangeland in general was similar to that of the preceding year with only slight changes in species composition in some of the degradation areas. In the SD area, perennial species comprised 6% of the vegetation compared to 4% in year 1 (Table 2). The most abundant perennial species were *S. ioclados* and *P. desertorum*, which are characteristic inhabitants of degraded or disturbed areas. In contrast, annual grasses, predominantly *S. verticillata* comprise 50% of the total botanical composition and unpalatable herbaceous forbs (others) 12% (Table 2). The MSD area consisted of 20%, 65% and 15% perennial grasses, annual grasses and others respectively. Similar to the previous year, *S. verticillata* was the most abundant species comprising 65% composition of the total herbage of this grazing area (Table 2).

In the MD area, similar to the previous year, perennials were more prominent (39% of the composition). The most frequently occurring species were *C. plumulosus*, *P. desertorum* and *P. coloratum* contributing 20%, 8% and 4% to the composition respectively. *Bothriochloa radicans*, *Sporobolus pellucidus* and Digitaria rivae were present in small numbers. The annual grass *S. verticillata* and other herbaceous forbs comprised 35% and 26% of the composition, respectively (Table 2). In the LD area, perennial grasses,

annual grasses and others comprised 38%, 36% & 25% of the total composition respectively, which was similar to the MD area. In contrast with the composition of the LD area in year 1, a low frequency of occurrence of perennials (38% compared to 46% in 2003) was recorded while abundance of the annual grass species increased (Table 2).

Table 2. Species composition (%) in the grazing gradients in year 2

			Percent composition of each grazing gradients			
Species Name	**Afar vernicular**	**Lifeform**	***severely***	***Moderate to severely***	***Moderately***	***lightly***
Perennial Grasses	Name		%	(%)	%	%
Chrysopogon plumulosus Hochst	Durfu	Perennial	0	4.72	20.16	20.08
Sporobolus ioclados	Denekto	Perennial	2	3.04	3.36	0.4
Panicum coloratum	Denekto(p)	Perennial	0	1.04	4.72	12.4
Paspalidium desertorum	Bohale	Perennial	2.56	11.04	7.92	0.88
Bothriochloa radicans(Lehm)	As ayso	Perennial	0	0	2.8	0.96
Cenchrus ciliaris	Serdoyta	Perennial	0	0	0	0.24
Lintonia nutans Stapf	Afara mole	Perennial	0	0	0	2.56
Sporobolus pellucidus Hoehst	Sosokete	Perennial	0	0.16	0.16	0.64
Digitaria rivae (choir) stapf	Forele/hamanto	Perennial	0.96	0	0.08	0.16
Total percentage (%)			5.52	20	39.2	38.32
Annual Grasses						
Setaria verticillata (L.) P.Beauv	Delayta	Annual	50.2	64.8	34.16	25.44
Tetrapogon tenellus(Roxb)choir	Aytodyta	Annual	0	0.24	0.24	0.08
Sporobolus panicoides A. Ruch	Gewita	Annual	0	0	0.72	10.64
Total percentage (%)			**50.2**	**65.04**	**35.12**	**36.16**
Edible forbs						
Edible annual						
Ipomoea sinensis	Halal	Annual	31.7	4.4	7.36	1.2
Other edible						
Blepharis spp.	Yamarukta	Annual	0	6.64	5.52	20.8
Legume annual						
Rhynchosia melacophylla (spreng,Boj)	Haro	Annual	0.24	0.72	3.44	0.16
Total percentage (%)			31.9	11.76	16.32	22.16
Others						
Phyllanthus maderaspa tensis L.	Akelekelmi	Annual	4.48	0.48	0.8	0.56
Leucas nubica Benth	Ergufuma	Annual	0	0	0	0
Amaranthus spp.	Bunkete	Annual	0.16	0	0	0
Orthosiphon pallidus Royle	Hebeke	Annual	0.32	0	0	0

	Alelus	Annual	0.96	0	0	0
Portulaca quadrifiola L.	Halihara	Annual	0.88	0.08	0.48	0.32
	Ashara	Annual	0.08	0	0	0
Abutilon fruticosum	Hanbukto	Annual	0.88	0.16	0.64	0.16
	Baroberbere	Annual	4.64	1.6	5.92	0.16
	Mituki	Annual	0	0.88	1.52	1.92
Total percentage (%)			12.4	3.2	9.36	3.12
Grand total percentage (%)			100%	100%	100%	100%

Ordination of species in year 2

Ordination of the species and the life forms using correspondence analysis was done for each degradation area (Fig. 4 and 5). From the figures certain trends could be observed in the botanical composition of the herbaceous species over the study period. Certain species were more abundant in the plots of degradation areas close to the watering point relative to the plots of degradation areas further away from the watering point. On the other hand, the decrease in abundance of other species was a common phenomenon observed. The species that increased in abundance relative to plots further from the watering point were the unpalatable species and *Ipomoea sinensis*, which is palatable. Although lower in abundance, the unpalatable species were also detected in the degradation areas further away from the watering point. The annual grass, *S. verticillata* existed in all grazing gradients but was more frequent in MSD and SD areas, similar to the trend observed for the same species in year 1 (Fig 4).

The perennial species were ordinated in accordance to their preference/palatability for animals and it was sometimes impossible to detect patterns of change of botanical composition for some of the species. For example, *P. desertorum*, which is less palatable, was more abundant in the MSD area relative to the MD and SD areas (Fig. 4). The lower abundance of this species in the SD area indicates that availability of preferred species is scarce and animals are persuaded to graze the less palatable species available.

C. plumulosus which is known to be a palatable species has a very low abundance in the MSD area closer to the watering point relative to the higher abundance observed in MD and LD areas further away from the watering point. *C. plumulosus* did not occur in the SD area. Similarly *P. coloratum* was more abundant in the LD area relative to the abundance in the MD area. The abundance of the species varied from nil to very low in SD and MSD areas respectively. *S. ioclados*, despite its low abundance in the SD area, existed at a consistent frequency in both MSD and MD areas (Fig. 4).

In terms of life forms the same trends as in year 1 were evident. The only deviation was the case of the "others" group that were more evenly distributed over the four degradation areas (Fig. 5) than in year 1, when it occurred mainly in the SD area (Fig. 2).

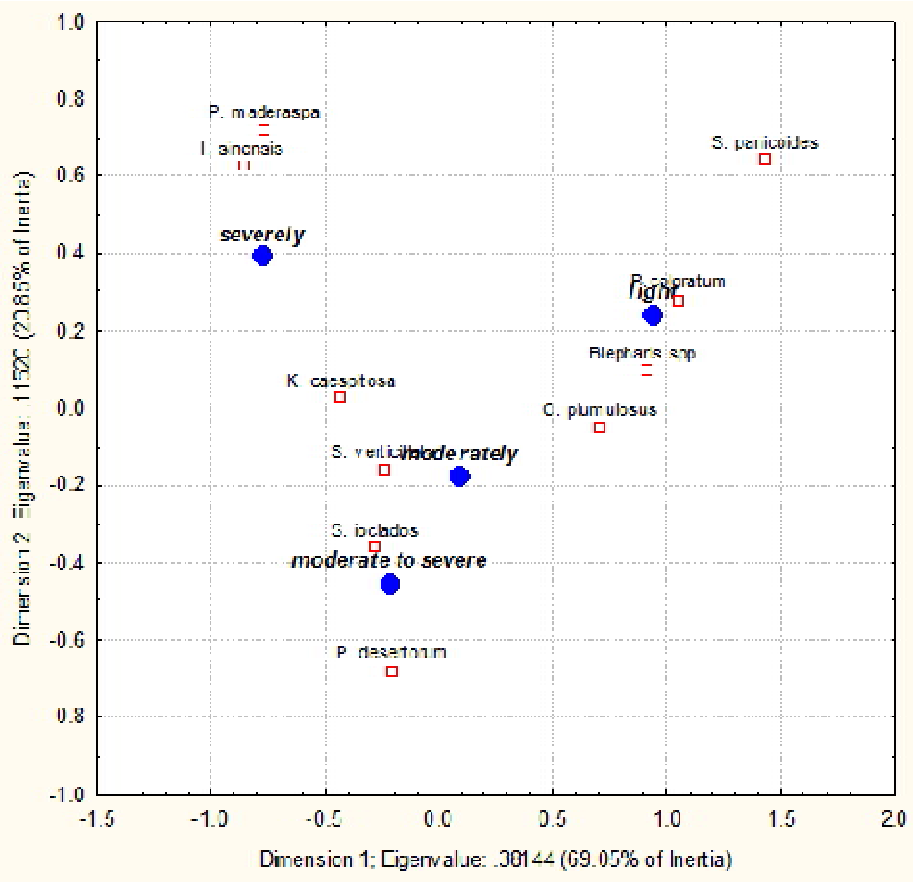

Figure 4. Ordination of the most abundant species in the rangeland according to degradation areas in year 2 (SD = severely degraded area, MSD = moderately to severely degraded area, MD = moderately degraded area and LD = lightly degraded area).

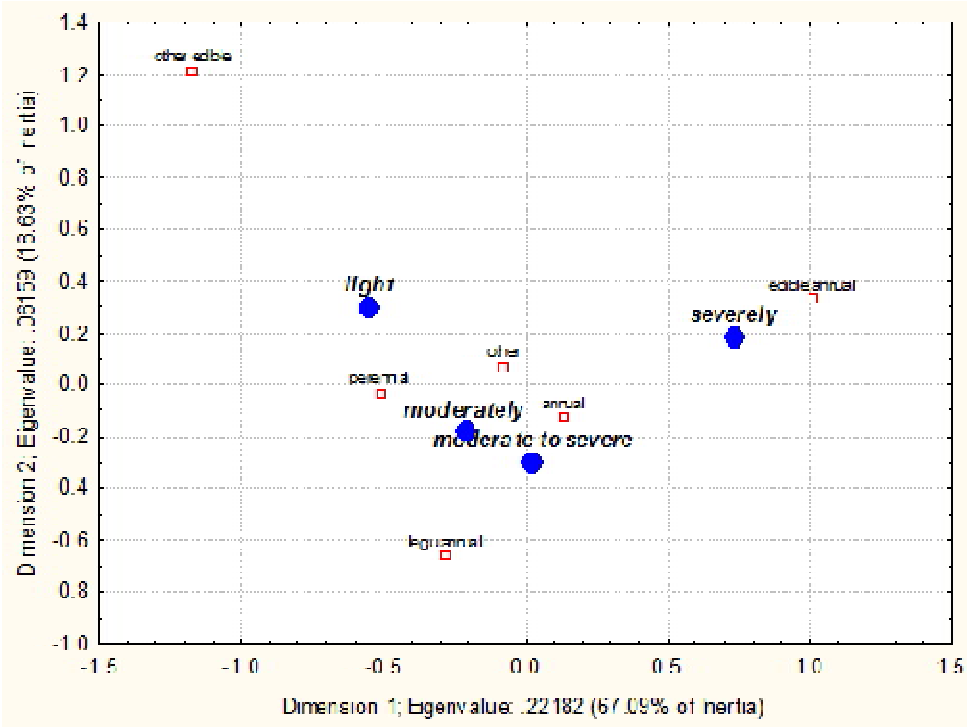

Figure 5. Ordination of life form groups in the rangeland according to degradation areas in year 2 (SD = severely degraded area, MSD = moderately to severely degraded area, MD = moderately degraded area and LD = lightly degraded area).

Frequency of life forms in grazing gradients in year 1 and year 2

Species compositional difference in each degradation area was examined based on the frequency of occurrence of different life forms (perennial grass, annual grass and others) observed in the field including all those species found to be very few in frequency of occurrence. This is because the life forms concisely categorized the species distribution in each degradation area. The perennial species distribution in the grazing gradient was emphasized for the important role they play in both animal production and soil erosion control. Before running a test comparison of each grazing gradient for the different life forms that occurred, a chi square test of the degradation levels (SD, MSD, MD & LD areas) and life forms of the species was carried out to evaluate if life forms are dependent on degradation or not. Accordingly, a highly significant difference ($p<0.05$) was recorded in both years for the different degradation areas and the three life forms considered (Figs 6 and 7).

In year 1, annual grasses and others were most abundant in the SD area with 48% and 49% frequency of occurrence respectively compared to the 3% occurrence of perennials. In the MSD area, annual grass species were dominant with a frequency of occurrence of 66%, whereas perennials and others were at equal proportions of 17%. In MD and LD areas a three-fold increase of frequency was recorded for perennials compared to the MSD area. On the other hand, annual grasses decreased to 41% and 30% and the others to 11% and 30% in MD and LD areas respectively (Fig. 6). This in general was evidence that the grazing gradient had an impact on the herbaceous composition. In year 2, the occurrence of annuals was high in SD and MSD areas with frequency of occurrence of 74% and 66% respectively. The others

and perennials were 18% and 8%, 11% and 21% for SD and MSD areas respectively. In MD and LD areas the annual grasses were more or less similar in frequency in both areas in both years. The others and perennials were almost similar in both MD and LD areas (Fig. 7).

Statistical compositional difference of life forms for year 1

A Bonferroni multiple comparison tests were made to observe the compositional difference in each degradation area for the different life forms (Table 7). The comparison made for almost all the combined tests implicated that the different life forms were significantly different ($p < 0.05$) for each comparison test of the life form vs (versus) degradation showing the impact of degradation on life form. One exception is combination test entry No. 10 made for MSD and MD areas vs the life forms of annuals and others, in which the case was not significant ($p > 0.05$). This means that the frequency of occurrence of the annuals and others was similar in both areas. (Fig.6). The same applies for entry No. 18, made for MD and LD areas vs others and perennials. Regarding perennial species, the relative proportion was compared to annuals and others in relation to each degradation area. The figure shows that the frequency of abundance of perennials increased along the grazing gradient away from the watering point for each comparison made (Fig 6).

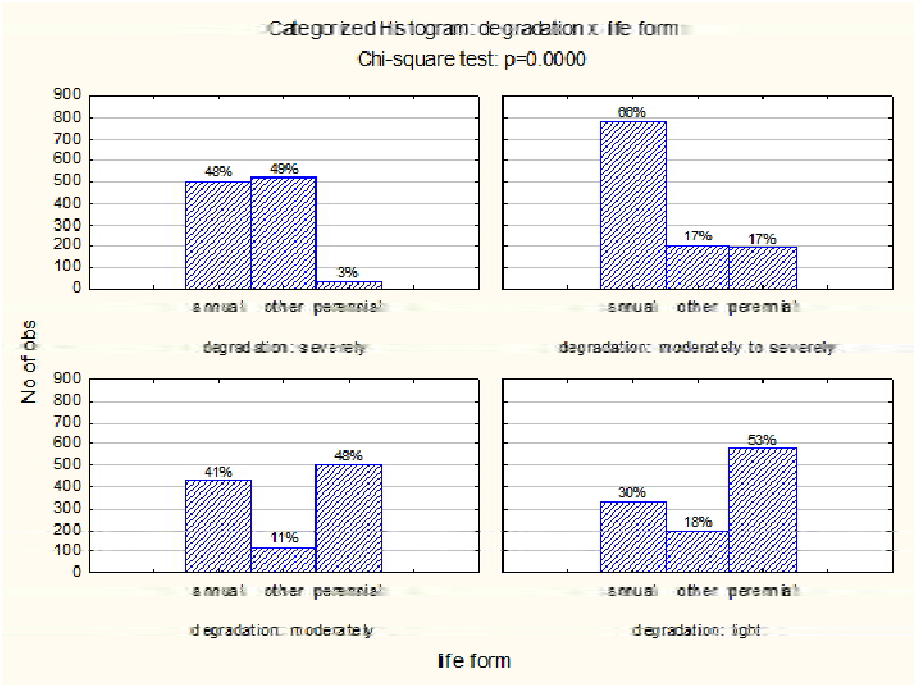

Figure 6. Frequency of occurrence of life forms in the grazing gradient in year 1 (SD = severely degraded area, MSD = moderately to severely degraded area, MD = moderately degraded area and LD = lightly degraded area).

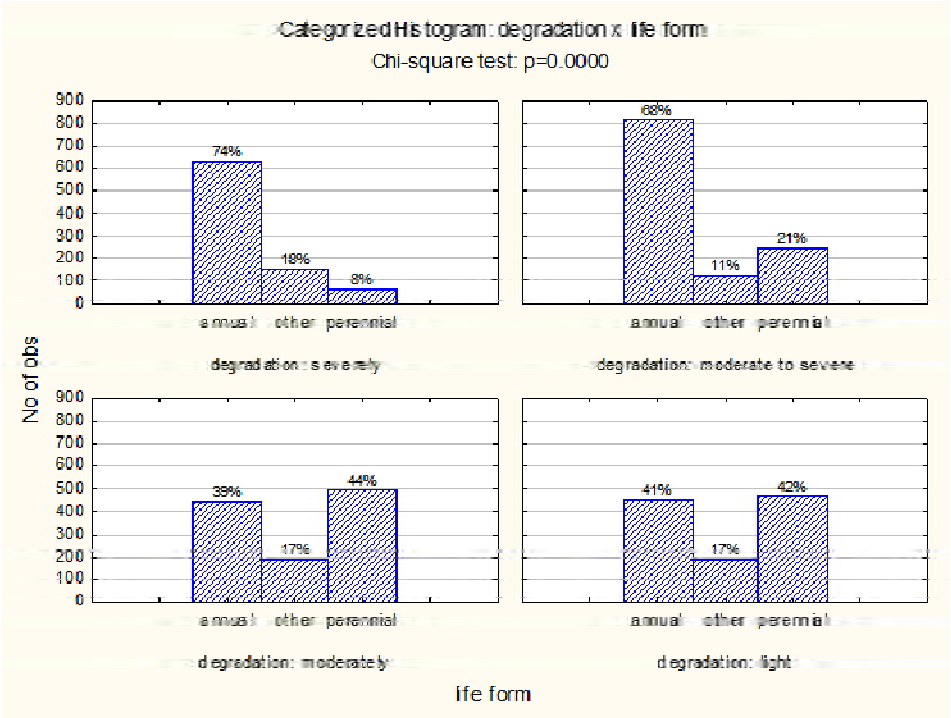

Figure 7. Frequency of occurrence of life forms in the grazing gradient in year 2(SD = severely degraded area, MSD = moderately to severely degraded area, MD = moderately degraded area and LD = lightly degraded area).

Table 1. Bonferroni comparison test for life form compositional difference in each grazing gradient in year 1 (SD = severely degraded area, MSD = moderately to severely degraded area, MD = moderately degraded area and LD = lightly degraded area)

	Combination	Bonferroni adapted p-value
1	(severely, moderately to severely) vs (annual, other)	< 0.01
2	(severely, moderately to severely) vs (annual, perennial)	< 0.01
3	(severely, moderately to severely) vs (other, perennial)	< 0.01
4	(severely, moderately) vs (annual, other)	< 0.01
5	(severely, moderately) vs (annual, perennial)	< 0.01
6	(severely, moderately) vs (other, perennial)	< 0.01
7	(severely, light) vs (annual, other)	< 0.01
8	(severely, light) vs (annual, perennial)	< 0.01
9	(severely, light) vs (other, perennial)	< 0.01
10	(moderately to severely, moderately) vs (annual, other)	1
11	(moderately to severely, moderately) vs (annual, perennial)	< 0.01
12	(moderately to severely, moderately) vs (other, perennial)	< 0.01
13	(moderately to severely, light) vs (annual, other)	< 0.01
14	(moderately to severely, light) vs (annual, perennial)	< 0.01
15	(moderately to severely, light) vs (other, perennial)	< 0.01
16	(moderately, light) vs (annual, other)	< 0.01
17	(moderately, light) vs (annual, perennial)	< 0.01

18(moderately, light) vs (other, perennial)	0.09

Statistical compositional difference of life forms for year 2

The Chi-square test in general denoted that the life forms differ significantly ($p<0.05$) along the grazing gradient (Fig. 7). Perennial grasses, which are the major fodder source for animals are low in abundance in both SD and MSD areas where the relative abundance of annuals was high.

On the other hand, quite satisfactory frequency of abundance for perennials was observed in MD and LD areas with a decline in abundance of the annual species. The MD and LD areas had more or less similar frequency of occurrence of annuals, others and perennials. The frequency of occurrence of the perennials in both gradients was two- fold that of perennials in the MSD area (Fig. 7).

Table 4. Bonferroni comparison test of life form compositional difference of each grazing gradient in year 2 (SD = severely degraded area, MSD = moderately to severely degraded area, MD = moderately degraded area and LD = lightly degraded area)

	Combination	Bonferroni adapted p-value
1	(severely, moderate to severe) vs (other, annual)	< 0.01
2	(severely, moderate to severe) vs (other, perennial)	< 0.01
3	(severely, moderate to severe) vs (annual, perennial)	< 0.01
4	(severely, moderately) vs (other, annual)	< 0.01
5	(severely, moderately) vs (other, perennial)	< 0.01
6	(severely, moderately) vs (annual, perennial)	< 0.01
7	(severely, light) vs (other, annual)	< 0.01
8	(severely, light) vs (other, perennial)	< 0.01
9	(severely, light) vs (annual, perennial)	< 0.01
10	(moderate to severe, moderately) vs (other, annual)	< 0.01
11	(moderate to severe, moderately) vs (other, perennial)	0.5
12	(moderate to severe, moderately) vs (annual, perennial)	< 0.01
13	(moderate to severe, light) vs (other, annual)	< 0.01
14	(moderate to severe, light) vs (other, perennial)	1
15	(moderate to severe, light) vs (annual, perennial)	< 0.01
16	(moderately, light) vs (other, annual)	1
17	(moderately, light) vs (other, perennial)	1
18	(moderately, light) vs (annual, perennial)	1

The Bonferroni test was carried out to compare the compositional difference of each degradation area versus life form was significant for most combinations (Table 8). The MSD combination test for both MD and LD areas implicated that the proportion of abundance of others and perennial species was more or less the same making the test insignificant ($p >0.05$). Similarly, the MD and LD areas were also insignificant ($p> 0.05$) for the life form comparison of other vs annual, other vs perennial and annual vs perennial. It could be assumed from Figs 5 and 6 that there was a decrease of perennials and an increase of others in

the MD area and an increase of annuals and a decrease of perennials in the LD area in year 2 compared to the preceding year.

Species compositional differences in year 1 and year 2

To compare changes in botanical composition of each degradation area over the two years, Classification Tree Analysis was carried out where it revealed that there were species differences in the 2 seasons. The differences were restricted only to the severely degraded area where frequency of occurrence of annual grasses was 73% in year 2 compared to 48% in year 1. On the other hand, 50% frequency of occurrence was recorded for others in year 1 and 20% in year 2. The species composition of other areas was more or less similar over the two years.

Discussion

The classification of the species in each degradation area in general was a reflection of the pasture species response to grazing intensity of the rangeland. Dyksterhuis (1949) and Foran et al. (1978) stated that the most realistic and ecologically sound method of classification is to classify the species according to their reaction to injudicious range management practices and other disturbances such as drought and fire. Similarly, Bosch and Janse Van Rensburg (1987) grouped the species of the western grassland biome into five categories on the basis of their abundance curves on the grazing gradient.

The plant species that characterize the severely degraded area close to the watering point were annual grasses and unpalatable herbaceous forbs in both seasons. These are in general defined as pioneer species or short-lived plants, which increase under high levels of continuous selective grazing. This definition and characterization agrees with reports made by Andrew and Lange (1986), Friedel and Blackmore (1988) and Beukes and Ellis (2003). The pioneer annual grass species was *S. verticillata* with abundance percentages of 40% and 50% in year 1 and year 2 respectively in the severely overgrazed vegetation close to the watering point (Table 1 and 2). The dominance of this species in overgrazed area was also reported by Van Oudtshoorn (1999).

In this study, most of the forbs found are unpalatable except the annual herb *Ipomoea sinensis* that comprised 15% of the composition of the total herbage of the severely degraded area grazed by cattle (Table 1). This study has recognized high percentage abundance of forbs in the SD area close to the watering point. However, some forbs were recorded in the degradation areas far from the watering point. This agrees with the finding of Friedel and Blackmore (1988) that some forb species were closely associated with the watering point where others occurred throughout the gradient. The 4% occurrence of perennial grass species in the SD area in year 1 (Table 1) consisted mainly of *S. ioclados* and *C. dactylon* while the 6% perennial grass species in year 2 consisted of *P. desertorum* and *S. ioclados* (Table 2). These are known to be less palatable species and usually dominant in heavily grazed areas (Van Oudtshoorn, 1999; Amsalu and Baars, 2002). Studies carried out around artificial water sources have indicated a decrease in palatable perennial plants (Pinchak et al., 1991; Hart et al., 1991, 1993). This study also highlighted the absence of palatable perennial species in the SD area that confirms results of previous studies.

The observed development of this less palatable species poor and sparse community in the inner 1500m zone around the watering point (SD area) is in agreement with other workers who found that grazing impacts are greatly diminished beyond 1-2 km from a watering point (Foran, 1980; Pinchak et al., 1991; Perkins and Thomas, 1993; Fusco et al., 1995).

In the MSD area a small increase in palatable perennial species was depicted in both seasons relative to the nil occurrences in the severely degraded area. The frequency of occurrence was less than 1% in year 1 and almost 5% in year 2 for *C. plumulosus*. *P. coloratum* exhibited 4% occurrence in year 1 and 1% occurrence in year 2. *C. plumulosus* and *P. coloratum* are the most preferred and palatable species but *C. plumulosus* is known as a more preferred species compared to *P. coloratum* (Personal communication: Afar elders and herdsmen). The finding was in agreement with Ayana and Baars (2000) who assessed the condition of the Borana rangelands in six communal grazing areas and on a Government owned ranch. In that study, *C. plumulosus* and *P. coloratum* were classified as desirable/preferred species, likely to decrease with heavy grazing pressure. The scientifically determined preferableness of the species substantiated the preferableness of the species as perceived by the community. Bogdan (1977) also concluded that these species are readily grazed by all kinds of stock and are much valued by pastoralists. Moreover, in the MSD area, an increase of the less palatable perennial species *S. ioclados* and *P. desertorum* was observed in both growing seasons. (In year 1*S. ioclados* was found to be dominant in the area with 12% frequency of occurrence. On the contrary in year 2, *P. desertorum* was more abundant than in year 1 growing season).

The annual grass *S. verticillata* has shown abundances as high as 63% and 65% in year 1 and year 2 respectively in the MSD areas (Table 1 and 2). The grass was evaluated as the sole crop in some of the plots and in the space between the tussocks of the perennial grasses. In year 2, the frequency abundance of annuals was high in the SD and MSD areas at 74% and 66% respectively (Fig. 7). This could be due to inter-annual variation of rainfall in year 1 and year 2 and agrees with many researchers who found that inter-annual variation in rainfall influence species composition of range vegetation (Ellis and Swift, 1988; Westoby et al., 1989). Others have critically stated that, short-term rainfall events (Van Rooyen et al., 1990), and certain rainfall conditions of semi-arid areas (Figueroa & Davy, 1991), influence the dominance of annual species. The frequency of occurrence of the unpalatable forbs has declined to 3% in this area.

In the MD and LD areas, which are far from the watering point, a drastic increase in abundance of the palatable perennial species was observed. In both areas, less than 10% frequency of abundance was recorded for the less palatable perennial species. In conclusion, this study confirmed what other researchers found in other semi-arid parts of the world. Unpalatable forbs and annual grass dominate the vegetation in heavily overgrazed areas (such as near a watering point). As the grazing pressure decrease further away from the watering point, some of the forbs are replaced by unpalatable perennial grass species and in areas that have low grazing pressure; palatable perennial grass species dominate the vegetation. Thus, the hypothesis that was tested is therefore rejected.

In general the study concluded that there was difference in botanical composition at increasing distances from the watering point. This was confirmed from the major distribution of annual grasses and unpalatable forbs in severely degraded area. The same species cover was observed in moderate to severely

degraded area, more prominently covered by annual grasses, indicating the loss in ground cover of the palatable perennial species attributing to loss in forage biomass yield of the range. This change in ecosystem is corrected by proper holistic range management practices where the need to exercise the four fundamental process of ecosystems is justified to manage the rangeland and reverse the degraded areas. At the same time, in degraded and soil seed bank exhausted areas; keeping large stock of animals to physically act on the land to improve soil physical and chemical characteristics where then re-seeding of the potential local grasses is to be advocated to restore the severely degraded grazing areas of the range.

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Youth and Women Engagement with Livestock Value Chains: Insights and Lessons

Daniel Temesgen, Yihenew Zewde and Getachew Gebru
ESAP CTA,

Introduction

The livestock sector contributes 35 percent of Agricultural GDP and 16-19 percent of the foreign exchange earnings of the country. With a rapidly growing population, increasing urbanization and rising incomes, domestic demand for meat, milk and eggs is expected to increase significantly in the foreseeable future. Furthermore, the country's geographic location offers substantial opportunities for exportation, thus earning foreign exchange from livestock products. The government clearly recognizes the potential of the sector for stimulating growth, reducing poverty and achieving food security, it also acknowledges the need for greater support in the development of the sector to realize its full potential. Traditionally, in Ethiopia, youth and women are the main players in livestock production and marketing but face persistent obstacles and societal and economic constraints that limit their control and benefit. The government has clear policy and strategy ensuring that opportunities are created for women and the youth to actively participate in political, economic and social affairs of the country. It also designed strategies to follow up and evaluate the development programs and projects to ensure that these give due consideration to women and youth issues. The government has developed youth and women packages and created support systems to access land and financial capital to engage youth and women in livestock value chains. Ethiopia is taking huge livestock sector transformation plan and committed to continue investing on the sector which would create potential improvement in the value chains. In this regards government has taken various steps in Mainstreaming youth and women programs with national and sectorial development plans to realize equal benefits from the fruit of development.

At this junction, Ministry of Agriculture, CTA, and ESAP in collaboration organized an international workshop on Youth and Women Engagement with Livestock Value Chains from IGAD Region. The objectives of this paper are to document, share insights and lessons. In addition, it is also to exploring the opportunities on how Information and Communication Technologies (ICTs) can assist the youth in engaging in profitable segments of the e-livestock value chains.

An overview of Insights and Lessons

There were several presentations of country cases and experience sharing and discussions made based on the papers presented. However, it was felt that more work is remaining to better understand the role of youth and gender in the livestock value chains for better engagement and benefiting them from these value chains. Particularly, the main issues which need further analyses and elaboration are highlighted below based on the discussions and notes taken from various individual paper presentations and group discussions. Some of the specific observations which are very similar across all the presentations are made below.

It is important to understand their aspiration to develop recommendations which can be accepted and adopted by the youth group. For example, do the youth aspire or are they interested to engage in the livestock production and along the livestock value chains.

The nature of demand for and supply of labor along the livestock value chain regardless of the age and gender needs to be discussed. In other words, there was no quantitative value chain analysis which shows the number of jobs that can be created at each stage of the livestock value chains and whether those jobs are gainful (have significant impact on the lives of youth and women). Therefore, there is a need for mapping out and quantitative analyses of the livestock value chains to determine the potential value that can be added at different stages in the livestock value chains.

The nature of livestock value chains in which the youth are engaged needs to be clear. In this case, the role of modernizing the livestock sector in attracting youth (increase of income, ease of work, increase interest, increase income) needs to be looked.

In all papers, the discussion of youth was very much generic and treated as homogenous. The youths are not homogenous groups and there is a need to disaggregate youth by age, sex, educational attainment, place of residence, etc.

In the papers, the discussion of gender assumes that women are homogenous groups. However, the women are also not homogenous group: there is a need to disaggregate women by marital status (married, separated, divorced, and widowed); educational status; by age, place of residence (rural or urban) to develop recommendations on policy and institutional interventions to increase women participations in the livestock value chains.

The perspectives of the private farmers and agribusiness on how they are engaging the youth and women are needs to be exploited. The employers' perspective is also required to fully understand the potential of the livestock sector to engage the youth and women.

There should be rigor value chain analysis, showing or provide evidence of significant market participation rates and income earning opportunities along the livestock value chains which attract the youth and women.

The extent to which the livestock sector provides employment opportunities (absorptive capacity) should be adequately quantified. This requires to distinguishing between family farming and commercially oriented private (small, large scale) farming; seasonal temporary employment or livestock related public employment opportunities, etc.

In order to serve the longer-term rural development, it is necessary to develop a methodology for regularly collecting and analyzing statistics and information on rural employment, unemployment and working hours, earnings statistical database disaggregated by place of residence (rural-urban), youth age groups, sex, educational attainment,

The issue of child labor and forced labor should be discussed. These issues have implications for youth educational attainment which has implication for employment outcome for decent living in the future. The nature of treatment of child labor has implications for life time achievements, educational attainments, labor market outcomes and the ability to find decent job and is important issue when discussing the youth employment.

The existence of appropriate labor statistical database is very critical for the analysis of labor market to better understanding of the need for appropriate rural development actions for youth and women and other segments of the population. There is a need for time series rural/urban

disaggregates of employment, unemployment, economically active population by age, sex, age groups for various years in order to understand the dynamics of labor market. None of the study makes use of such databases in making their cases.

The income diversification activities by rural people is not considered which shows the relative contribution of livestock and livestock related income generating activities in relation to other income generating activities –employment in agriculture is multi-dimensional and the work often is casual, temporary and/or seasonal

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Animal Production

Factors Affecting Technology Adoption in Smallholder Livestock Production Systems in Ethiopia

Kebebe Ergano Gunte
International Livestock Research Institute, P.O. Box 5689, Addis Ababa, Ethiopia

Abstract

In response to population growth, rising income and urbanisation, the demand for livestock products, such as milk, meat and eggs is growing in Ethiopia. The growing demand for milk products offers opportunities for smallholders to realize better livelihoods. Whereas the growing demand for milk products in Ethiopia is widely recognised, the dairy sector has not been able to produce adequate milk to satisfy this demand, mainly due to low productivity of dairy animals. The use of technological inputs, such as improved breeds of dairy cows and cultivation of improved forages, is often seen as a prerequisite to increasing livestock productivity and resource use efficiency in the smallholder dairy sector. However, adoption of such technologies has been low, despite numerous efforts to disseminate the technologies in the past. This poses a question as to why the majority of smallholders have not adopted livestock technologies in the Ethiopian highlands. The overall objective of this study was understanding the factors affecting adoption of technologies that enhance the productivity of livestock production and water use efficiency in the Ethiopian highlands, with particular emphasis on dairy production. The study was intended to deepen the understanding on the role of factors at the levels of farm households, value chains and macroeconomic institutions and policies on farmers' decision to adopt technologies. The study employed interdisciplinary approach to analyse micro and macro level constraints that affect adoption of technologies in livestock production. The findings in the empirical chapters show that low adoption of the technologies that enhance the productivity of livestock production and water use efficiency stem from farmers' limited access to farm resources, differentials in potential welfare impacts of the technologies, lack of effective and reliable supply chains for inputs and outputs, inadequate physical infrastructure and weak institutions and policies. The findings show that smallholders have been subjected to multiple constraints. Given the multiple constraints at different scales and the associated transaction costs facing smallholders in rural Ethiopia, the returns to investment for the technologies may be too low to justify widespread adoption of the technologies. Therefore, adoption of technologies in the dairy sector requires interventions at production, storage, transportation, processing and marketing chains and at macroeconomic institutions and policies. In the short and medium term, dairy development programs in Ethiopia will have a better chance of success if they target farmers who have better resource endowments and who are connected to better-functioning value chains rather than blanket technology scaling-up targeting the majority of smallholders. Future agricultural research needs to shift the focus from predominantly developing new biophysical technologies towards social science research that assesses issues at value chain, macroeconomic institutions and policies that influence adoption of technology.

***Key words**: Dairy; production system; technology adoption; value chain*

Introduction

In response to population growth, rising income and urbanisation, the demand for livestock products, such as milk, meat and eggs is growing in Ethiopia. The growing demand for milk products offers opportunities for smallholders to realize better livelihoods. Whereas the growing demand for milk products in Ethiopia is widely recognised, the dairy sector has not been able to produce adequate milk to satisfy this demand, mainly due to low productivity of dairy animals. The national average daily milk yield from indigenous dairy cows is 1.9 litres per cow and even in the Ethiopian highlands, where this study was conducted, and average daily milk yield is only around 2.3 litres per cow. The use of technological inputs, such as improved breeds of dairy cows and cultivation of improved forages, is often seen as a prerequisite to increasing livestock productivity and resource use efficiency in the smallholder dairy sector. However, adoption of such technologies has been low, despite numerous efforts to disseminate the technologies in the past. This poses a question as to why the majority of smallholders have not adopted livestock technologies in the Ethiopian highlands. The overall objective of this study was to understand the factors affecting adoption of technologies that enhance the productivity of livestock production and water use efficiency in the Ethiopian highlands, with particular emphasis on dairy production. The study was intended to deepen the understanding on the role of factors at the levels of farm households, value chains and macroeconomic institutions and policies on farmers' decision to adopt technologies.

The primary aim of this study was to understand why many farmers in Ethiopia have not adopted dairy technologies, taking Kenya as a comparative case study. Adopters and non-adopters of dairy technology were compared based on variables describing ownership of farm resources, and access to markets and information. Results show a higher fraction of sample households in Kenya kept improved dairy breeds, cultivated improved forages, used artificial insemination and veterinary services, and participated in dairy cooperatives than their counterparts in Ethiopia. The difference in the level of technology adoption between sample farmers in the two countries was attributed to the better market development for dairy products in Kenya than in Ethiopia. Farmers who adopted dairy technologies had more family labour, resided closer to markets and had better access to information compared to non-adopters. The results indicate that dairy technology adoption increases with increase in farm resource endowment and better access to markets.

Table 1. Multilevel mixed effect model estimates of factors explaining variation in Livestock Water Productivity (LWP in US$ m^{-3})

Variables	LWP[§]
Age of household head (yrs)	-0.11 (0.05)**
Gender of household head (1=male, 0=female)	2.26 (2.86)
Education level of household head (yrs)	0.47 (0.58)
Family labor (adult equivalent)	1.55 (0.48)***
Land holding (ha)	-8.14 (1.03)***
Livestock holding (TLU)	2.46 (0.43)***
Value of grain products (US$ yr^{-1})	0.01 (0.01)
Farmer's wealth status (1=better off, 2=medium, 3=poor)	-2.9 (1.89)
Constant	30.10 (8.25)***
Number of observations	220

*Standard errors in parentheses, * p<0.05, *** p<0.001*

The impact of adopting dairy technologies on household nutrition and income has been investigated using propensity score matching and a sample treatment effect estimator. Results show that adopting crossbred dairy cows and improved forages increased household nutrition and income. The comparison of adoption impact estimates by propensity score matching and the sample treatment effect estimator indicated that unobservable variables have influence on technology adoption and impacts, which suggests that smallholders are heterogeneous in initial resource ownership conditions and in individual characteristics, such as entrepreneurial ability, motivation or ingenuity, attitude towards risk and networking ability. The variation in such initial resource ownership status and in individual characteristics may explain part of the variation in adoption of dairy technologies and their impacts.

Table 2. Mean differences in key farm resources between adopters and non-adopters of improved dairy technologies in Ethiopia

Variables	Improved dairy technologies				
	Improved cows	AI services	Improved forages	Veterinary services	Dairy coops
Age of household head (y)	5.16	3.28	0.54	-1.34***	-10.33**
Gender of household head (1=male)	0.023	-0.01	0.15***	0.09	0.16
Marital status of household head (1=married)	0.03	0.00	0.09	0.08***	0.06
Education level of household head (y)	-0.11	0.16	-0.36	-0.55***	-1.42**
Number of family members in working age group	1.60***	1.73***	0.50*	0.75***	-0.81
Dependency ratio	-0.32**	-0.31	-0.02	0.07	0.08
Total land holding (ha)	-0.53	-0.05	-0.55	0.07	-0.74
Total livestock holding (TLU)	0.54	1.91*	0.03	-0.23	1.56
Oxen holding (TLU)	0.42	0.46	0.06	0.00	0.79
Access to mobile telephone (1=yes)	0.37***	0.38***	0.22***	0.14***	0.15
Distance to nearest market centre (km)	-0.79	-3.45*	2.67**	0.89	-6.34**
Distance to Farmer Training Centre (km)	-1.33	21.95***	7.08***	0.73	-1.36
N	658	658	658	658	657

*** p<0.01, ** p<0.05, * p<0.1

Table 3: Crossbred dairy cows and improved forages adoption effects on household dietary diversity score and income (US$ per household per year)

Intervention	Welfare indicator	Impact	
		Adopters	Non-adopters
Crossbred dairy cow	Dietary diversity score	0.69***	0.01*
	Income	217.75***	147.42**
Improved forages	Dietary diversity score	0.66***	0.65**
	Income	63.33***	37.22**

The influence of macroeconomic institutions and policies on adoption of technologies in the dairy sector was also examined. A functional-structural analysis framework was used to analyse the historical evolution of the macroeconomic institutions and policies, which are relevant to dairy development. Systemic failures, such as limited capacity of actors, absence of some key actors and poor interaction among actors, institutional problems and inadequate infrastructure, have been prevalent in Ethiopia during the period covered in this study (1960s -to date). Some of the important institutional problems were cumbersome bureaucratic processes, failures of accountability in public service delivery system, corruption, poor law enforcement, insecure property rights, rigid and restrictive procurement regulations, unclear and ever-changing government regulations, and protection measures that resulted in high import costs of technological inputs. Examples of infrastructural inadequacies include poor rural roads and unreliable supply of water and electricity. Out of the seven innovation functions studied, entrepreneurship, knowledge diffusion, market development and legitimacy creation have been particularly weak. In the analysis, the chapter illustrated how historical institutions and policies were important for technology adoption and dairy development.

Table 4. Systemic problems causing weakness or absence of the functions in the Ethiopian dairy sector

Innovation function	Observed weakness in innovation functions (missing/ weak)	Systemic failure (Reasons why a system is missing or weak)	Type of systemic failure
Entrepreneurship	Majority of farmers practice subsistence farming Few farmers own high grade dairy cows Negligible private sector investment in the dairy sector	Smallholder farmers lack the capacity to identify opportunities and articulate their strategies Members of small scale dairy enterprises are composed of persons with low levels of education	Missing actors, capability failure, institution failures directionality failure, demand articulation failure
Knowledge development	Education and research institutions underdeveloped until 1990s Inadequate knowledge on institutional arrangements for coordinating complementary sources of knowledge Little attention given to organisational innovation	Narrow research focus on technology generation and dissemination Research system lacks the capacity to analyse the bottlenecks in dairy value chains Weak research capacity in socio-economics	Missing actors, capability failure, hard and soft institution failures, Interaction failure, merits in increased manpower training
Knowledge diffusion	Adequate knowledge on livestock technologies is not accessible to farmers Extension focus on dissemination of scientific knowledge and technology only Smallholders left out of dairy development initiatives until 1980s Few and weak dairy cooperatives	Inadequate capacity in public extension system for knowledge diffusion Lack of coordination between agricultural departments Budgetary constraints for extension agents to run activities Extension agents overloaded with multiple activities	Hard and soft institution failures, interaction failure

(Continued to the next page)

Innovation function	Observed weakness in innovation functions (missing/ weak)	Systemic failure (Reasons why a system function is missing or weak)	Type of systemic problem
Guidance of search	Poor public service delivery, prevalence of corruption, uncertain property rights and poor law enforcement Limited access to land, loans, duty-free privileges, tax holidays, etc. Uncertainty among farmers about potential demand for their product	Policies failed to set clear vision, objectives and targets for livestock sector development Nationalization of private farms and stringent regulation on private dairy farms during the Derg regime had negative effects Lack of demand-pull policy instruments to induce entrepreneurship among smallholder farmers Poor road networks & telecommunication	Capability failure of existing actors , institutional, interaction and infrastructural failures Directionality failure, demand articulation failure
Market formation	Coordination failure hindering delivery of inputs and services and collection of milk from unorganised smallholders in rural areas	Shortage of actors who raise and sell dairy heifers and provide artificial insemination and veterinary services and transport and sell milk	Missing actors, market failure, institution failures, interaction failure
Resource mobilization	Most livestock development programs and projects are financed by donors, meagre government R&D funding for the livestock sector	Most livestock projects were financed by donors Inadequate funding	Physical infrastructure failure, shortage of financial resources, limited research capability
Creation of legitimacy	Advocacy and interaction among farmer organisations, professional associations, researchers, policy makers is weak	Weak connectivity between actors No legal framework for interactions between relevant actors	Missing actors, interaction failure, capability failure, reflexivity failure

Note: This analysis is based on the framework proposed by Wieczorek and Hekkert, 2012.

Finally, we tried to synthesize empirical findings. The findings show that low adoption of the technologies that enhance the productivity of livestock production and water use efficiency stem from farmers' limited access to farm resources, differentials in potential welfare impacts of the technologies, lack of effective and reliable supply chains for inputs and outputs, inadequate physical infrastructure and weak institutions and policies. The findings show that smallholders have been subjected to multiple constraints. Given the multiple constraints at different scales and the associated transaction costs facing smallholders in rural Ethiopia, the returns to investment for the technologies may be too low to justify widespread adoption of the technologies. Therefore, smallholders are simply responding to the incentives and constraints of their agricultural circumstances. Unless the technologies are accompanied by simultaneous improvements in access to farm resources, input and output markets and measures to overcome institutional and policy barriers, large scale technology adoption in the near future appears unlikely. Therefore, adoption of technologies in the dairy sector requires interventions at production, storage, transportation, processing and marketing chains and at macroeconomic institutions and policies. In the short and medium term, dairy development programs in Ethiopia will have a better chance of success if they target farmers who have

better resource endowments and who are connected to better-functioning value chains rather than blanket technology scaling-up strategies targeting the majority of smallholders. Future agricultural research needs to shift the focus from predominantly developing new biophysical technologies towards social science research that assesses issues at value chain, macroeconomic institutions and policies that influence adoption of technology.

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Antimicrobial Susceptibility of *Staphylococcus Aureus* in Cow Milk, the case of Asayita District, Afar Region Ethiopia

Girum Faris Beyene
Ethiopian Biodiversity Institute
girumf@gmail.com

Abstract

In most pastoral communities, milk is consumed raw without any heat treatment and this can pose a health hazard to consumers. The presence of Staphylococcus aureus in raw milk generally comes from cows with mastitis, from handlers or from deficient hygiene. Staphylococcus aureus is a major problem associated with milk causing number of human and animal diseases. A cross-sectional study was conducted on traditionally managed lactating cows in Afar region to determine the prevalence of Staphylococcus aureus in milk and its antimicrobial susceptibility from February to April, 2014. A total of 384 pastoralist lactating cows were tested for mastitis using the California Mastitis Test (CMT). Forty four samples (11.4%) were positive for California Mastitis Test, and on culturing all the 44 samples showed the presence of Staphylococcus aureus bacteria. The antibiotic sensitivity was done on all isolates against seven commonly used antibiotics in the pastoral community using a standard method. Results showed that Staphylococcus aureus isolates were very sensitive to Chloramphenicol and Streptomycin, Gentamycin in (100%, 94%, and 90%), respectively. Intermediate resistance was recorded for Erythromycin (60%). Isolates also showed high resistant rate to penicillin (100%), Ampicillin (96%), Amoxycillin (92%),and Trimethoprim- sulpha methoxazole (88).On the basis of this result improving the hygienic conditions of milking processes, timely treatment of infected cows and avoiding use of the antibiotics for which the pathogens had shown resistance have been recommended.

Key words: *- Pastoral community, California mastitis test, sensitivity, Staphylococcus aureus.*

Introduction

Food-borne diseases are of a major concern, worldwide. The pathogenesis of bacteria causing food-borne poisoning depends on their capacity to produce toxins after or intoxication. Among the bacteria predominantly involved in these diseases, *Staphylococcus aureus* is a leading cause of gastroenteritis resulting from the consumption of contaminated food. Staphylococcal food poisoning is due to the absorption of Staphylococcal enterotoxins preformed in the food (Loir *et al*., 2003). Staphylococcal food poisoning includes symptoms such as sudden onset of nausea, vomiting, abdominal cramps and diarrhea. On heating at normal cooking temperature, the bacteria may be killed but the toxins remains active (Thaker *et al*., 2013). Milk and milk products are the prime habitat to complex microbial ecosystems; these are responsible for the broad variations in taste, aroma and texture of milk and milk products (Soomro, 2003). Contamination of milk and milk products with pathogenic bacteria is mainly due to processing, handling and unhygienic environment (Soomro, 2003). Diseases that can be spread through milk include: tuberculosis, typhoid fever, scarlet fever, poliomyelities, undulant fever, septic sore throat, brucellosis and diphtheria (Sinell, 1973). Pathogenic bacteria can be present in raw milk as a direct consequence of the udder infection. Among the micro-organisms commonly producing mastitis in cows, *Streptococcus agalactiae*, *Staphylococcus aureus* and *Escherichia coli* are pathogenic to man (Robinson, 1990).

Antimicrobial resistance is a major public health problem in many countries due to the persistent circulation of resistant strains of bacteria in the environment and the possible contamination of water and food (Erskine *et al*., 2002). This antimicrobial resistance has been documented by a number of workers in different areas. Several studies suggested that administration of antibiotics to food-producing animals for therapeutic purposes or as growth promoters may be a primary factor in selecting for antimicrobial-resistant bacterial pathogens (Barber *et al.,* 2003). Antibacterial therapy of bacterial-induced diseases in cattle has been incriminated as a catalyst for resistance in bacteria isolated from treated animals, other animals within the herd, and food derived from cattle for human consumption (Berghash *et al.,* 1983). These days, antibiotic resistant bacteria are emerging as a consequence of drug use in treating the disease mastitis. Ethiopia has the largest livestock population in Africa which contributes, significantly to the agricultural economy. Livestock contributes to the livelihoods of 60-70% of the Ethiopian population and is responsible for 98% of the milk production (Aklilu, 2002). Cows represent the largest proportion of cattle in the country according to the Food and Agriculture Organization (FAO, 2001). Therefore, this study was designed to determine the overall prevalence of bacterial mastitis and to identify *Staphylococcus aurous* with the following specific objectives.

Determine the prevalence and distribution of *Staphylococcus aureus* in cattle in Asayita zone
To see the distribution of mastitis in the study area and
To test the antibiotic resistance *Staphylococcus aureus* from collected samples

Materials and Methods

Study Area

The study was conducted in Afar region, Zone one and Asayita district. Asayita zone is located at North east direction of Addis Ababa with 850 km from capital Addis Ababa. Asaita district was selected because of large cattle population in the region.

Study design and Sample size

A cross sectional laboratory-based survey study was employed to determine the prevalence and antimicrobial sensitivity patterns of *Staphylococcusaureus* isolated from milk samples in Afar region Asayita zone between February and April, 2014. The sample size was determined using an appropriate formula based on the 95% confidence limits and 5% sampling error as n = (Zα/2)2 p (1-p)/d2. In determining the sample size, the p value was taken as 50% (maximum value) because of the absence of recent data on prevalence of Campylobacter species in the study area. Thus, the total sample size used in this study, as determined by the above formula, was 384. This formula was deliberately used to get maximum number of samples to examine.

Milk Collection and handling

Milk samples for bacteriological examination were collected aseptically following the routine procedures. A total of 384 raw milk samples were collected from 384 lactating cows of pastoralists during the study period.

Isolationand Identification

Bacteriological examination was done according to the National Mastitis Council Guideline (1990).The collected samples were transported to the laboratory using ice box and tested for the presence of mastitis with California Mastitis Test (CMT). Milk samples from mastitic cows were stored at 4°C for a maximum of 24 h cultured on blood agar media. All the samples were directly streaked onto 7% sheep blood agar and incubated aerobically at 37^0C for 24–48 hours. Plates were examined morphologically and for the presence of *Staphylococcus* colonies. Round, smooth and white or yellow colonies and hemolytic pattern were taken and sub-cultured on nutrient agar plates and incubated at 37^0C for 24-48 hours. Final identification of the organism and species was done based on Gram staining, catalase test, O-F glucose test, oxidase test, sugar fermentation and coagulase test (by using rabbit plasma). The pure isolates in the nutrient slant were preserved and maintained at 4^0C for further need (Quinn *et al*., 2002).

Antimicrobial susceptibility test for Campylobacter Species

The antimicrobial susceptibility test was performed for all (44) isolated *staphylococcus aureus* isolates identified from milk samples. Standard agar disk diffusion method wasemployed according to the recommendations of the National Committee for Clinical Laboratory Standards (NCCLS, 2003) using commercial antibiotic disks (Oxoid).

Data Analysis

The data collected were entered and managed in MS Excel program. SPSS version 16 for windows was used for data analysis. A P-value <0.05 was considered indicative of a statistically significant difference.

Results and Discussion

Prevalence of Staphylococcus aureus

Results showed that 44 of the samples (11.4%) were positive for mastitis through CMT test from 384 lactating cows of the pastoral community during this study period. On culturing and laboratory test diagnoses tests all the 44 (11.4%) milk samples were positive for the presence of *Staphylococcus aureus*s species. This finding of this study was closely comparable with the findings of Bishi (1998) and Hussein *et al.* (1997) who reported 9 and 10% prevalence in Addis Ababa, respectively. It is also in contrast with findings of Lakew *et al.*, (2009), Ndegwa *et al.* (2000) and Bedada and Hiko (2011) who reported 41.1 and 43.3, 39.1% in dairy cows, respectively. The possible explanation for this might be that *Staphylococcus aureus* is a contagious pathogen transmitted from one cow to another or individual by contact with animals during unhygienic milking procedures (Rowe, 1999). Based on observations made

throughout the study period in the fields, improper practices contributed to the presence of *Staphylococcus aureus* incidence is at a considerable higher percentage. Prevalence of mastitis in the study area may be directly related with poor hygienic conditions of the owners during milking processes. Because, it is a potential risk factor that can predispose cows for environmental and contagious mastitis infections.

However, the present findings are much lower than that of Workineh *et al.*, (2002), Dego and Tareke (2003) who reported 39.2 and 40.3% *Staphylococcus aureus* isolates at Addis Ababa and Southern Ethiopia, respectively. The finding in this study is still lower than other studies done in Ethiopia, The products specific prevalence of *Staphylococcus* were found to be 47.1%, 58%, 38% 34%, 70.6% and 38% from udders milk, farm tanks milk, farm tanks swab, buckets swab, nasal and hand swab of milkers samples, respectively. This finding still lesser than other finds findings in Ethiopia, Mekonnen *et al.* (2011) and Alehegn (2008) who reported 33% and 29.5% *Staphylococcus* prevalence in tank milk, respectively, in Debrezeit. Factors that could be hypothesized to be causes of contamination of milk in this study include insufficient pre-milking udder preparation and material contamination. The weather condition may contribute for the less prevalence of the bacteria.

Antibiotic susceptibility patterns of Staphylococcus aureus Isolates

The antibiotic susceptibility tests were made to all *Staphylococcus aureus species* isolated from milk samples. The overall percentage of resistance pattern is shown in (Table). Results showed that isolates were highly sensitive to Chloramphenicol, Streptomycin and Gentamycin in (100%, 94%, and 90%), respectively. Intermediate resistance was recorded for Erythromycin (60%). Isolates also showed high resistant rate to penicillin G (100%), Ampicillin (96%), Amoxycillin (92%), and Trimethoprim- sulpha methoxazole (88%). The high frequency of resistance observed with Penicillin G (90.2%), Erythromycin (70.9%), in similar studies in Ethiopia. This could be due to the free accessibility of pastoralists to certain antibiotics in open market.

Table 2. Antimicrobial drug resistance patterns of *Campylobacter* isolates.

***S. aureus* (n= 44)**	**Susceptibility**	**AMX No. (%)**	**AM No. (%)**	**CH No. (%)**	**ER No. (%)**	**GE No. (%)**	**P No. (%)**	**ST No. (%)**	**SXT No. (%)**
	S	0	0	44(100)	8(18)	40(94)	0	41(94)	0
	I	3(8)	3(4)	0	26(60)	2(3)	0	3(6)	2(7.8)
	R	41(92)	41(96)	0	10(22)	2(3)	44(100)	0	40(90.2)

AM=Ampicillin, AMX=Amoxicillin; CH=Chloramphenicol; ER=Erythromycin; GE=Gentamycin; P=penicillin-G; ST= Streptomycine; STX= Trimethoprim-sulphamethoxazol; S= Sensitive; I=Intermediate; R= Resistant.

Conclusion and Recommendations

The importance of proper handling and cooking of foods of animal origin are very important in preventing S. *aureus*and other potential pathogens. Coordinated actions are needed to reduce or eliminate the risks posed by these pathogens at various stages in the food chain. More epidemiological studies are needed in order to determine the possible role of bovine as a source of reservoir of the pathogen.Public education is crucial not to eat raw meat or any undercooked animal origin foods.Indiscriminate use of antimicrobial

agents and antibiotic sale behavior (for example, sale of antibiotics without prescription, sale of under dose and substituting brands) enhances the development of drug resistance.

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Quality Inspection and Performance Evaluation of Framed (Modern) Beehives in the Central Zone of Tigray

Bruh Weldemariam
Axum Agricultural Research Center, P. O. Box 230, Axum, Tigray, Ethiopia
bruhweld@gmail.com

Abstract

This survey study was done to develop information on the quality and productivity of modern (framed)hives which have been introduced at different years and its determinant factors and drawing policy implications for future extension approaches. The study included four districts of central zone of Tigray where beekeeping has significant role in the livelihoods of smallholder farmers. Two local administrations from each district were taken purposely and totally 200 beekeepers including cooperatives were used for interview. About 92.5% of the beekeepers were male and the rest women. Use of framed bee hive started in the central zone since 1998 with massive introduction during 2005 to 2008 .The study indicated that only 63.4% of the respondents received technical support and 75.1% of beekeepers exercise replacing of old combs in addition to this 81.4% removed and applied suppering according to the feed availability and strength of the colony. Absconding of bee colonies from framed hive indicated increasing over years. The productivity of colonies in the framed hive was almost similar across year except the first two. The highest honey yield (31.5kg/hive) *was record during the early years while the minimum (19.59kg/hive) was in 2009.Pests and predators, lack of management, poor skill, improper use of agrochemicals and feed shortage were identified by beekeepers as the most factors affecting beekeeping in all areas. About 60.3% of the beekeepers had full trust and confidence on the framed beehive while the rest 39.1% outlined that the technology has drawbacks. About 89.7% of the interviewed farmers reflected their interest to use the hive in an increasing way for the future. The results showed that performance of framed hive had slight difference across years with maximum at the early stages. This could be due to the difference in the quality of extension service delivered with time. Therefore effective use of the technology needs effective training and extension support and supply of accessories and rising of awareness on application of herbicides and pesticides with developing its application rules.*

Keywords: *absconding, framed-beehive, beekeeping, beekeepers, extension, farmers, predators*

Introduction

Ethiopia has a diverse agro climatic zones that favor tremendous plant and animal species. Owing to its varied ecological and climatic conditions, the nation is home to some of the most diverse flora and fauna in Africa. These all makes Ethiopia to stand one of the countries of the continent, which own big honey production potential. Ayalew and Gezahegn (1991) elaborated that plentiful forage availability coupled with favorable and diversified agro-climatic conditions of Ethiopia create environmental conditions conducive for the growth of over 7000 species of flowering plants which has supported the existence of large number of local bee colonies in Ethiopia. The same authors outlined that over two million bee-colonies in the countries exists in the forest and crevices. The density of hives occupied by the honeybees on the land may be the highest, at the present moment, of any country in the African continent. According to HBRC (2004) report Ethiopia produces about 28,500 tons of honey and 5000 tons of bee wax. Because of this phenomenon beekeeping is one of the most important income-generating activities in the rural communities and it provides an employment opportunity for many Ethiopians. To improve the productivity of the sector so many skilled personnel have been dispatched to every corner of the region, improved practices and technologies including framed hives supplied for millions of beekeepers.

In Tigray regional state bee production has special place in the development of the economy and many peoples based their life in this sector though, productivity has not commensurate with the huge numbers of honeybee colonies and the region's potentiality for beekeeping. This is attributed to different factors and constraints and the system has more of traditional nature. To enhance productivity of the sector and livelihood of beekeepers integrated development activities have been practiced at all corners of the region starting from the natural resource conservation programs that has special contribution for honey production. Improved practices and very large numbers of framed beehives with their accessories have been distributed to all districts of Tigray to date. Since Tigray region is one of the potential beekeeping areas and the sector play special role in contributing to wards food security and creating job opportunity for many landless youths. According to Ethiopian central statistical agency (2010/11) study the contribution of traditional hives reached 96.4% nationally but only 78.1% in the Tigray region. Accordingly honey contributed from the traditional hive was 95.8% and 51.28 to the total honey production of the country and the region respectively. Indirectly the contribution of framed hive for honey production was closer to half in Tigray but below 5% in the whole country. Indicating that the attention given by the regional government and the beekeepers need for the better technology.

Central zone is one of the Tigray regional stat's zones where there is high honey production potential and huge number of framed hive dissemination persisted since the early times. However, there is no adequate information on the productivity trends and determinant factors. There were reports from some beekeepers on decline in performance from year to year as opposed to the mass introduction of the framed hives and there is serious claim rising here and there about the quality problems related to the recently supplied framed hives in all districts of the central zone. Generally there are believes that the formers hives were good in quality in terms of the material they constructed as well the specifications of their designs. Nevertheless, the lately introduced hives have a defect in either of the above-mentioned quality parameters according to the bee keepers. There are two arguments, one is related to the absconding of huge numbers of bee colonies and the other is low harvests of honey. These variables were considered as best indicators to the inferior quality of the hives according to beekeepers' views. Therefore this project

was designed to investigate whether the questions raised by some framed hive users are really related to the inferior quality of the recently introduced hives or simply related to other factors which have significant effect to the success of the technology.

Objectives

- To inspect whether absconding of bee colonies from the framed hives are related to the inferior quality of the materials from which the hive is constructed or lack of improved managements
- To see the productivity trends of framed hives across years
- To analyze factors negatively affecting the performances of framed beehives currently
- To produce base line information and draw policy implication recommendations which will helpful on the future development plans and uses of the technology.

Materials and Methods

Study area description

The study was performed in four districts namely Naedier-Adiet, Geter-Adwa, Tahtay-Maichew and Ahferomin the central zone of Tigray. Central zone consists of 9 administrative districts centering the historic city Axum its zonal capital located at 1024 km far away from Addis and 243km far from Mekelle capital city of Tigray. The zone is approximately situated between 13°15’ and 14°39’ North latitude, and 38° 34’ and 39°25’ East longitude. The zone owned lowland, midland and highland agro ecological zones covering 9741km^{2} areas of land. Beekeeping in the central zone has great potential to the livelihoods of the farming community and this area is known for its honey production and massive use of framed beehives. The 2014 annual reports of the zone showed that total bee colony population of the zone is about 142104 of which 42755(30.09) are framed hives and the rest 99349 (69.91) are traditional hives.

Sampling techniques

Peasant associations (PAs) were selected purposely to carry out the study based on their potentials to beekeeping and earlier massive introduction of the framed beehives. Semi structured questionnaire was developed to collect the necessary information pertinent to beekeeping conditions in every beekeeper.

Sample size

First, the numbers of farmers in the study PAs were identified and appropriate sample size was determined. Based on this 25 farmers from each PA; 50 from one district totally 200 beekeepers who used framed hives were included for the interview.

Data Collection

Source of hive, year of hive introduction, colony absconded/rate of absconding across year from framed hives, honey yield per hive across years and others were collected. In addition perception data of beekeepers over framed beehive technology were collected.

Statistical analysis

Collected data from surveyed households was organized and analyzed using statistical package for social science (SPSS version 16). Mean values of different parameters were compared among the four study districts and time series of honey production.

Results

General household characteristics

The results of this study showed that majority of the respondents were males involved in beekeeping activity than females and accounts 92.5% to male head while only 7.5% to females headed. This is in line with the results of Gabiso (2015), which was 91% of the interviewed bee keepers were male headed while 9% were female headed in Arsi zone. Age has its influence on beekeeping and other agricultural activities. Most of the beekeepers (48.8%) were found to be between 41 to 55 years old followed by peoples under 40, 56 to 66 and above 66 were 24.9 %, 22.4% and 4%respectively. The survey also revealed that 18% of the respondents were illiterate, 7.6 able to read and write while the rest (48.0 %, 22.5% and 3.9%) had educational back ground for primary education, junior education and high school level respectively. Land holding in these surveyed districts is very limited and 91.2% of the respondents were owned only 0.25 to 1 hectare of cultivable land and only 2% of them owned 1.5 to 2 hectares while the rest 6.9% had no land at all.

Extension service and management issues

Framed or Modern hive has been used since 1997 in the central zone of Tigray .But the massive introduction was observed in 2004 to 2007 and about 62.8% of the respondents introduced their framed hive within these four years with maximum during 1997 and 2007, 19.5% and 19% respectively. The study indicated that 63.4% of the respondents received technical support in the form of formal training and support while the rest 36.6% didn’t get either formal training or advice how to keep bees on framed hive. From the respondents who got technical support 32.3% feel confidential to manage the technology and 63.1% of them said they can manage it moderately but 4.6% of the bee keepers who got training still in a problem to manipulate the hive that means they lack the skill and knowhow to manage the bee colony.

Bee colony holding per beekeepers is greatly different and 5.9% of them have no bee colony at present that means missed their colony due to different cases. On the other hand 36.6% of respondents owned 2 bee colony and 27.8% owed only 1 colony at present, 14.1% owned 3 colonies. Majority of beekeepers got their colony from market through purchase.However, 4.4% of the respondents used their own colony.

From the beekeepers, 75.1% exercise replacing of old combs from the base while the rest beekeepers (24.9%) do not practice replacing the old comb in addition to this 81.4%removed and reapplied the supper according to the feed availability and strength of the colony while the rest responded once they put the supper they do not exercise removing and reapplying following the strength of the colony. Bee forage availability is not equal in all seasons and therefore supplementary feeding is one of the management options to scape dry spells. Beekeepers exercise this practice and 75.2% supplement their bees. The types of feeds they supplement are water, sugar and different flours.

The trends of bee colonies in the framed hive in terms of numbers and productivities showed that 34.6% of the respondents said decreasing, 43.4% said constant and only 22% responded there is an increasing trend over time. The productivity of framed hive in the central zone of Tigray from its introduction is indicated in the following.

Table 1. Productivity of framed hive in central Tigray over years

Years	Number of beekeeper owned MH	Mean number of bee colony in MH. Owned per beekeeper	Percent of absconding	Honey productivity (kg)/hive
Before 2003	15	1.60	0	31.50
2003	26	2.42	4.96	27.00
2004	38	2.61	5.18	22.28
2005	77	3.00	5.41	23.75
2006	98	2.65	4.76	21.98
2007	127	2.50	9.61	21.12
2008	166	2.39	8.11	20.22
2009	177	2.37	10.53	19.59
2010	189	2.30	13.08	21.06
2011	196	2.24	13.11	21.62
2012	200	2.33	12.01	21.33

The study indicated that use of the framed hive increased over time from 15 farmers before 2003 with mean number of 1.6 framed hives and reached maximum holding during 2005 to 3 colonies in framed hive. The whole period indicated that the trend of adding framed hive was in a constant way with little change but total peoples owned the hive increased from time to time.

Absconding of bee colonies from framed hive indicated increasing over years. In the early times there was no any absconding event recorded but gradually increased with time. The maximum absconding problem was recorded during 2010 and it reached 13.04%. The productivity of the framed hive also followed similar fashion. The highest honey yield 31.5kg/hive was recorded during the early years while the minimum (19.59kg/hive) was in 2009. However, starting 2004 to the consecutive years the productivity of honey showed almost similar. There were no sharp yield fluctuations for the last 9 years. Honey yields from framed hive over 2004 to 2012 ranged from19.59 to 27kg/hive. The mean honey yield from the framed hive in this study area is within the results of Haftom and Awet (2013) which was 19.94 and 25.67kg and similar to the national average, (20-25 kg/year) (Werkneh *et al.*, 2008).

However, this result necessarily does not mean that the technology performed better at the earlier times than the recent years because during the beginning times there was limited area coverage with few users possibly they could got better training and support in addition the few numbers of users and framed hives might have significant effect on the mean result as compare to large samples.

When we compare the absconding rate and honey productivity of bees in framed hive it was better during the early times however, the number of farmers who used the technology was incomparable with consecutive years as a result little absconding rate and slightly higher honey yields recorded. The other determining factor is the small number of users of the beekeepers during the early period could have significant effect on the support and helps and the quality of training. Therefore, this could result different in efficiency of the beekeepers on the use and management of the framed hive technology finally productivity of the hive. Sex and location had significant effect on framed hive owned, honey productivity and absconding of bee colonies from framed hives in the central Tigray as indicate in Table 2.

Table 2. Productivity trends of framed hive over years by different categories in central Tigray

Variables	category	Production year										
		Before 2003	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Bee colony owned/hh	Male	1.6	2.42	2.30	2.86	2.48	2.32	2.25	2.24	2.24	2.26	2.30
	Female	-	-	2	2.2	2.14	1.91	1.92	1.46	1.15	1.2	1.27
Absconding rate	Male	0	4.95	6.20	5.75	5.70	9.71	7.74	10.12	11.27	10.787	12.37
	Female	-	-	0	9.09	0	23.81	24.00	41.11	7.226	17.86	5.60
Honey yield kg/hive	Male	31.5	27.0	22.1	24.24	21.97	21.52	20.99	20.19	21.40	22.12	21.73
	Female	-	-	0	14.25	16.29	10.25	9.92	8.85	12.4	12.0	10.92
Bee colony owned by location	Ahferom	-	-	-	2.7	2.5	2.33	2.19	1.94	2.05	1.74	1.58
	Adwa	1	2.5	2.14	2.9	2.31	2.33	2.13	2.02	1.85	1.9	2.02
	T.Machew	1.64	2.57	3.05	3.44	3.39	3.55	3.71	3.82	3.56	3 .57	4.00
	Adiet	-	1	1.67	1.67	2	1.56	1.53	1.63	1.66	1.63	1.58
Absconding rate by location	Ahferom	-	-	-	0	0.3.64	11.43	3.39	18.95	13.16	21.84	20.14
	Adwa	0	4.44	7.18	10.26	10.12	12.94	8.74	14.05	11.7	6.36	5.13
	T.Machew	0	5.56	3.12	1.16	0	1.71	5.26	2.33	16.05	18.13	10.79
	Adiet	-	0	20	0	0	21.37	18.97	18.01	7.54	1.43	18.73
Honey yield kg/hive by location	Ahferom	-	-	-	26.75	26.45	23.78	21.65	20.11	22.72	23.36	17.44
	Adwa	-	21.33	14.2	18.80	18.45	16.94	15.37		15.90	17.27	18.42
	T.Machew	31.5	28.5	27.42	28.58	27.32	27.47	28.25	25.21	25.44	26.22	30.33
	Adiet	-	35	16.67	23.33	17.86	20.17	18.40	19.77	22.61	20.87	18.25

The problems mostly affecting the beekeeping in the study areas were identified and the top six factors are presented in Table 3.The results showed that the most problems challenging beekeepers according to their order of seriousness are pest and predator, pesticides, lack of appropriate care and management, shortage of bee forage and lack of skill and awareness. Here 29.4% of the respondents placed as first problem to bee production is pests and predators, 18% for indiscriminate application of agrochemicals, 16% poor management, 14.9% feed shortage and 11.3% skill and knowledge related problems. This is in agreement with results Gidey and Mekonen (2010), inadequate availability of production Technologies, limited beekeeping Knowledge, limited availability of vegetation, limited training and technical assistance in beekeeping and honey marketing. Lack of proper bee management and marketing facilities are also problems facing the honey sub sector in the region. Moreover a synthesis of IPMS value-chain development experiences in Tigray in which limited knowledge/skills on modern apiculture development by producers and service providers and inadequate supply of inputs/accessories like beekeeping accessories and bee forage identified as major honey production constraints. Different research results from HBRC (1997), Ayalew (2001) and Edessa (2002), also listed these problems as the major constraints in the beekeeping subsector in Ethiopia

It was found that bees mostly abscond during the rainy season followed by long dry spell (April and May). From interviewed beekeepers 47.7% said most absconding of bee colonies occur in the rainy period especially at the beginning of this season and 34.9% said April to May. With related to reuse of the empty framed hive most of the beekeepers (64.9 %) reintroduce bee colony after the loss while 33.1% did not try to introduce again a colony once disappeared. From the farmers who reused it again 81.9% said there was frequent absconding but 18.1% of them reported no repeated absconding. The absconding rates were 38.2% once, 50% twice, 7.9% three times and more than four 3.9%.

Table 3. Responses of beekeepers to causes of absconding and reduced performance of bee colonies in the framed hives

Rank of problem	Most prevailing problems for honey production											
	lack of bee forage	absence of appropriate management	Lack of skill and awarenes	pest and predator	Disease	pesticides and herbicide	Absconding	poor hive quality	Cold	inappropriate construct of hive	poor wax quality	Death
1st	14.9%	16%	11.3%	29.4%	1.5%	18%	2.1%	0.5%	2.1%	1%	3.1%	0%
2nd	12.8%	17.1%	15.5%	25.7%	5.9%	17.1%	4.9	0	0	0	0.5	0.5
3rd	7.6%	20.6%	15.9%	17.1%	3.5%	14.7%	1.2	2.9	0.6	0	1.8	4.1
4th	6.7%	14.8%	15.6%	11.9%	0%	16.3%	14.1	5.9	0	3	0.7	11.1
5th	11.6%	11.6%	5.8%	10.5%	7%	8.1%	23.3	8.1	1.2	0	2.3	0
6th	19.3%	3.5%	10.5%	8.8%	11.8	8.8%	22.8	7	0	5.3	1.8	10.5

Perception of farmers on framed beehive

The perception of the bee keepers on framed hive showed that 60.3% of the respondents have full confidence and they did not mention any draw backs and problems over the technology. They have good understanding on advantages of framed hive related to higher yield, ease for inspection and honey quality. They have full confidence and no hesitation on its advantage, appropriateness and qualities. However, 39.1% of them outlined that the technology has its draw backs. They mentioned that materials used to construct modern hives are not suitable to bees and may have repelling nature. Some also believed that peoples who are engaged on bee hive manufacturing could use "Nim" timber products which are not suitable to bees. Others said that the technology by itself is not enough without its accessories and difficult to manage without obtaining training and assistance..

Next plan of bee keepers on use of the technology

As indicated above most of the farmers using the technology showed confidence and they plan to use and continue for the future. Statically 89.7% of the interviewed farmer reflected their interest to use the hive in an increasing way while the rest 10.30% of the bee keepers did not want continue using the technology.

Conclusion and Recommendations

The study revealed that the involvement of women in beekeeping activity is very limited in the study area and it also showed that problems related to absconding of bee colonies and low productivity is definitely a result of external factors neither from the quality nor suitability of framed hive. There were big gap between users in many aspects which results substantial difference on productivity of the hive and benefits. Therefore, it is possible to conclude that productivity problem of bee colony reared on framed hive are caused due to lack of knowhow on the technology and basic principles of beekeeping aspects. Considerable numbers of farmers introduced the technology without getting trainings, orientations, help and follow-ups. This leads to unable to care and manage their bees. The main problems ,therefore, are Predators, lack of management, lack of skill and awareness on the framed hive technology, shortage of bee forage, and use of uncontrolled agro-chemicals are the most problems challenging bee keepers. Therefore to maximize the productivity and quality of honey from framed hive is must, however, introduction by itself couldn't bring any advantage but with necessary accessories and packages. Therefore points that must be given attentions are:

Farmers should get effective, training and extension support how to manage bees in framed hive since the technology needs skilled manpower. The technology is lacking its accessories so this problem is series and disserves solution because beekeepers couldn't manage and inspect even harvesting honey without getting the accessories like protective clothes, smokers,…etc.

Uncontrolled use of agrochemicals is the potential problem in the future and needs raising of awareness on its use and more importantly introducing application rules. By solving the above listed problems it is possible to maximize honey productivity and quality using the technology and the income of the beekeepers.

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Study on Silkworm Bed Cleaning Frequency during Larval Growth Period

Abiy Tilahun. Kedir Shifa., Ahmed Ibrahim and Metasebia Terefe.
Ethiopian Institute of Agricultural Research, Melkassa Agricultural Research Center,
P.O. Box-436, Melkassa, Ethiopia

Abstract

Bed cleaning is an important silkworm rearing process to ensure the hygiene in the immediate vicinity of silkworms in order to protect from disease infection and to ensure them good feeding appetite. Hence, timely bed cleaning is essential to keep the worms healthy and productive. The treatments used for this study were one time bed cleaning frequency per instar, two times bed cleaning frequency per instar, three times bed cleaning frequency per instar, once bed cleaning frequency per day, twice bed cleaning frequency per day and no bed cleaning (control) to evaluate the effects of silkworm bed cleaning frequencies on silkworm races. Observations on larval mortality, larval period, single cocoon weight, shell weight, length of silk thread and silk ratio were carefully noted for each treatment and replications. Three replications were used for each treatment. The young larval stages/instars (1st to 3rd instars) showed low larval mortality rate than mature larval stages (4th and 5th instars) in all silkworm races. Bed cleaning frequencies had no significant effect for 1st instar for all silkworm races. All bed cleaning frequencies had no significant effect for Korean silkworm races and Vietnamese multivoltine silkworm races until the 3rd instars. Hence, bed cleaning is not necessary during these stages in silk worm rearing practices for such races. Bed cleaning has showed a positive effect to reduce larval mortality rate for Vietnamese eri-silkworm races, Indian eri-silkworm races and Kenyan bivoltine silkworm races during 2nd and 3rd larval growth. Long spinning silk thread, robust silk cocoon and shell weight and higher percentage of silk ratio of silkworm races were registered from one time bed cleaning frequency per day and two times bed cleaning frequency per day.

***Keywords**: bed cleaning frequency, silkworm races, larval period, larval mortality, cocoon weight, shell weight, silk thread, silk ratio*

Introduction

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In Ethiopia, agricultural production is of a subsistence nature. Poverty and unemployment are the main challenges to the population, which therefore, requires additional on farm and off farm income generation technologies like raising of silkworms (silk production) (Metaferia *et al.*, 2007). As a result, silk production from eri silkworm (*Samia cynthia ricini*), a polyphagous insect, its primary feed plant (castor (*Ricinus communis* L.) (Raghavaiah 2003), and mulberry silkworm (*Bombyx mori)*, a monophagous insect, feeds on only mulberry plant (*Morus* species) (Takano and Arai 1978) are commonly practiced in Ethiopia currently. Even though it is recently introduced in the country, promising results have been recorded in terms of generation of income and creation of employment opportunities (Metaferia *et al*., 2007).

Silkworm rearing is an extensive month-long exercise starting from egg stage and terminating in adults laying eggs and dying their natural death. During this course, they pass through five larval instars (1st, 2nd, 3rd, 4th, and 5th instars) intervened by four moults, cocoon and pupal stage (Singh *et al.*, 2002). Silkworm rearing effectively means the culturing of five larval instars as other stages like egg, pupa and adults are non-feeding stages. In Ethiopia, whole life cycle spans through 46-56 days with 10-13 days of egg stage, 21-30 days of larval stage, 2-3 cocoon spinning days, 10-15 days as pupal duration and 3-5 days in adult stage (Abiy *et.al* unpublished). During larval growth stage bed cleaning is an important silkworm rearing process to ensure the hygiene in the immediate vicinity of silkworms in order to protect from disease infection and to ensure them good feeding appetite (Gogoi and Goswami 1998). The larvae should feed with appropriate quantity of leaves and feeding frequency based on the age/size of the larvae and their population in the bed (Ahmed *et.al* unpublished). Silkworms do not consume all the leaves that are supplied to them and invariably a part of the feed is left behind on the rearing bed. At the same time the larvae also defecate and their feces remaining on the rearing bed. If the residual leaves and the fecal matter are left on the rearing bed for some time, both start decomposing and fermenting there by quickly increasing the dampness of the bed. This adversely affects the larval physiology (Reddy and Swamy 1999). Therefore, it is essential to periodically remove these materials from the bed and keep it clean. The process of doing this is known as bed cleaning.

Dried leaves, rejected leaf in the bed, silk worm's excreta, exuviae, dead worms, diseased larvae all will increase the humidity, fermentation and temperature in the bed (Reddy and Swamy 1999). The authors further indicated that prevailing environmental conditions especially, temperature and relative humidity are vital in determining silkworm physiology as it is a cold-blooded organism. As soon as the larvae grow-up, the unconsumed leaves and litter increase in the rearing bed which ultimately cause changing atmosphere and favoring multiplication of pathogenic organisms such as protozoa, fungi, bacteria and viruses (Sannappa and Jayaramaiah 1999). Hence, bed cleaning should be done to remove fecal matter, dead worms and leaf remnants which would promote fungal, bacterial and viral infections (Sannappa and Jayaramaiah 1999). Diseases are the behavioral and physiological changes induced by pathogens in an organism (Hisao, 2001). If proper bed cleaning is not done in time it leads to various complications viz. ill health of larvae, disinterest of the larvae to feed due to unhygienic conditions, ultimately worms become weak and low in productivity (Hisao, 2001).Since they cause substantial financial loss to the silk producers, their prevention and control assumes utmost importance. Hence, timely bed cleaning is essential to keep the worms healthy and productive.

The frequency of bed cleaning studies revealed that when larvae were not cleaned more number of dead larvae was observed compared to the treated beds (Zhang,*et al.*, 2002). They further revealed that regular bed cleaning every day minimizes the larval mortality (0.67%). It was higher in untreated beds (2.0-23.67%). This study indicated that the eri-silk worms allowed to clean once per day was recorded statistically significant highest cocoon weight (3.67 g) followed by twice per day (3.53-3.46 g). The worms on the untreated bed were recorded lowest cocoon weight (2.78-2.65 g) compared to other treatments used. The bed cleaning has influence on the shell weight and silk ratio of eri silkworms (Devaiah *et al*., 1985. Sakthivel (2004) observed superior larval growth, development and higher cocoon production when eri silkworms were regularly cleaned according to their age, especially at late ages of 4th and 5th larval instars. According to them the progressive growth of silkworms was superior when properly fed and cleaned. The silkworm culture adaptation is being practiced in a large scale on the leaves of castor and mulberry with ideal feeding to administer nourishment to all the worms simultaneously and thereby to secure uniform growth and development of the worms (Neelu *et al*., 2000). Sharma *et al*., (1996) also observed that silkworms at regular bed cleaning resulted in significantly higher larval weight, larval survival, cocoon weight, shell weight, shell ratio, pupal weight, and rate of pupation, silk productivity, fecundity and egg hatching with lower larval and pupal durations than those raised under no bed cleaning condition in farmers' practices. Bed cleaning is done after every moult for the young silkworms and every other day for the mature worms by some silk producers in others it is done once per day for all ages of silkworms as a blanket recommendation. Frequent cleaning is better but it involves more labor and ultimately silkworm rearing uneconomical. The present study was therefore conducted to determine stage wise bed cleaning frequency for each larval instars of the different silkworm races reared at Melkassa sericulture laboratory. The study also sought to examine the effect of bed cleaning frequency on larval mortality, larval period and yield components of the different silkworm races.

Materials and Methods

This experiment was carried out at Melkassa Agricultural Research Center, sericulture research laboratory between 2011 and 2013. Mulberry and eri-silkworm rearing were carried out on multivoltine and bivoltine silkworm breeds in the same laboratory as per appropriate recommendations (Dayashankar, 1982). The silkworm rearing equipments were cleaned, washed, sun dried and disinfected with 2% formalin solution at the rate of 800 ml per 10 m^2 areas before the commencement of rearing (Nataraju *et al*., 2005). The breeds were reared following shelf rearing techniques starting from brushing till cocoon spinning. Silkworms at larval stage were fed on mulberry and castor leaves four times a day with tender leaves until 3rd instar and mature leaves for 4th and 5th instars. Silkworms are fed four times in a day – morning (8-8:30 A.M.), mid-day (11:30-12:00 A.M.), after noon (2:00-2:30 P.M.) and evening (5-6 P.M.). Before bed cleaning, leaves spread on top of the feeding tray. Worms crawl up to feed. Then, the worms were shifted using the news paper to new beds and feeding is then resumed. The litter, leftover food and dead silkworms, were removed carefully and disposed off away from the rearing house. The grown up worms, after completing feeding during late fifth instar at their ripened stage (ready to spin silk) were picked and transferred on the mountages (equipment to provide support for cocoon formation) for spinning silk cocoons. Ripened silkworms were identified by their characteristics movement to the corners of the rearing beds, reduction in size and transparent yellow appearance. After six to eight days of spinning, cocoons were harvested from the mountages.

Observations on larval duration, larval mortality rate and qualitative characters of the cocoon (fresh cocoon weight, cocoon shell weight, length of spinning thread and silk ratio) were recorded. Then, cocoon was boiled to make the serecin soft to dissolve. Silk filament was extracted out in which the coarser floss layer was removed. For the identification of causes of larval death, diseased larvae were examined. To grow fungal pathogens potato dextrose agar and for bacterial growth nutrient agar were applied. On the other hand, direct microscopic observation of the infected silkworm parts was used for the identification of silkworm diseases. Data such as number of infected silkworms versus total number of silkworms were recorded to determine the silkworm larval mortality rate.

Silkworm races used for this study were Vietnamese eri-silkworm races, Indian eri silkworm races, Kenyan bivoltine silkworm races, Korean bivoltine silkworm races, and Vietnamese multivoltine silkworm races. The treatments used for this study were one time bed cleaning frequency per instar, two times bed cleaning frequency per instar, three times bed cleaning frequency per instar, once bed cleaning frequency per day, twice bed cleaning frequency per day and no bed cleaning (control). Complete randomized design with three replications was used for each treatment and 200 silkworms were brushed in each replication and allowed to complete the larval period. Statistical analysis software (SAS) was used to analyze the data using analysis of variance (ANOVA) procedure. Least significant difference (LSD) was used for mean separation. Percentage proportions were calculated for larval mortality rate.

Results and Discussions

Effect of bed cleaning frequency on silkworm larval period

Once bed cleaning frequency per day, twice bed cleaning frequency per day and three times bed cleaning frequency per instar significantly ($P < 0.05$) shortened the larval period of Vietnamese eri-silkworm races (23.7, 25 and 24.3 days), Indian eri silkworm races (29.8, 28.6, 29.6 days), Kenyan bivoltine silkworm races (27.5, 30.6 and 31.5 days), Korean bivoltine silkworm races (24.7, 25.3 and 25.8 days) and Vietnamese multivoltine silkworm races (25.7, 25.8 and 25.8 days) respectively as compared to the untreated check which was 36.3 in Vietnamese eri, 55.4 days in Indian eri, 33.1days in Kenyan bivoltine, 30.2 days in Korean bivoltine and 30.3 days in Vietnamese multivoltine silkworm races as indicated in figure 1.

Sachan and Bajpai (1973a) observed the larval duration of Eri silkworm on different host plants revealed that 22-27 days were required in good silkworm rearing condition to complete the larval development. The larval period in our study falls more or less within the same range as indicated by the authors. Significantly ($P < 0.05$) longer larval growth period was registered from the untreated check (55.5 days) as opposed to the shortest larval growth period from once bed cleaning frequency per day in Vietnamese eri silkworm races (23.7 days), in Kenyan bivoltine silkworm races (27.5 days), in Korean bivoltine silkworm races (24.7 days), in Vietnamese multivoltine silkworm races (25.7 days) (figure 1).

The entire larval period (1st to 5th larval stages) ranged from 23.7 days to 31.5 days feeding on castor and mulberry host plants (Reddy, 2008). The authors observed superior larval growth and higher cocoon production when eri silkworms were received ideal feeding, spacing and bed cleaning. Further, the larvae receiving once bed cleaning frequency per day during fifth instar had better growth (Joshi, 1987).

According to this author the ideal bed cleaning is to administer good health to all the worms simultaneously and thereby to secure uniform growth and development of the worms. In this study the larval period to spin cocoons (the harvested row silk) was delayed (up to 46.5 days) when the bed cleaning frequency has prolonged to one time bed cleaning frequency per instar (figure 1). With no bed cleaning situation larval period was as high as 55.5 days and in treated silkworms it was as low as 23.7 days with a difference of about 22 days (figure 1). Shorter larval period indicate fast production period of row silk and longer larval period indicate prolonged production period of row silk which could influence the number of silk production times per year.

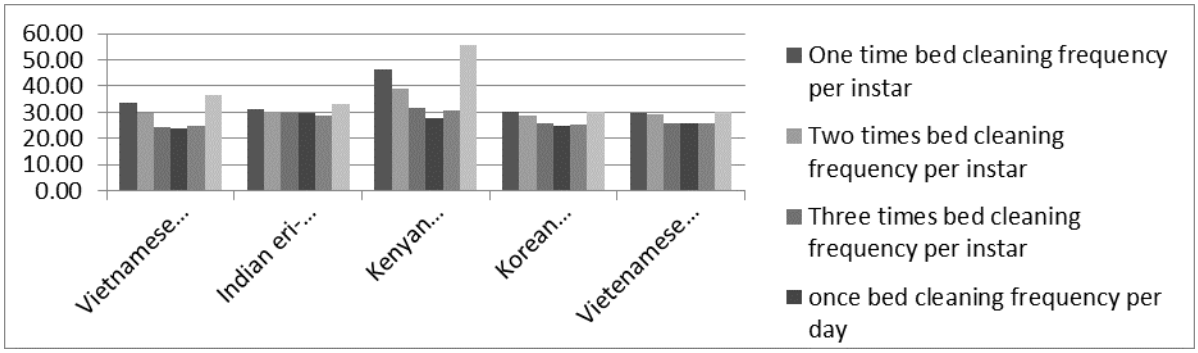

Figure 1: Effect of silkworm larvae bed cleaning frequency on larval period of different silkworm races

Effect of bed cleaning frequency on mortality of different larval instars and qualitative characters of the cocoon of silkworm races

This study attempted to understand the effect of bed cleaning frequency on mortality of each larval instars (1st instar up to 5th instar larval stages) of silkworm races introduced from different countries. In this study qualitative characters of the silk cocoon **(**length of silk thread, silk cocoon weight, silk shell weight and silk ratio) were also evaluated to the different bed cleaning frequencies. Figures 2 to 6 summarizes the mean values of each larval instars mortality rate and Tables 1 to 5 summarizes qualitative characters of the silk cocoon after the 5th larval instar was treated to the different bed cleaning frequencies.

Vietenamese eri-silkworm races

Bed cleaning during the 1st instar larval growth has no significant effect on their mortality rate. A significant effect of bed cleaning was observed from 2nd instar up to 5th instar larval ages. The percentage of larval mortality ranged from 2.58% in the 2nd instar to 15.58% in the 5th instar in the control plots (figure 2). All levels of bed cleaning frequency except one time bed cleaning per instar was significantly superior in reducing larval mortality (below 0.41%) in 2nd and 3rd instar (figure 2). However, for these larval stages using two times bed cleaning frequency per instar among others could be economical to save time and labor. Significant variation was observed from three times bed cleaning per instar, once bed cleaning per day and twice bed cleaning frequencies per day in 4th and 5th instars which showed low number of larval death (below 0.33%).

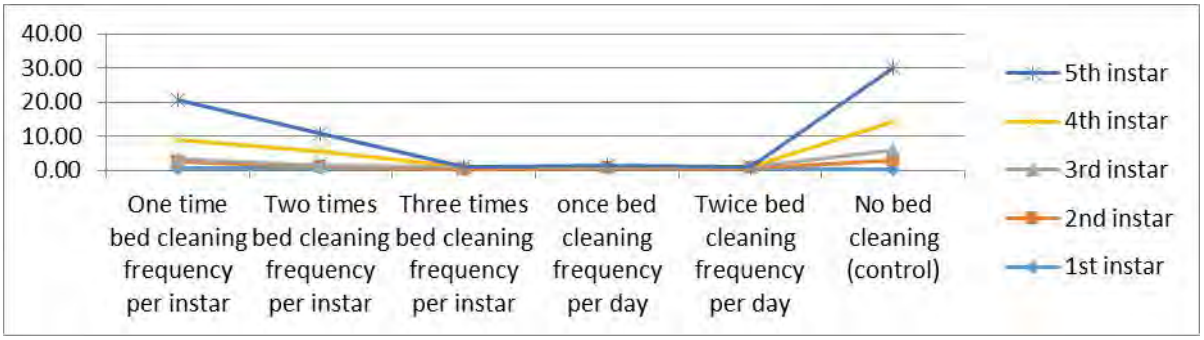

Figure 2. Effect of bed cleaning frequency on mortality of different larval instars of Vietnamese eri-silkworm races

Length of silk thread (5.77 m), silk cocoon weight (2.94 g), shell weight (0.28 g) and silk ratio (9.53%) were significantly ($P < 0.05$) lower when larval bed refuse and fecal matter of Vietnamese eri-silkworm larvae were not cleaned from rearing beds during their growth period than the tested bed cleaning frequencies (Table 1). Once and twice bed cleaning frequencies per day during the 5th instar were significantly ($P < 0.05$) resulted in higher length of silk thread (8.65 m & 8.51 m), silk cocoon weight (3.43 g & 3.44 g), shell weight (0.426 g & 0.436 g) and silk ratio (12.50% & 12.82%) as opposed to the other larval bed cleaning frequencies as indicated in Table 1.

Table 1. Effect of bed cleaning frequency on the qualitative characters of the cocoon of Vietnamese eri- silkworm races

Treatments	Length of silk thread (m)	Silk cocoon weight (gm)	Silk shell weight (gm)	Silk ratio (%)
One time bed cleaning frequency per instar	6.76±0.15 b	3.11±0.02 b	0.306±0.003 d	9.78±0.07c
Two times bed cleaning frequency per instar	7.09±0.26 b	3.28±0.06 a	0.33±0.005 c	10.02±0.22 c
Three times bed cleaning frequency per instar	8.25±0.23 a	3.35±0.03 a	0.39±0.05 b	11.68±0.16 b
once bed cleaning frequency per day	8.65±0.16 a	3.43±0.05 a	0.426±0.003 a	12.5±0.23 a
Twice bed cleaning frequency per day	8.51±0.52 a	3.44±0.06 a	0.436±0.003 a	12.82±0.16 a
No bed cleaning (control)	5.77±0.08 c	2.94±0.04 c	0.28±0 e	9.53±0.17 c

Indian eri-silkworm races

There was no clear trend observed in the 1st larval instar interms of larval mortality rate through applying bed cleaning frequencies. Larval mortality was significantly higher in the untreated control during 2nd instar (2.46%), 3rd instar (6.4%), 4th instar (5.01%) and 5th instar (11.66%) larval stages as opposed to all levels of cleaning frequencies (Figure 3). Significant results were achieved in reducing larval mortality rate from all levels of bed cleaning frequencies compared with the control (Figure 3). Two times bed cleaning per instar in 2nd larval age (0.66%), three times bed cleaning per instar (0.4%) and one time bed cleaning per day (0.28%) in 3rd larval age, once bed cleaning per day (0.61% and 0.58%) and twice bed cleaning per day (11.73% and 13%) in 4th and 5th larval stages respectively significantly reduced larval mortality rate (Figure 3). Though significant results were achieved in reducing larval mortality rate in all

levels of bed cleaning frequencies, the result suggested that two times bed cleaning frequency per instar for 2nd , three times bed cleaning per instar for 3rd and once bed cleaning per day for 4th and 5th instars could be recommend to save time and labour.

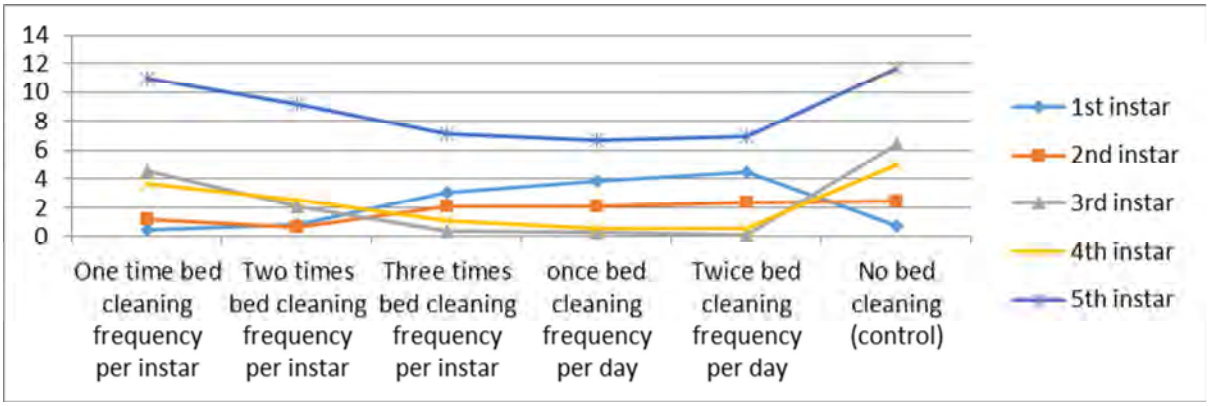

Figure 3. Effect of bed cleaning frequency on mortality of different larval instars of Indian eri- silkworm races

Length of silk thread (8.35 m & 8.28 m), and cocoon weight (3.36 g & 3.38 g), silk shell weight (0.4 g & 0.41 g) and silk ratio (11.95% to 12.21% were significantly ($P < 0.05$) increased when fecal matter of silkworm larvae and other left over's (dead worms and leaf remnants) cleaned in once bed cleaning frequency per day and twice bed cleaning frequency per day. In the control beds length of silk thread, silk cocoon weight, silk shell weight and silk ratio were greatly reduced to 5.9 m, 2.87 g, 0.246 g and 8.72% respectively (Table 2).

Table 2. Effect of bed cleaning frequency on the qualitative characters of the cocoon of Indian eri-silkworm races

Treatments	Length of silk thread (m)	Silk cocoon weight (gm)	Silk shell weight (gm)	Silk ratio (%)
One time bed cleaning frequency per instar	6.56±0.02c	3.05±0.06c	0.29±0.01d	9.61±0.15d
Two times bed cleaning frequency	6.98±0.15b	3.12±0.05cb	0.313±0.003c	10.09±0.03c
Three times bed cleaning frequency	8.3±0.10a	3.24±0.09ab	0.38±0.005b	11.73±0.19b
Once bed cleaning frequency per day	8.35±0.07a	3.36±0.01a	0.4±0a	11.95±0.05ab
Twice bed cleaning frequency per day	8.28±0.01a	3.38±0.04a	0.41±0a	12.21±0.15a
No bed cleaning (control)	5.9±0.03d	2.87±0.02d	0.246±0.003e	8.72±0.16e

Kenyan bivoltine silkworm races

The highest larval mortality (3.6% to 30.06%) was registered when the larvae did not receive bed cleaning treatment in all level of larval instars except 1st instar (Figure 4). Two times bed cleaning per instar (1%) in 2nd larval stage, three times bed cleaning per instar (0.96%), one time bed cleaning per day (0.8%) and two times bed cleaning per day (0.53%) in 3rd larval stage, once bed cleaning per day (0.9% and 1.06%) and twice bed cleaning per day (11.73% and 13%) in 4th and 5th larval stages respectively significantly reduced larval mortality rate (Figure 4). Though significant results were achieved in reducing larval mortality rate in the above bed cleaning frequencies the result suggested that two times

bed cleaning frequency per instar for 2nd , three times bed cleaning per instar for 3rd and once bed cleaning per day for 4th and 5th instars could be recommend to save time and labour.

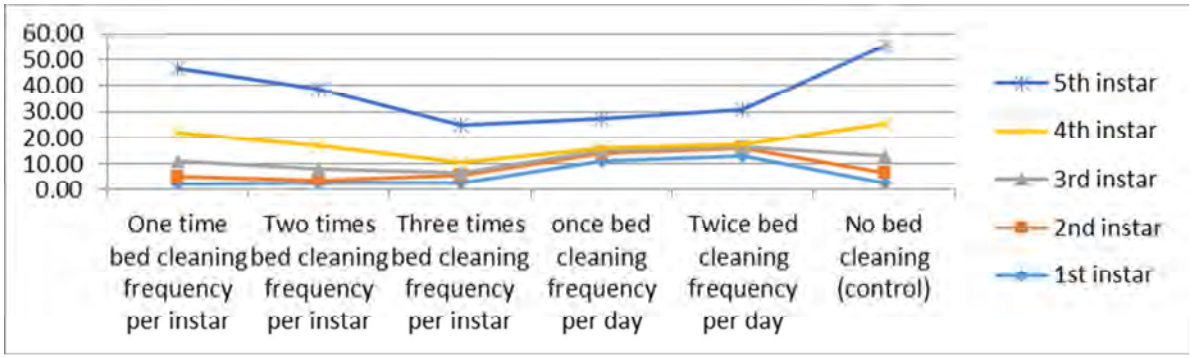

Figure 4. Effect of bed cleaning frequency on mortality of different larval instars of Kenyan bivoltine silkworm races

The untreated control significantly ($P < 0.05$) reduced the important yield components of silkworm larvae as indicated by the short length of single spinning thread (583 m), smaller silk cocoon weight (1.42 g), and smaller silk shell weight (0.263 g). Significantly ($P < 0.05$) higher percentage of silk ratio was registered from one time bed cleaning frequency per day (23%) and two times bed cleaning frequency per day (22.45%) as opposed to the lowest percentage of silk ratio from the check (18.49%). Significantly higher length of single spinning thread (915 m to 952 m), big silk cocoon weight (1.81g to 1.82 g) and big silk shell weight (0.41g to 0.42g) were obtained from the same treatments followed by three times cleaning frequency per instar larval developmental period for the same parameters (Table 3).

Table 3. Effect of bed cleaning frequency on the qualitative characters of the cocoon of Kenyan bivoltine silkworm races

Treatments	Length of silk thread (m)	Silk cocoon weight (gm)	Silk shell weight (gm)	Silk ratio (%)
One time bed cleaning frequency	692.43±15.06c	1.62±0.02c	0.313±0.006c	19.25±0.10c
Two times bed cleaning frequency	698.83±22.37c	1.64±0.01bc	0.316±0.003c	19.35±0.25c
Three times bed cleaning frequency	854.56±19.62b	1.75±0.01ba	0.387±0.006b	22.11±0.40b
once bed cleaning frequency per day	915.18±15.38a	1.82±0.02a	0.410±0.005ba	22.45±0.08ba
Twice bed cleaning frequency per day	952.17±30.16a	1.81±0.01a	0.420±0.005a	23.00±0.35a
No bed cleaning (control)	583.01±5.44d	1.42±0.07d	0.263±0.013d	18.49±0.07d
One time bed cleaning frequency per instar	692.43±15.06c	1.62±0.02c	0.313±0.006c	19.25±0.10c

Korean bivoltine silkworm races

Bed cleaning has no significant effect in all level of treatments on larval mortality rate of Korean silkworm races until the 3rd larval instar. This indicates bed cleaning is not essential in 1st, 2nd and 3rd larval stages. Percentage larval mortality rate in these life stages was less than 0.83%. A significant effect among treatments was merely observed in 4th and 5th larval instars. A significant high mortality rate was recorded in the untreated control silkworm rearing beds during the above mentioned life stages. This was 13.83% and 32.83% respectively. Three times bed cleaning per instar (1.66%), one time bed cleaning per

day (1.5%) and two times bed cleaning per day (1%) in 4th larval stage, once bed cleaning per day (0.83%) and twice bed cleaning per day (0.5%) in 5th larval stage caused a statistically low mortality rate (Figure 5).

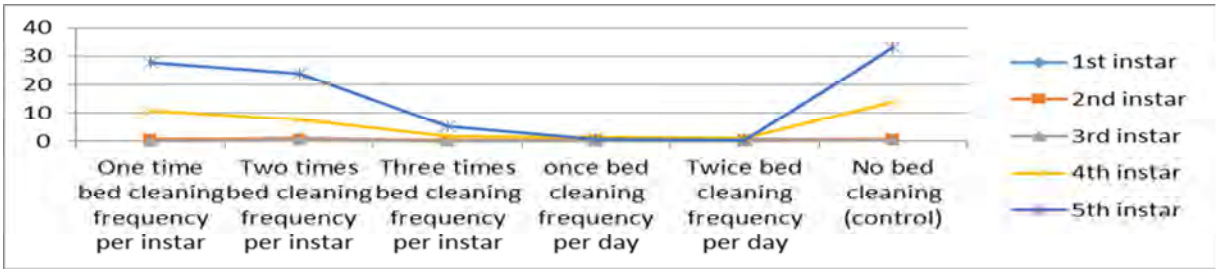

Figure 5. Effect of bed cleaning frequency on mortality of different larval instars of Korean bivoltine silkworm races

The length of spinning silk thread, silk Cocoon weight, silk Shell weight and Silk ratio produced from Korean bivoltine silkworm races were 611 m, 1.45 g, 0.27 g and 19% in the untreated check for the above order, while in the least effective cleaning frequency treatment (one time bed cleaning frequency per instar of larval growth period) this was 673 m, 1.65 g, 0.33 g, and 20.26% in the same order (Table 4). Once bed cleaning per day and twice bed cleaning per day were significantly ($P < 0.05$) superior than other treatments in improving length of spinning thread (950 m and 961 m), Cocoon weight (1.81 g and 1.77 g), Shell weight (0.42 and 0.40 g) and Silk ratio (23.03% and 22.31%) respectively (Table 4).

Table 4. Effect of bed cleaning frequency on the qualitative characters of the cocoon of Korean bivoltine silkworm races

Treatments	Length of silk thread (m)	Silk cocoon weight (gm)	Silk shell weight (gm)	Silk ratio (%)
One time bed cleaning frequency per instar	673.66±20.43dc	1.65±0.02b	0.337±b	20.26±b
Two times bed cleaning frequency per instar	719.00±22.23c	1.68±0.05ba	0.347±b	20.41±b
Three times bed cleaning frequency	796.33±46.81b	1.80±0.04a	0.357±b	19.48±cb
once bed cleaning frequency per day	950.66±19.06a	1.81±0.05a	0.420±a	23.03±a
Twice bed cleaning frequency per day	961.00±17.61a	1.77±0.02ba	0.400±a	22.31±a
No bed cleaning (control)	611.66±13.86d	1.45±0.09c	0.277±c	19.00±c

Vietnamese multivoltine silkworm races

There was high larval mortality rate in some of the treated larvae than the untreated one in 1st instar larvae. This could be explained by the existence of other larval death causes such as mechanical damage of worms while feeding and bed cleaning practices. In the 2nd instar there was no much variability among the treatments with regard to larval mortality rate. A significant bed cleaning effect was not found in the 3rd and 4th instar larval growth by which larval mortality rate was not exceeded 0.83%. However mortality was drastically increased (45.5%) during the 5th larval stage in the untreated control. Mortality was

reduced to 0.66% in **t**hree times bed cleaning per instar and once bed cleaning per day .No larval mortality bring into being from twice bed cleaning frequency per day treated rearing beds (Figure 6).

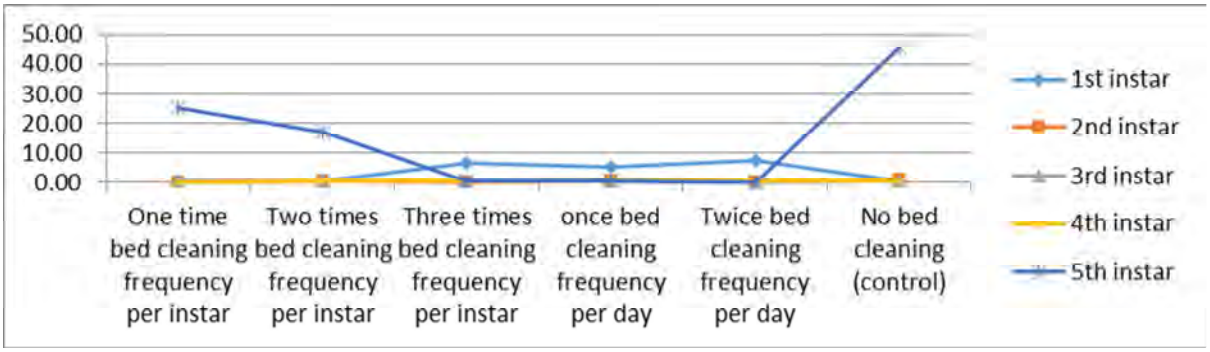

Figure 6. Effect of bed cleaning frequency on mortality of different larval instars of Vietnamese multivoltine silkworm races

Length of spinning silk thread (684 to 954 meters), Shell weight (0.303 to 0.377 gms) and Silk ratio (18.77 to 22.29%) (Table 5) were significantly ($P < 0.05$) higher in the treated silkworm larvae than the untreated one (666m, 0.27gms, and 18.59% respectively). Superior results were obtained from once bed cleaning frequency per day, twice bed cleaning frequency per day, and three times bed cleaning frequency per instar of silkworm larval growth period. Therefore we can use three times bed cleaning frequency per instar which is the least frequent bed cleaning interval among others to reduce larval mortality rate and to gain better silk cocoon yield.

Table 5. Effect of bed cleaning frequency on the qualitative characters of the cocoon of Vietnamese multivoltine silkworm races

Treatments	Length of silk thread (m)	Silk cocoon weight (gm)ns	Silk shell weight (gm)	Silk ratio (%)
One time bed cleaning frequency per instar	684.33±16.79c	1.59±0.07	0.303±0.020bc	19.00±0.34b
Two times bed cleaning frequency per instar	772.33±54.75bc	1.64±0.11	0.3100±0.017bc	18.77±0.19b
Three times bed cleaning frequency per instar	895.00±90.50ba	1.62±0.11	0.360±0.015ba	22.29±0.93a
once bed cleaning frequency per day	954.67±40.06a	1.72±0.01	0.377±0.003a	21.86±0.35a
Twice bed cleaning frequency per day	925.67±41.98a	1.65±0.06	0.367±0.013ba	22.13±0.26a
No bed cleaning (control)	666.33±11.83c	1.46±0.22	0.270±0.040c	18.59±0.46b

Sannappa and Jayaramaiah (1999) reported that as soon as the larvae grow-up, the unconsumed leaves and litter increase in the rearing bed which ultimately cause changing atmosphere and favoring multiplication of pathogenic organisms such as protozoa, fungi, bacteria and viruses. They further mentioned that due importance towards strict adherence to maintenance of hygienic conditions in and around the rearing house are a prerequisite for a successful cocoon harvest. So, ideal rearing condition such as bed spacing and bed cleaning should be done as per the different instars of larval stages and silkworm breeds. This study also confirmed there was variability in larval mortality rate among instars of different silkworm races in respective with various bed cleaning treatments. The results showed that bed cleaning caused significant reduction in larval mortality due to diseases against the control in all silkworm

races. Silkworm diseases observed during our study were bacterial, fungal, and viral diseases. Rearing under better feeding and bed cleaning, ensuring pathogen free rearing conditions are some of the vital requirements for the growth of healthy worms that enables the silkworm tolerate adverse conditions. Periodic removal of bed refuse and fecal matter ensures good bed hygiene, prevention of diseases and good larval growth. The pilling of litter makes beds moist became favoring for multiplication of pathogenic microorganisms affects the health of worms and culture (Sannappa and Jayaramaiah 1999).

Devaiah *et al*., (1985) reported that feeding and cleaning are important silkworm management practices affecting the larval weight, silk gland weight, cocoon weight and shell weight considerably. Their observation on different bed cleaning frequencies indicated that once and twice bed cleaning treatments caused less mortality and greater effective rate of rearing compared to other treatments and these are statistically significant. Though these bed cleaning frequencies were consuming more time and labor they can resulting in less larval mortality and maximum effective rate of rearing. In our study the cocoon characters after the 5th instar was treated in once and twice bed cleaning treatments providing supportive evidence for good rearing condition, also statistically significant compared to other types of bed cleaning frequencies on many parameters. Bed cleaning experiment revealed that once bed cleaning per day, twice bed cleaning per day followed by three times bed cleaning per instar treatments were statistically superior in terms of minimum larval mortality, shorter larval period, longer silk thread, bigger cocoon weight, bigger silk shell weight and maximum percentage silk ratio depending on the successive larval stages of silkworm races (Tables 1 to 5).

After successful silkworm rearing such as ideal bed cleaning, cocoon weight gain was recorded in previous findings. This difference in cocoon weight gain may be attributed to the difference in the bed cleaning treatments selected for the study and it may be inferred that treatments are a better performer than the control. Results from our study revealed that higher effective rate of rearing, higher cocoon weight; shell weight and silk ratio were obtained in the treatment against the control in all silkworm races. The findings of our study are in agreement with those of Joshi and Misra (1982); Hajarika *et al*., (2003). They found that higher effective rate of rearing, cocoon weight, shell weight and shell ratio were achieved in the bed cleaning treatments against the control. This was achieved by integration of not a single but a multitude of approaches viz. proper disinfection of the rearing room and appliances, use of bed disinfectant, bed spacing, bed cleaning and feeding as per recommendations. Prevention is better than Cure" is the correct approach and that should be adopted in integrated silkworm rearing management (Nataraju *et al*., 2005). This means that one should go about actively preventing diseases before it occurs, and it is only when preventive measures are in force that we can hope to effectively control the occurrence and spread of diseases. Patil *et al*., (2009) observed that eri silkworms receiving ideal bed cleaning treatment showed significantly higher larval weight (7.904 g), effective rate of rearing (90.0%), cocoon weight(3.683 g), shell weight (0.426 g), shell ratio (13.31%), pupal weight (3.256 g) with lower larval and pupal durations. Reddy *et al*., (1989b) recorded survival rate (95.67%), shell ratio (12.20%), and shorter developmental period (26.49 days) when eri silkworms were reared on ideal bed cleaning treatment. In Our study results indicating that the maximum shell weight (0.436 g), silk ratio (12.82%) and cocoon weight (3.44 g) have been obtained in eri silkworm shelf rearing method. Devaiah *et al*., (1985) reported that feeding, bed spacing and bed cleaning are important worm management practices affecting the larval weight, silk gland weight, cocoon weight and shell weight considerably. According to

them maximum larval weight (7.6 g), cocoon weight (2.96 g) ,effective rate of rearing (90.0%), shell weight (0.44g) and silk ratio (14.9%) has been obtained in shelf method of rearing on castor.

Conclusion and Recommendations

This study confirmed that, once bed cleaning frequency per day, twice bed cleaning frequency per day and three times bed cleaning frequency per instar significantly shortened the larval period of Vietnamese eri-silkworm races, Indian eri silkworm races, Kenyan bivoltine silkworm races, Korean bivoltine silkworm races and Vietnamese multivoltine silkworm races. Larval mortality was significantly higher in all the tested silkworm races of the 4th and 5th larval instars in the control beds. Among the tested treatments, one time bed cleaning frequency per day, two times bed cleaning frequency per day and three times bed cleaning frequency per instar, significantly reduced larval mortality rate during the 4th and 5th larval instars of all silkworm races. The young larval stages (1st, 2nd, and 3rd instars) showed low larval mortality rate than the mature larval stages (4th and 5th larval instars). Bed cleaning frequencies had no significant effect for 1st larval instar in all silkworm races. All bed cleaning frequencies had no significant effect for Korean silkworm races and Vietnamese multivoltine silkworm races until the 3rd larval instars. Hence, bed cleaning is not necessary during these stages in silk worm rearing practices for such races. Bed cleaning has showed a positive effect to reduce larval mortality rate for Vietnamese eri-silkworm races, Indian eri-silkworm races and Kenyan bivoltine silkworm races during 2nd and 3rd larval growth. The grown up worms, after completing feeding during late fifth instar at their ripened stage (ready to spin silk) are the once to be transferred on mountages for spinning silk cocoon.

Bed cleaning is an important silkworm rearing process to ensure good hygiene and better feeding appetite especially during the 5th larval instar to obtain better cocoon yield components of silkworm races. In this regard, long spinning silk thread, robust silk cocoon and shell weight and higher percentage of silk ratio of silkworms were registered from one time bed cleaning frequency per day and two times bed cleaning frequency per day in the ripened stage of silkworm larvae for Vietnamese eri-silkworm races, Indian eri silkworm races, Kenyan bivoltine silkworm races, Korean bivoltine silkworm races. For Vietnamese multivoltine silkworm races better results for the same parameters were obtained from three times bed cleaning frequency per instar in addition to one time bed cleaning frequency per day and two times bed cleaning frequency per day. Though the above mentioned three treatments are superior in reducing larval mortality and increasing yield components of silkworm races, one time bed cleaning frequency per day and three times bed cleaning frequency per instar could be recommended to save time and labor for silk growers to ensure higher cocoon yield depending on the type of silkworm races . From this study it can be concluded that, if proper bed cleaning is not done in time it leads to various complications viz. ill health of larvae, disinterest of the larvae to feed due to unhygienic conditions, ultimately worms become weak and low in productivity. To this effect, stage wise bed cleaning frequency for each larval instar of the different silkworm races should be done to reduce larval mortality, to shortened larval period and to improve the yield components of the different silkworm races.

Acknowledgment

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Evaluations of Different Montage types and Sizes on Eri and Mulberry Feeding Silkworms Cocoon Yield and Quality of Silk at Melkassa Agricultural Research Center, East Shoa, Ethiopia.

Ahmed Ibrahim[1] Kedir Shifa, Abiy Tilahun and Metasebia Terefe
[1]Ethiopian Institute of Agricultural Research, Melkassa Agricultural Research Center, P.O.Box-436, Melkassa, Ethiopia

Abstract

The experiments were conducted at Melkassa Agricultural Research Center in the sericulture research laboratory during 2011/12-2012/2013 cropping seasons. Different mountage types (ply wood, cartoon made, Banana leaf, plastic board, rolling paper and mango leaf montages) and sizes (3 x 3cm, 3 x 4cm, 3 x 5cm, 4 x4cm, 4 x 5cm and 5 x 5 cm) were evaluated on Eri and Mulberry silkworm cocoon yield and quality of silk. In the mountage type evaluation, 4cm x4cm recommended mountage size was prepared from ply wood, cartoon and plastic board. Different mountage sizes were prepared from plywood purchased from the market. Hundred silkworm larvae were used for each mountage type and sizes, and the treatments were arranged in randomized block design with three replications. Daily relative humidity and temperature of the laboratory were taken during the experiment. Cocooning percentage, defective cocoon percentage, reeling/spinning quality, average filament length and silk ratios were used to evaluate the montage types. Similarly, number of double pupae formation per cocoon, average weight of 10 cocoons of five days after 4th instars, defective cocoon percentage, spinning /reeling quality, length of single cocoon and silk ratios were used to evaluate montage sizes. Significantly (P<0.01) higher cocooning percentage, lower defective cocoon percentage, higher spinning quality, higher filament length and silk ratios were recorded in plywood made, carton made and banana leaf made mountage than the other treatments followed by mango leaf made mountage for both Eri and mulberry silkworms. Number of double pupae formation per cocoon significantly lower in all sizes of the mountages except 5cm x 5cm mountage size for Eri silkworms. However, number of double pupae formation per cocoon significantly P<0.01 higher in 5cm x 5cm followed by 3cm x 5cm, 4cm x 5cm mountage sizes than the other treatments for Mulberry silkworms. Therefore plywood made, carton made and banana leaf made mountage followed by mango leaf mountage types should be recommended for eri and mulberry silk worms. Regarding the mountage sizes, 4cm x 4cm and 4cm x 5 cm mountage size made from ply wood should be recommended for mulberry and Eri- silkworms, respectively, and used by the end users.

Key Words*; *Eri-silkworms, Mulberry silkworms, Mountage types, Mountage sizes, Relative humidity, Temperature

Introduction

Mounting is the last stage of rearing operation. Transferring mature fifth instar larvae to mountages is called mounting. When larvae are fully mature, they become translucent, their body shrinks, and they stop feeding and start searching for suitable place to attach themselves for cocoon spinning and pupation. These movements clearly indicate to transfer the mature larvae into the mountages. They are picked up and put on mountages. The worms attach themselves to the spirals of the mountages and start spinning the cocoon. By continuous movement of head, silk fluid is released in minute quantity which hardens to form a long continuous filament. The silkworm at first lays the foundation for the cocoon structure by weaving a preliminary web providing the necessary foot hold for the larva to spin the compact shell of cocoon. Owing to characteristic movements of the head, the silk filament is deposited in a series of short waves forming the figure of eight. This way layers are built and added to form the compact cocoon shell. After the compact shell of the cocoon is formed, the shrinking larva wraps itself and detaches from the shell and becomes pupa or chrysalis. The spinning completes within 2-3 days in multi-voltine varieties and 3-4 days in uni- and bivoltine.

Mountages types which are having proper sizes play a vital role in quality cocoon production. Farmers depend on resources and use different types of materials available locally for making Mountages. Types of material used, finishing of Mountages, space available for spinning worms in Mountages etc., will decide the quality of cocoon. Narrow space affects ventilation and results in poor reliability of cocoons. Similarly more space results in wastage of silk in the form of floss (Mathur *et. al*, 2010). Different types of mountages are used in different parts of silk producing areas of the world. In addition to support the spinning worms, the mountages should satisfy the requirements like, it provide convenient space of suitable dimension for spinning good sized cocoons, should not promote formation of double cocoons, malformed cocoons and flimsy cocoons, should have provisions for drying up of the last excreta of the worm prior to spinning and prevention of its falling on the cocoons of other worms, should be suitable for easy mounting and harvesting.

The material and structure of montages significantly affect the quality of cocoon filament and also the labor required for mounting and harvesting the cocoons. The basic concept of proper montages types and sizes are to provide an angular uniform space for silk worm to facilitate easy cocoon formation. The fabrication and type of mountages depends on the availability of chief materials in the respective places. If the material and structure of mountages are not proper, it will affect the shape and size of cocoons, besides increasing of double, deformed, soiled cocoons and wastages of silk in the form of floss. The common mountages used at present in India and China are made out of bamboo, plastic material, wood etc. However, the works on mountage types and size are scanty in Ethiopia. Therefore, it is very crucial to evaluate different types of mountages types and size for better cocoon yield and silk quality for our case.

Material and Methods

Description of study area

The experiments were conducted at Melkassa Agricultural research center, for two years (2012 and 2013). The place lies at 8° 24' N latitude and 39° 21' E longitude, 17 km south of Adama, at an altitude of 1550 m.a.s.l. The area is characterized by warm and semi-humid climate. The annual average rainfall and relative humidity of the laboratory during 2012 and 2013 cropping seasons are 810.1mm, 924.7mm and 50rh, 55rh**,** respectively**.** The average minimum and maximum atmospheric temperatures of the laboratory during 2012 and 2013 cropping seasons are 9.3, 13.2 and 28.9, 29.1^{oc}, respectively.

Experimental design and methods

The experiment was conducted for two years, i.e. during the 2012, 2013. Cropping reasons. Six different montage types (ply wood, cartoon made, Banana leaf made, plastic, rolling paper and mango leaf montages) and six different montage sizes (3x3, 3 x 4, 3 x 5, 4 x 4, 4 x 5 and 5 x 5cm) were evaluated. The experiment was laid out in complete randomized design with four replications during 2012 and 2013 seasons experiment. For the montage type activity, ply wood, cartoon and plastic made mountage were purchased from the market and montages were made in the center. Banana and mango branch with leaf were collected from Horticultural Research Center of Melkassa Agricultural Research Center and dried under shade and used as montage for the silkworm. Regarding the montage size experiment, ply wood was purchased from the market and montages were prepared which are having different sizes. Cocooning percentage, defective cocoon percentage, reliability, average filament length and silk ratios were used to evaluate the montage types. Similarly, number of double cocoon formation/plot, average weight of 10 cocoons, defective cocoon percentage, spinning quality, length of single cocoon and silk ratios were used for the evaluation of montage sizes. Data were subjected to SAS 6.12 soft ware.

Results and Discussions

The effects of different mountage types on silkworm cocooning percentage, defective coccon percentage, spinning quality, filament length and silk ratios of Eri-3.4 are indicated in Table1 and Table2. Significantly ($P<0.01$) higher cocooning percentage, lower defective cocoon percentage, higher spinning quality and higher filament length were recorded in plywood, carton made and banana leaf made mountage followed by mango leaf made mountage (Table1 and Table2). Even though lower cocooning percentage and higher defective cocoon percentage were observed in plastic made mountage, significantly higher spinning quality, higher average filament length and silk ratios were observed (Table1). On the other hands, silk ratios for all the treatments were in the acceptable ranges for both Eri-India and Eri-3.4 silkworms, except for rolling paper treatment of Eri-3.4 silkworms (Table1).

Tabele 1. The effects of different mountage types on silkworm cocooning percentage, defective coccon percentage, spinning quality filament length and silk ratios of Eri-3.4 silkworms

No.	Treatments	Cocooning percentage (%)	Defective cocoon percentage (%)	Spinning quality (%)	Average filament length of 10 cocoons (M)	Silk ratio %
1	Ply wood made mountage	97.20 ± 0.44a	0.012 ± 0.01c	96.87 ± 0.62 a	8.88 ± 0.32a	11.53 ± 0.22ab
2	carton made maountage	95.69 ± 0.56a	0.014 ± 0.01c	96.65 ± 1.01a	8.36 ± 0.64ab	11.44 ± 0.04b
3	Banana leaf made mountage	96.69 ± 0.22a	0.015 ± 0.01c	95.63 ± 0.68a	7.86 ± 0.13cb	11.77 ± 0.18a
4	Plastic made mountage	69.01 ± 0.50c	0.459 ± 0.02a	91.74 ± 5.75**a**	8.34 ± 0.16ab	11.42 ± 0.20ab
5	Rolling paper mountage	70.84 ± 3.76c	0.473 ± 0.01a	65.01 ± 4.40b	6.63 ± 0.11d	9.74 ± 0.22c
6	Mango leaf made mountage	80.50 ± 5.10b	0.050 ± 0.01b	97.46 ± 0.99a	6.93 ± 0.09cd	11.41 ± 0.17ab
CV%		**5.33**	**9.35**	**6.26**	**6.58**	**3.08**

Means followed by the same letter within a column are not significantly different from each other at 1% level of probability (Student-Newman-Keul`s Range Test).

Table 2. The effects of different mountage types on silk worm cocooning percentage, defective cocooning percentage, spinning quality, filament length and silk ratios of Eri - India mixed silkworms.

No.	Treatments	Cocooning percentage (%)	Defective cocoon percentage (%)	Spinning quality (%)	Average filament length of 10 cocoons (M)	Silk ratio %
1	Ply wood made mountage	93.26+ 0.75a	0.088+ 0.01c	85.78+ 0.78a	8.09+ 0.13a	12.38+ 0.08a
2	carton made maountage	93.70+ 0.42a	0.105+ 0.01c	86.83+ 0.44a	8.24+ 0.22a	12.05+ 0.18a
3	Banana leaf made mountage	92.11+ 0.63a	0.094+ 0.01c	86.15+ 0.11a	7.92+ 0.12ab	11.87+ 0.39a
4	Plastic made mountage	67.09+ 1.30c	0.332+ 0.02b	76.67+ 2.31b	8.19+ 0.18a	11.83+ 0.13a
5	Rolling paper mountage	62.93+ 1.73d	0.447+ 0.03a	62.91+ 2.50c	7.55+ 0.29b	11.12+ 0.34b
6	Mango leaf made mountage	82.59+ 0.28b	0.124+ 0.02c	88.07+ 0.13a	6.76+ 0.26c	10.76+ 0.08b
CV%		**1.76**	**13.05**	**2.69**	**3.97**	**3.28**

Means followed by the same letter within a column are not significantly different from each other at 1% level of probability (Student-Newman-Keul`s Range Test).

Significantly higher cocooning percentage, reeling quality and lower defective cocoon percentage were observed in plywood, carton made and banana leaf made mountage followed by the other mountage types for both Korean and Kenyan silkworms and non significant differences were recorded among the treatments with in the column (Table4). An average filament length and silk ratios were significantly higher in all the mountage types and insignificant differences were observed among them with in the column for both Korean and Kenyan bivoltine . Similarly, cocooning percentage significantly higher in cartoon and banana leaf made mountage followed by ply wood mountage for mulberry multivoltine silkworms. Defective cocoon percentages significantly higher in plastic made mountage followed by rolling paper mountage but significantly lower in the other treatments. An average filament length significantly (P<0.01) higher in the plywood, cartoon, banana leaf and plastic made mountages than the other treatments and non significant differences were observed among them. But, significant differences were recorded among the treatments with respect to the silk ratios; however, all the values recorded were in the acceptable ranges for mulberry multivoltine silkworms .

The effects of different mountage sizes of plywood on the number of pupae /cocoon/plot, weight of cocoon, defective cocoon percentage, spinning quality, length of single cocoon and silk ratios of Eri- 3.4 and Eri India silkworm are indicated in Table6 and Table7. Significant differences were observed among the treatments within the column for all parameters. Number of double pupae/cocoon/ plot significantly lower in all sizes of the mountages, except for 5cm x 5cm mountage size. An average weight of 10 cocoons and length of single cocoon significantly lower in the 3cm x3cm and 4cm x3cm but significantly higher in the other treatments and non significant differences were observed among them within the column. On the other hands, insignificant and similar results were observed among the treatments within the column for defective cocoon percentages, spinning quality and silk ratios of different mountage sizes . On the other hands, number of double pupae/cocoon/plot significantly (P<0.01) higher in 5cm x5cm followed by 4cm x5cm and 3cm x5cm mountage sizes . However, significantly lower numbers of double pupae/cocoons/plot formation were appeared in the other mountage sizes. Similarly, insignificant and higher average weight of 10 cocoons were observed among the mountgae sizes. Defective cocoon percentage and length of spinning thread significantly higher in 3cm 5cm, 4cm x5cm and 5cm x5cm mountage sizes than the other treatments. Nevertheless, the reeling quality and the silk ratios were significantly higher in 3cm x 3cm, 3cm x 4cm and 4cm x 4 cm mountgae sizes and non significant differences were recorded among them within their columns. Mounting and mountages considerably influences the quality of cocoons. The farmers are said to be losing about 5-8 % of yield due to improper mountages [Chandrakanth et al. 2004].

It is evident from the mean data of the experiment that in general, ply wood, cartoon and banana leaf mountages showed a marginal tendency to improve many of the economic character as compared to the plastic and rolling paper montage. The results of the present study correlate with [Chandrakanth et al. 2004] where the author used seven types of mountages: Banana leaf type, mango twigs type, shoot rearing rack rotary type, plastic collapsible, fixed vertical type, bamboo mountages and rotary mountages considering cocooning (%), double cocoon(%), floss(%), defective cocoon (%), single cocoon weight (gm), shell weight (gm), shell ratio (%), and reel ability (%) in which the bamboo mat base easily available, cheap and can last 4-5 years but demerit using lot of space during mounting but both all of these mountages shows some merits as well as demerits during study time and also shows variations in economic parameters of cocoon production and quality in each type of mountages. Datta (Biswas) *et al.*,

[2008] also shows Plastic collapsible montage, plywood montage, mango and banana leaf mountage are an alternate to bamboo spiral and others mountage in Eastern India for better cocoon yield. Chikkanna *et al*., [2009] also study qualitative improvement in terms of economic gained by using more than two different types of mountages for silkworm cocoon. He also quote that, types of mountages, sizes and mounting environmental condition play a paramount role in determining the quality of cocoons of silkworm, *Bombyx mori*. Pandey *et al*. (2007] indicated that, plywood and cartoon made mountages with 4x5cm for Eri silkworm larvae and 4cm x4cm and 4cm x3cm for mulberry silkworm mounting space sizes in North-western India showed better result during study period. Datta (Biswas) *et al*., [2007] also showed comparative study of spinning of silkworm in more than three types of mountages (mango leaf, carton made, rolling paper, plastic mountage and banana leaf made montage). The Mango tree twigs and banana leaf mountages are playing important role in saving the cocoon crop and are easily available and easy to use for farmers but it has some major draw backs that during harvesting the dried leaves some times stickup to cocoons and the cost of twigs cannot be calculated. According to Mathur and Quadri, (2010) also estimated that farmers loss about 12-15 % of crop due to defective cocooning which is attributed to inadequate Mountages, poor quality of Mountages, shortage of time, lack of proper mounting space, mounting care and management of environmental conditions. Our studies confirmed that, the percentage of urinated cocoon was more in plastic and rolling paper mountage compared to other types of mountages. Pandey *et al.*, (2007) also used banana and mango leaf mountage in North-Western India which shows better results in improving cocoon quality during study period.

Thus from the present study it can be concluded that the mountage made from plywood, Mango tree twigs, banana leaf and cartons are directly placed on rearing bed to spin cocoon helping the farmer to save labor and do not have any problems of identifying and picking ripe larvae at newly joined sericulturist. However, this method needs more space but during emergency time when there were no sufficient mountages or no any mountages with poor, newly joined farmers at that time Mango tree twigs and banana leaf mountages play vital role for farmers to save cocoon crop.

Table 3. The effects of different mountage types on silkworm cocooning percentage, defective cocoon percentage, reeling quality, filament length and silk ratios of **Kenya bivoltine (K1, K3, K4 and K5) silkworms**

No.	Treatments	Cocooning percentage (%)	Defective cocoon percentage (%)	Reeling quality (%)	Average filament length of 10 cocoons (m)	Silk ratio %
1	Ply wood made mountage	95.31 ± 1.21 a	0.020 ± 0.001c	83.53± 1.76ab	811.90 ± 12.87 a	21.87 ± 0.49a
2	carton made maountage	87.45 ± 5.31a	0.025 ± 0.001c	82.31± 2.00 ab	827.45 ± 20.95a	23.74 ± 0.04a
3	Banana leaf made mountage	87.88 ± 0.92a	0.032 ± 0.001c	81.20± 1.64ab	830.85 ± 45.20a	22.46 ± 1.17a
4	Plastic made mountage	62.19 ± 3.49b	0.131 ± 0.001b	86.76± 0.23a	797.44 ± 10.39a	21.39 ± 0.41ab
5	Rolling paper mountage	64.47 ± 5.09b	0.351 ± 0.026a	64.63± 3.92c	851.49 ± 56.00a	19.04 ± 1.14b
6	Mango leaf made mountage	57.83 ± 2.58b	0.017 ± 0.001c	79.81± 2.45b	805.73 ± 15.01a	22.91 ± 0.17a
CV%		**8.44**	**19.79**	**4.67**	**7.36**	**6.23**

Means followed by the same letter within a column are not significantly different from each other at 1% level of probability (Student-Newman-Keul`s Range Test).

Table 4. The effects of different mountage types, on silkworm cocooning percentage, defective cocoon percentage, reeling quality, filament length and silk ratios of **Korea- bivoltine silkworms.**

No.	Treatments	Cocooning percentage (%)	Defective cocoon percentage (%)	Reeling quality (%)	Avarage filament length of 10 cocoons (M)	Silk ratio %
1	Ply wood made mountage	75.71 ± 1.18a	1.34 ± 0.06b	73.68 ± 2.07ab	701.67 ± 2.33a	21.43± 0.57b
2	carton made maountage	74.08 ± 0.57a	1.23 ± 0.07b	74.60 ± 0.77a	709.00 ± 1.00a	23.15± 0.44a
3	Banana leaf made mountage	71.61 ± 1.08a	1.34 ± 0.04b	74.15 ± 0.58a	707.44 ± 4.61a	22.21 ± 0.48ab
4	Plastic made mountage	57.21 ± 4.02c	2.59 ± 0.25a	65.28 ± 5.89bc	575.81 ± 17.01b	22.91± 0.36ab
5	Rolling paper mountage	74.71 ± 0.35 a	2.58 ± 0.26a	59.72 ± 2.86c	574.34 ± 20.57b	23.80± 0.16a
6	Mango leaf made maountage	65.46 ± 1.39b	1.31 ± 0.10b	75.05 ± 1.01a	707.89 ± 2.08a	22.33± 0.16ab
CV%		**4.74**	**15.02**	**6.68**	**3.14**	**4.00**

Means followed by the same letter within a column are not significantly different from each other at 1% level of probability (Student-Newman-Keul`s Range Test).

Table 5. The effects of different mountage types on silkworm cocooning percentage, defective cocoon percentage, reeling quality, filament length and silk ratios of Multivoltine silkworm.

No.	Treatments	Cocooning percentage (%)	Defective cocoon percentage (%)	Reeling quality (%)	Average filament length of 10 cocoons	Silk ratio %
1	Ply wood made mountage	89.81± 0.75 b	0.128± 0.005d	83.91± 1.52a	825.57 ± 31.35abc	21.61± 0.32c
2	Carton made maountage	91.21± 0.14ab	0.190± 0.007c	84.13± 1.52a	877.17 ± 4.34a	23.28± 0.28a
3	Banana leaf made mountage	93.51± 1.50a	0.175± 0.006c	83.10± 1.00a	815.02 ± 15.50bc	23.38± 0.30a
4	Plastic made mountage	70.13± 0.80d	0.423± 0.004a	67.84± 3.93b	834.33 ± 18.18ab	22.46± 0.56ab
5	Rolling paper mountage	62.89± 0.92e	0.368± 0.013b	63.13± 2.25b	638.04 ± 13.76d	20.62± 0.28c
6	Mango leaf made mountage	73.94± 0.58c	0.138± 0.001d	81.39± 1.37a	768.33 ± 10.80c	22.59± 0.38ab
CV%		**1.84**	**5.84**	**5.24**	**4.14**	**3.01**

Means followed by the same letter within a column are not significantly different from each other at 1% level of probability (Student-Newman-Keul`s Range Test).

Table 6: Effects of different mountage sizes of plywood on number of cocoon /single space, weight of cocoon, defective cocoon percentage, spinning quality, length of single cocoon and silk ratios of Eri- 3.4 and India silkworm.

No	Treatments	Number of double and above/plot	Average weight of 10 cocoons	Defective cocoon percentage (%)	Spinning quality (%)	Length of a single cocoons	Silk ratio %
1	3 cm x 3 cm	0.00 ± 0.00b	2.46 ± 0.22c	0.00 ± 0.00a	76.53 ± 1.94a	5.803 ± 0.52c	11.63 ± 0.33 a
2	3 cm x 4 cm	0.00 ± 0.00b	3.30 ± 0.02b	0.00 ± 0.00a	73.58 ± 1.31a	7.660 ± 0.11b	11.95 ± 0.12a
3	3cm x 5 cm	0.00 ± 0.00b	3.92 ± 0.09a	0.00 ± 0.00a	74.01 ± 2.13a	8.380 ± 0.14a	12.20 ± 0.49a
4	4 cm x 4 cm	0.00 ± 0.00b	3.79 ± 0.03a	0.00 ± 0.00a	74.74 ± 0.37a	7.667 ± 0.08**b**	12.90 ± 0.95a
5	4 cm x 5 cm	0.00 ± 0.00b	4.07 ± 0.02a	0.00 ± 0.00a	74.43 ± 0.85a	8.086 ± 0.04ab	12.23 ± 0.88a
6	5 cm x 5 cm	2.05 ± 0.00a	4.08 ± 0.07a	0.00 ± 0.00a	73.81 ± 1.52a	8.106 ± 0.02ab	11.68 ± 0.27a
CV%		**5.34**	**5.34**	**--**	**3.74**	**5.01**	**7.77**

Means followed by the same letter within a column are not significantly different from each other at 1% level of probability (Student-Newman-Keul`s Range Test).

Table 7. Effects of different mountage sizes of plywood on number of cocoon /single space, weight of cocoon, defective cocoon percentage, reeling quality, length of single cocoon and silk ratios of bivoltine and multivoltine silkworms (K1, K3, K4, K5, yellow cocoon, white cocoon and Korea).

No	Treatment	Number of double and above/plot	Average weight of 10 cocoons	Defective cocoon (%)	Reeling quality (%)	Length of a single cocoon	Silk ratio %
1	3 cm x 3 cm	1.65 ± 0.33d	1.87 ± 0.31a	0.00 ± 0.00b	91.79 ± 1.25a	674.33 ± 10.17c	21.26 ± 0.32bc
2	3 cm x 4 cm	2.00 ± 0.00d	2.67 ± 0.17a	0.00 ± 0.00 b	94.50 ± 1.21a	933.67 ± 35.17b	23.59 ± 0.83a
3	3cm x 5 cm	14.00 ± 1.52c	2.97 ± 0.05a	0.39 ± 0.01a	67.57 ± 1.21b	1002.00 ± 17.03a	19.13± 0.43d
4	4 cm x 4 cm	2.00 ± 0.57d	2.69 ± 0.09a	0.00 ± 0.00b	94.03 ± 0.98a	987.67 ± 11.69b	22.65± 0.74ba
5	4 cm x 5 cm	23.54 ± 2.60b	3.08 ± 0.06a	0.40 ± 0.03a	64.92 ± 1.80b	979.00b ± 25.69a	19.63± 0.42dc
6	5 cm x 5 cm	28.63 ± 1.20a	2.90 ± 0.02a	0.43 ± 0.01a	66.11 ± 3.28b	1023.00 ± 5.89a	18.62± 0.49d
CV%		**21.24**	**10.30**	**12.56**	**3.88**	**3.91**	**4.81**

Means followed by the same letter within a column are not significantly different from each other at 1% level of probability (Student-Newman- Keul`s Range Test).

Conclusion and Recommendations

Therefore from the present study it can be concluded that, plywood made, carton made and banana leaf made mountage followed by mango leaf mountage types should be recommended for eri and mulberry silk worms. Regarding the mountage sizes, 4cm x 4cm and 4cm x 5cm mountage size made from ply wood should be recommended for mulberry and Eri- silkworms, respectively, and used by the end users.

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Effect of Different Agronomic Practices for Optimum Production of Yield and Yield Components of Castor/*Ricinus Communis L.*

Metasebia Terefe, Ahmed Ibrahim, Abiy Tilahun and Kedir Shifa
Ethiopian Institute of Agricultural Research Center, Melkassa Agricultural Research Center, P.O.Box-436, Melkassa, Ethiopia

Abstract

Determination of planting space, planting date and leaf harvesting date for castor (Ricinus communis L.) is very important for obtaining optimum leaf yield for the production of eri-silkworm (Samia Cynthia ricini B.). These experiments were conducted to find out intra and inter row spacing, planting date and appropriate leaf harvesting dates of improved castor leaf productivity. Four within plant spacing (50, 75, 100 and 120 cm) and three inter- row spacing (120, 100 and 75 cm) were arranged in factorial combination (12 treatment combinations) in RCBD design in three replications for spacing trial. Whilst, for Planting of castor at different planting dates (3rd - 4th week of May, 1st - 2nd week of June, 3rd - 4th week of June, 1st - 2nd week of July, 3rd - 4th week of July, 1st - 2nd week of August) and leaf harvesting date at 10, 12, 14, 16, 20 weeks after planting of castor. All experiments were carried out for three years (2010-2012) at Melkassa Agricultural Research Center (MARC).The result showed that significantly (P<0.05) higher fresh leaf weight (13295 kg/ha) and dry leaf weight (2912 kg/ha) were observed from 50 cm within plant and 75cm inter- row spacing. However, the least fresh (6376 kg/ha) and dry leaf weight (1460 kg/ha) were observed from combination of 120cm with 120 cm spacing. Whereas, planting of castor at 3rd-4th week of June and leaf harvesting at 10 weeks after planting gave high yield and yield components. Therefore, a plant and row spacing or treatment combinations of 50 cm x 75 cm or a plant population of about 26670 plants per hectare, planting interval between 3rd-4th week of June and starting of leaf harvesting at 10 weeks after planting can be used for optimum leaf production for better eri- silk worm production.

Key words: *Castor (Ricinus communis L.), Spacing, Planting date, leaf harvesting date, leaf production*

Introduction

Castor *(Ricinus Communis L.)* (Fam. Euphorbiaceae) is a flowering plant of the ancient oil seed crops and the major feed plant for the production of eri-silkworm, *Samia cynthia ricini*, which belong to family saturnidae, the one among the commercially exploited silkworm species and can be reared in doors throughout the year to produce silk (Joshi, 1992). It is indigenous to the southeastern Mediterranean Basin, Eastern Africa (including Ethiopia) and India, but is widespread throughout tropical regions. Castor has also established in waste areas, the edges of cultivated fields, canal banks, *etc* (Zimmerman *et al.*, 1958). Castor can also be considered as commercial crop from seed and sericulture business .Its seed contains 50-55 % oil (Weiss, 1971). Though, eri-silkworm is multivoltine feeding on a wide range of feed plants, castor (*Ricinus communis*) serves as primary food plant. Reddy *et al.* (1989b) recorded higher survival rate, maximum growth index, higher shell ratio, higher net reproductive rate and shorter developmental period when eri-silkworms were reared on castor. Devaiah *et al*. (1985) also reported that castor is the best host plant affecting the larval weight, silk gland weight, cocoon weight and shell weight considerably. Hence, determination of optimum plant population, planting and leaf harvesting date for castor *(Ricinus communis L.)* is important for obtaining optimum leaf yield for the production of silk.

However, very little information is available on the agronomic/cultural practices of castor for better production of leaf. Therefore, these experiments were conducted to find out optimum intra and inter row spacing, planting date and appropriate leaf harvesting dates to improved castor leaf productivity for better production of cocoon.

Materials and Methods

Description of the study area

The experiments were conducted in Melkassa Agricultural Research Center (MARC), from 2010-2012 for determination of spacing, planting and leaf harvesting dates of castor *(Ricinus communis L.)*. MARC is one of the research center under the Ethiopian Institute of Agricultural Research (EIAR). It is found 117 kms away from Addis Ababa and 17 km to South-East of Nazareth in the East-Shewa zone of Oromia region. It is located 8°24'N latitude and 39°12'E longitude having an elevation of 1500 meters above sea level and a mean annual rainfall of 770 mm.

Preparation of land

MARC experimental field was used for planting of seeds of castor. Prior to planting, the land was prepared by ploughing, digging and leveling. Two seeds of castor per hole were planted in a row at the onset of the rain and during the rain fails, the land was provided with supplemental irrigation for spacing and leaf harvesting trials. However, supplemental irrigation was not provided for planting date trial. A Castor seed was planted at a spacing of 75 cm x 75 cm.

Treatments include

Spacing Trial: Four within plant spacing (intra row spacing) (50, 75, 100 and 120cm) and three inter- row spacing (120, 100 and 75 cm) were arranged in factorial combination (12 treatment combinations) in RCBD design with 3 replications.

Leaf harvesting date trial: 10, 12, 14, 16, 18 and 20 weeks after planting were used as treatments and it was arranged in RCBD design with 3 replications.

Planting date trial: 3rd - 4th week of May, 1st - 2nd week of June, 3rd - 4th week of June, 1st - 2nd week of July, 3rd - 4th week of July and 1st - 2nd week of August were used as treatments and arranged in RCBD design with 3 replications.

Data collected

Data such as planting date, date of germination, plant height, date of flowering and maturity, fresh and dry leaf weight, leaf yield per plant, disease and insect pest incidence and severity, Seed yield, Number of capsule/racemes, *etc* were recorded.

Data analysis

The data were subjected to analysis of variance (ANOVA) using Statistical Analysis Software (Gomez and Gomez, 1984) (*version* 9.00, SAS, Institute Inc., Cary, NC, USA). Treatment means were separated using the least significant differences (LSD).

Results and Discussion

Determination of plant population, planting and leaf harvesting date for castor *(Ricinus communis L.)* is very important for obtaining optimum leaf yield for the production of reasonable amount of cocoon. Leaf and seed yield of castor can be maximized by using optimum plant population, appropriate planting/sowing date, quality seed and recommended fertilizer rate and weeding practices. Practicing optimum spacing can significantly improve leaf yield. Castor oil is unique among vegetable oils because it is the only commercial source of a hydroxylated fatty acid. This unique fatty acid comprises about 90 % of castor oil. It appears that the level of ricinoleic acid is influenced very little by the growing environment (Severino*et al.* 2012).

In the present studies, significant differences (P<0.05) between treatments were observed in spacing, leaf harvesting and planting dates trials in parameters such as plant height, number of leaf production, fresh and dry leaf weight and other parameters. Significantly (P<0.05) higher number of fresh (13,295 kg/ha) and dry leaf weight (2,912 kg/ha) were observed from 50 cm plant and 75cm row spacing (Table 3 and 4). However, the least fresh (6,376 kg/ha) and dry leaf weight (1,460 kg/ha) were observed from combination of 120 cm with 120 cm spacing (Table 3 and 4). Kittock and Williams 1970, studied the effect of plant population on the yield and yield components of castor in irrigated and non-irrigated castor and they obtained the optimum plant population of dwarf irrigated castor was 55,000 plants/ha. Row spacing from 0.5m to 1m did not affect seed yield if plant population was held constant or narrow intra row spacing. On the other hand, SorattoRogerro Peres 2011, evaluated the effect of inter and intra row spacing on the yield and oil contents of two varieties of castor. The highest plant population (55,000 plants/ha) by the narrower plant spacing with combination of (0.45 x 0.60 cm) produced a higher seed yield. Solomon 1988, tested the castor plants vary size from short annuals to small tree like plants, therefore, row and plant spacing will have significant effect on yield and yield components. Getnet *et al.* also revealed, 80cm row with 50 cm plant spacing is optimum for top branching castor variety Hiruy. The current study showed that, plant and row spacing/ treatment combinations of 50cm x75 cm or a plant population of about 26,670 plants per hectare gave better results as compared to the other combinations.

Table 1. Mean effect of row and plant spacing on plant height of castor variety, Hiruy grown at melkassa during 2010-2012 cropping season

Intra Row spacing in cm	**Inter Row spacing in cm**			
	120	**100**	**75**	**Mean**
50	120ab	105bcd	118ab	114
75	102cd	100cd	106bcd	102.6
100	91d	95cd	101cd	96
120	96.7cd	123a	110abc	110
Mean	102.4	105.75	108.75	105.6

Means within the same column with a common letter are not significantly different (P<0.05)

For leaf harvesting and planting dates parameters like plant height, number of leaves, number of primary and secondary branches, fresh and dry leaf weight, and disease and insect pest prevalence were taken to meet the trial objectives. The stage of growth at harvesting and method of harvesting have great impact on final yield. There were no significant differences (P<0.05) in treatments observed in all the parameters during various leaf harvesting period. The data indicated that from 10 weeks up to 20 weeks after planting, yield and yield components did not have any variability which showed there was an equal harvest in all the treatments (Table 7). Though, there were significant differences (P<0.05) between treatments in terms of fresh and dry leaf weight and seed weight. Leaf harvesting dates from 10 to 18 weeks gave similar yield in fresh (4438 to 6441 kg/ha) and dry leaf weight (2521 to 3709 kg/ha). With regard to biotic factors, rust was the major disease in all the treatments and there was a reduction of edible leaf area (up to 57%) for silk worms in all the years of the experiment which requires a control measure in future. The three years results showed that starting of first leaf harvesting of castor at 10 weeks after planting is advisable for the feed of eri-silkworms to obtain the optimum production of cocoon.

Table 2. Mean effect of row and plant spacing on number of leaf per plant of castor variety, Hiruy grown at melkassa during 2010-2012 cropping season

Intra Row spacing in cm	**Inter Row in cm**			
	120	100	75	Mean
50	26.6a	26.7a	25.7a	26.3
75	27a	24.8a	22.8a	24.9
100	22.8a	25.9a	24.8a	24.5
120	25a	23.7a	26.7a	25
Mean	25.4	25.3	25	25.2

Means within the same column with a common letter are not significantly different (P<0.05)

Moreover, in planting date, significant differences (P<0.05) were observed among treatments in all the testing period (2010 to 2012). Optimum sowing dates were studied for most oil seeds at major growing areas but the rainfall variability in recent years indicates that oil seeds should be planted when there is sufficient moisture in the soil or when the main rainy season starts. The recommended sowing dates for oilseeds are still good information during normal/good years. Although a range of sowing dates should be identified since no one can be certain whether there will be sufficient moisture or not during that period. Sowing noug between late June to early July for higher altitude (>2000 masl) mid to late June for the lower altitudes (<2000 masl) were found optimum for the production of late maturing noug ecotypes (Nigussie *et al* 1992a) which was in line with our findings. Planting date at 1st-2nd week of June to 1st-2nd week of July gave higher and equal amount of fresh and dry leaf weight, plant height, production of branch, number of capsule and seed weight as compare to other treatments . Parallel results was obtained by Solomon 1988, optimum date for sowing sunflower at Hawassa and surrounding state farms is first to third week of June. Late planting predispose the crop to sever downy mildew infection. Planting of castor at 3rd-4thweek of June gave maximum leaf yield (25 leaf/plant). Whereas, planting at 3rd-4th week of July and 1st-2nd week of august gave least and equal amount of fresh and dry weight. Sowing date and seed rate trials on rape seed and gomenzer conducted during 1970 to 1982 showed that seed yields were high when planted during the onset of the main rainy season (end of May to late of June)(Nigussie, *et al* 1992a) which was in agreement with our findings. Therefore, from the three years result it can be conclude, planting of castor at 3rd-4th week of June is advisable to obtain optimum leaf yield of castor for the feed plants of eri silkworm for optimum silk production.

Table 4. Mean effect of row and plant spacing on dry leaf weight (kg/ha) of castor variety, Hiruy grown at melkassa during 2010-2012 cropping season

Intra Row spacing in cm	Inter Row Spacing in cm			
	120	100	75	Mean
50	2050bc	2304ab	2912a	2422
75	1896bc	1872.8bc	2335ab	2034.6
100	1687.6bc	1775bc	2179.7abc	1880.8
120	1460c	1598bc	1715bc	1591
Mean	1773.4	1887.5	2285.4	1982.1

Means within the same column with a common letter are not significantly different (P<0.05)

Table 5. Mean effect of row and plant spacing on seed yield (t ha^{-1}) of castor variety, Hiruy grown at melkassa during 2010-2012 cropping season

Intra Row spacing in cm	Inter Row Spacing in cm			
	120	100	75	Mean
50	1.02abc	0.74abc	1.4a	1.05
75	0.659bc	0.653bc	1.105ab	0.806
100	1.08ab	0.53bc	0.8abc	0.803
120	0.38c	0.43bc	0.637bc	0.482
Mean	0.785	0.588	0.986	0.786

Means within the same column with a common letter are not significantly different (P<0.05)

Table-6 Mean effect of planting dates on agronomic and yield characters of castor at melkassa between 2010-2012 cropping seasons

PD	PH (cm)	NLPP	NB	FLW (kg/ha)	DLW(kg/ha)	NCPP	SY (tha-1)	100 SW (g)/plant	DI (%)
3rd-4th week of May	138bc	19b	5.8b	2ab	6135bc	1481ab	29ab	1.1a	28c
1st-2nd week of June	166ab	23ab	8b	3.2a	7815.7ab	1867a	45a	1.3a	40a
3rd-4th week of June	186a	25a	6.5ab	1.9b	8223a	2036.7a	40ab	1.2a	41.7a
1st-2nd week of July	147abc	18bc	5b	2.2a	7432ab	1977a	35ab	1.1a	37ab
3rd-4th week of July	111cd	14cd	4.7b	1.4bc	4212cd	1138bc	24bc	0.8b	29bc
1st-2nd week of August	83d	10d	2.9c	0.7c	3609d	764c	14.7c	0.6b	25.5c
LSD	**42**	**5**	**1.8**	**1.2**	**2080.9**	**624.5**	**19**	**0.27**	**8.4**
CV	**17**	**14.4**	**18**	**35**	**18**	**22.2**	**34**	**14**	**13.7**

NB: PD=Planting dates, PH=Plant height, NLPP= Number of leaf per plant, NB=Number of branch, FLW=Fresh leaf weight, DLW=Dry leaf weight, NCPP=Number of capsule per plant, SY=Seed yield, SW= Seed weight, DI= Disease incidence, DS= Disease severity, Means within the same column with a common letter are not significantly different (P<0.05)

Table-7 Mean effect of leaf harvesting date on agronomic and yield characters of castor at melkassa between 2010-2012 cropping seasons

LHD (Weeks)	PH (cm) NS	NLPP	NB	FLW (kg/ha)	DLW (kg/ha)	NCPP NS	SY (tha-1) NS	100 SW (g)/plant	DI (%)
10	135	19	7.5ab	4.7	5962a	3620a	46	1.1	44ab
12	137	20	6.8ab	5	5815a	3209a	36	1.1	50a
14	141	21	5.7b	5	4438ab	2564ab	41	1.05	36c
16	140	21	8.5a	6	6441a	3709a	49	0.98	45ab
18	141	19	7.9a	5	4520ab	2521ab	43	1.1	46ab
20	142	18	6.9ab	5	3050b	1752b	44	1.06	40bc
LSD	24	7.8	2	2	2376.7	1375	24	0.16	6.5
CV	9.5	21.8	15	23	26	26	30	8.3	8.2

NB. LHD= leaf harvesting date, PH= plant height, NLPP= Number of leaf per plant, NB= Number of branch, FLW=Fresh leaf weight, DLW=Dry leaf weight, NCPP=Number of capsule per plant, SY=Seed yield, SW= Seed weight, DI= Disease incidence, DS= Disease severity, Means within the same column with a common letter are not significantly different (P<0.05)

Conclusion and Recommendations

The present experiments were conducted to evaluate intra and inter row spacing, planting date and appropriate leaf harvesting dates of castor to improved leaf productivity. The result showed that significantly (P<0.05) higher fresh leaf weight (13, 295 kg/ha) and dry leaf weight (2912 kg/ha) were observed from 50 cm within plant and 75cm inter- row spacing as compared to other treatments. However, the least fresh (6,376 kg/ha) and dry leaf weight (1460 kg/ha) were observed from combination of 120cm with 120 cm spacing. Whereas, planting of castor at 3rd-4th week of June and leaf harvesting starting at 10 weeks after planting gave high yield and yield components. From the result, plant and row spacing or treatment combinations of 50 cm x 75 cm or a plant population of about 26,670 plants per hectare, planting interval between 3rd-4th week of June and starting of leaf harvesting at 10 weeks after planting can be recommended for optimumleaf production for better silk production in Central Rift Valley of Ethiopia. Moreover, these experiments should be tested in different agro-ecologies of the country for the wider use of castor for silk production.

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Challenges of Box Hive Technology Usage: The Case of Gubalafto District North Wollo Zone, Easten Amhara Region

Tessema Aynalem[1], Nuru Adgaba[2], Zeleke Mekuriaw[3]
[1]Bahir Dar University, [2]Holleta Bee Research Center, [3]

International Livestock Research Institute, Lives Project, Bahir Dar

Abstract

This study was conducted in Gubalafto District of North Wolo Zone, Amhara Region of Ethiopia with the objectives assessing beekeeping practices using improved beekeeping technologies. Purpesive sampling technique was employed to identify the sample respondents. About 40 representative sample respondents were selected from each of the three agro ecologies. Based on the sampling technique, 120 improved beekeeping technology users were selected. The data were collected using structured and semi-structured questionnaire interview individually and were analyzed using descriptive statistical procedure of SPSS Version 12 software. Major problems for promoting improved beekeeping technologies were identified in the study area. Percentage ranking revealed that incompleteness of the box hive package, honeybee pests and enemies, shortage of bee forage, agro chemicals application, absconding of honeybee colonies, honeybee disease and lack of improved beekeeping skill were found to be the major challenges for the improved beekeeping technology usage in the District in their decreasing order of importance. Because of lack of proper technological inputs, trained manpower and different bee enemies, the beekeeper households have not been sufficiently benefiting from the sub sector.There is still enormous opportunity and potentials to boost the production and quality of hive products specially honey in the area.Hence, it is recommended that beekeeping extension, researchers and NGOs should enhance research and extension activities on full packaged provision of box hive technologies: honey extractor, queen excluder, foundation sheet, protective clothes and developing protection methods of honeybee enemies, bee forage development, management of pesticide application, absconding management, economically important honeybee disease control, developing a technology from locally available materials and organizing visit to apiary demonstration.

Key words: *Bee keeping technology; beekeeping extension; box hive technology; honeybee enemies*

Introduction

Beekeeping is long standing and deep rooted household activity for rural communities of Ethiopia where millions of honeybee colonies are kept in traditional hives in backyard and in forest using different management practices at different geographical locations (Ayalew and Gezahegn, 1991; Girma, 1998). Amhara Regional state is endowed with varied agro ecological zones that are suitable for apiculture, holding about 1.03 milion honeybee colonies (CACC, 2013), which is a real reflection of the potentiality of the region. However; the level of beekeeping remained in traditional system where more than 95.9% bee colonies were still kept in traditional hives, with its various limitations. This has resulted small amount of honey to be exported due to the low quality of the honey produced from traditional hives sum up with other reasons (Beyene and David 2007).

In spite of introduction of improved beekeeping technologies since 1965 (Ayalew, 1983)such as box hives and accessories, the development has not traveled long distance in the country as well as in the region.

The regional government has recently put beekeeping as one of development agendas as one of the strategies to reduce poverty and to diversify farmers' income as well as to diversify national export commodities. As the result, the extension service has disseminated thousands of improved beekeeping equipments, like frame hives, Kenyan top bar hives and other accessories aggressively. Despite the attempt of disseminating improved beekeeping technologies through District office of Agriculture and different NGOs in Gubalafto District, still over 80% of colonies are kept in traditional hives, indicating the less adoption of improved beekeeping technologies, which requires being investigated (BOA, 2012).

There was little or no feedback study from farmers about challenges to use improved beekeeping technologies as well as opportunities to take advantage. However; there was complain from beekeepers that they do not have the expected and boosted honey yield after using box hive technologies. Identification of bottle neck factors is important for policy makers, extension workers, researchers, and non-governmental organizations involving in beekeeping development programs and helps to modify their strategies by providing the information about types of challenges and identifying opportunities to use further. Hence, the study was aimed to contribute much in generating appropriate information on factors affecting the use of improved beekeeping technologies. So far there is no compiled and reliable information on the challenges for usage of frame hives beekeeping activities and other constraints associated. Therefore, this research study was undertaken to identify bottle neck factors and opportunities of using improved beekeeping technologies in Gubalafto District, Amhara Region.

The Specific objective of the study was:

To assess challenges of using box hive beekeeping technology
To suggest possible solutions

Materials and Methods

Description of the Study Area

The study was conducted in GubalaftoDistrict of North Wollo Zone, Amhara National Regional State. Agro-ecologicaly it has *Dega*(highland,about 37 %),*Woynadega* (midaltitude,about 46%), and *Kolla*(lowland,about 17 %). In the highlands, there are Olea, Rosa abyssinica, Albizzia, Gizotia; in the midaltitude,there are Acacia, Coffee, Combretum, Croton, Guizotia, Trifolium, Olea, and Vernonia and in lowlands,there are Acacia, Albizzia, Commiphora and Croton. Generally, the topography of the woreda is rugged and chain of mountain terrains. The current rain fall either begins lately or quits early before the crops are mature. The mean annual temperature of the area is recorded as 22 ^{0}C and the maximum and minimum averages are 25 ^{0}c and 7.5^{0}c respectively as information obtained from Sirinka Agricultural Research Center meteorological information. The livelihood of the people in the study areas is based on subsistence mixed farming system. Most of the sample households owned less than one hectare of land. 5,803 honeybee colonies and about 11% are in box hives (GWOARD, 2009).

Sampling Procedure and Data Collection

Out of 32 *kebeles* that the District has, about 20% has selected purposively. Before commencing data collection, preliminary survey using a checklist (pre-testing questioner) was conducted to gather information relevant for the study. Primary data were obtained from beekeeper household heads where as secondary data were taken from the District and zonal Agriculture and Rural Development Offices as well as NGOs of the District. The target sampling populations in the study District were farm households who currently own honeybee colonies in the improved hives as well as those who recently lost their honeybee colonies from their improved hives due to various reasons.

To collect qualitative and quantitative data on improved beekeeping technology usage, six rural *kebeles*from the 32*kebeles*, two from each agro-ecological zones; highland, midaltitude and lowlandwere selected. The household selection was carried out from list of farmers registered as members of the rural *kebeles* and using improved beekeeping technologies in the respective agro ecologies. A total of 120 beekeeper sample households; 40 beekeeper households from highland, 40 beekeeper households from mid altitude and 40 beekeeper households from lowland were interviewed using semi structured questioner. The study was designed to address determinant factors of using improved beekeeping technologies; such as beekeeping activities experience, apiary site location, awareness on improved beekeeping technologies, trend using improved beekeeping technologies and labor division for beekeeping. The study has also addressed areas of credit access and beekeeping extension service, honey yield of different bee hive types, marketing of hive products, honeybee ecotypes and management, availability of improved beekeeping equipments, honeybee diseases, pests and predators, honeybee flora of the study area, herbicides, insecticides and poisonous plants which all affects the usage of improved beekeeping technologies. The data were analyzed using Statistical Package for Social Science, SPSS version 12 software (SPSS, 2002) to carry out descriptive statistics on qualitative and quantitative variables on improved technology usages and productivities as well as cross tabulation.

Results and Discussion

Access to box hive accessories

According to the respondents, all box hives disseminated by BoA were 100% incomplete. About 86.7% and 84% of respondents do not have free access for casting mold and honey extractor respectively (Figure 1).In the study area both equipments were rare and the few existing ones were used in group at *wereda* level by rotating among user *kebeles*. To be effective, box (frame) hive beekeeping requires such accessories. If the casting mold is expensive, there is an option to use non embossed wax foundation sheet, which is proven to have no significant difference with embossed foundation sheet on acceptance and honey yield (Kebede and Amsalu, 2001). So, those who cannot buy casting mold can use this technology to make box hive productive. On the other hand, Kibebew (2004) has reported that local honeybees can construct fully centrifugable combs in frames with out foundation sheets, adjusting the combs cell with their body size easily. Once they have built the combs in frames, the combs should not be destroyed to harvest honey until too old to use. Comb honey production takes a toll of whatever forage is available, since the bee consumes honey for energy in order to secrete the wax (Hooper, 1997).

It was observed that foundation sheet was provided for beekeepers when they transfer honeybee colonies from traditional hives to box hives for brood chamber only. Interview results of experts coincided with the farmers' response. This is because the price of wax was high and farmers reserved to use it by buying themselves. Thus, there is no foundation sheet or smearing wax supply during supering. Such practice has decreased the acceptance of super by honeybee colonies. Similarly, HBRC (2004) recommends using frames of comb foundation, using one or more of foundation frames with drawn combs is good to attract the bees to work on the foundation more readily. The aim of using wax foundation sheet is to save time, energy, and labor required to construct wax comb so that more bees take part in foraging instead of wax secretion and comb building (Dadant and Sons, 1975).

Thus, the accessories are the barriers for using box hives. Ancillary equipment such as smoker hive tool, protective clothing; (bee veil, bee suits, leather gloves and boots) are essential for working with bees. The interviewed beekeepers have no embedder, honey strainer, honey presser, uncapping fork, and chisel. Some beekeepers have frame hives without frame wire. As stated by EARO (2000), as the impact of improved technology seems to be small because of insufficient support service, infrastructure has contributed largely to the low adoption of improved beekeeping technologies by the large number of beekeepers. WOARD and concerned organizations should participate in adequate supply of basic improved beekeeping equipments.

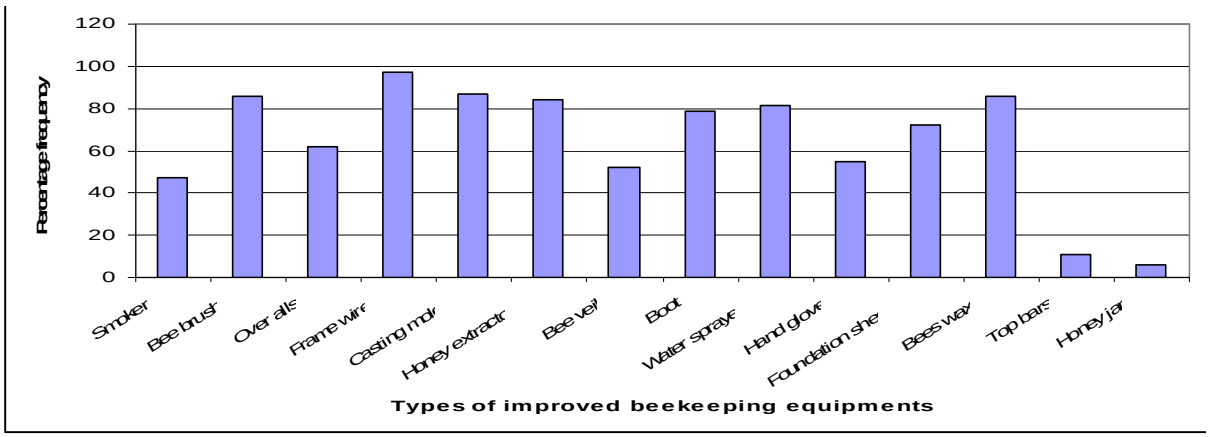

Figure 1. Deficit of % improved beekeeping equipments

They have also associated problems such as beekeeping equipments are not equally shared for improved beekeeping technology users, no supply of complete protective clothing, accessories like honey extractor, honey presser, foundation sheet, wax, queen excluder and materials such as saw and meter to make KTBH and top bars. Equipments are given in-group in different *kebeles* without considering geographical proximity, so that until to get these equipments, the harvesting period passes and bees reuse the honey. The price of improved beekeeping equipments is high to be fulfilled by farmer level and are not available in nearby local market. There is no enough and continuous refreshment training to fulfill the need of technologies for high skilled labor. After the hives have disseminated, there is no timely expertise support.

The bees wax supply is the major requirement of box hive beekeeping technology to make foundation sheet or the prepared foundation sheet should be supplied for beekeepers. The means of getting bees wax for foundation sheet to start improved hives was mostly supported by BoA office (75.2%). Only 28.3% of them have now access to foundation sheet inputs where as the rest (71.7%) have no access to foundation sheet. Out of those who get foundation sheet inputs, about 8.8% are found by themselves by purchasing or from their apiaries and the rest was provided by BoA. Because of incompleteness of frame hive package, no foundation sheet or wax supply; bees refused to go up to the supper to build combs honey is harvested by cutting combs. As a result, productivity has highly decreased. The farmers cannot even pay the hive loan from sell of bee products, some farmers have neglected the technology, and some requested to return the hive rather than paying loan.

Trend of improved beekeeping technologies usage

According to the respondents, the trend of using improved beekeeping technologies over the last 5 years was generally decreasing. About 53.3% of the total improved beekeeping technology users responded as the trend and acceptance of frame hives by other farmers and by themselves is decreasing (48.4% from lowlands, 26.6% from highlands and 25% from mid altitudes in which one beekeeping cooperative is found). On the contrary, about 43.3% beekeepers responded as improved beekeeping technology usage is increasing (42.3%from highland, 42.3%from mid altitudes, and 15.4%from lowland). The rest 3.4% responded that there is no significant difference in the trend (constant).

The reasons for increasing the number of box hive users were awareness given on productivity of frame hive by extension agents, hope on high yield if well managed and accessories are fulfilled, better protection of the colonies from pests and other enemies and practical observation of the results from first participants, who have got good quality and quantity of honey from frame hives. The frame hive is also selected for its favorability for migratory beekeeping. Whereas the reasons for decreasing the trend of improved beekeeping technology usage were low honey yield and frequent absconding of colonies from frame hives due to coldness of the hive in highland areas, drought, and high internal hive temperature by absorption of heat from cover in lowland areas, and poor technical support and incomplete package supply. Beeswax for example to make foundation sheet has only given once when the beekeepers take the frame hive from District Office Agriculture and Rural Development to transfer their colonies from different sources. Due to absence of foundation sheet supply during adding super and the presence of queen excluder, bees neglected to go up to the added super. The bees overcrowd at brood chamber and more frequently swarm than giving honey. As the result, the expected product has not been obtained and it was producing even lower than the traditional hives.

Death of honeybee colonies by pesticides and unknown reasons, attack by predators, low productivity of these hives; let the beekeepers unable to pay the loan of the hives. The respondents have also indicated that the price of the hive was unaffordable and the hive management was impractical for them. As the result, primary users of the frame hive technology have failed and told for others as the new technology was unproductive for them. This has also played a great contribution for decreasing trend of using box hive technology. The beekeepers as well as crop producers should be taught about importance of honeybees for honey production as well as crop pollination and to overcome the price effect as well as unproductiveness of box hives, increased use of transitional hives should be encouraged.

Honey harvesting and Yield

In the study area, about 80% of the sample beekeepers harvest honeyonly once, 20% twice and about 14% three timesin a year depending on the location of their apiaries: near irrigation areas, near forest and water source areas and based agro ecologies. However, harvesting technique is still very traditional. About 41.3% of the interviewed Zander hive user households collect comb honey from frame hives and 20% use no protective materials to do well on frame hives. In order to provide proper and timely extension service as well as technical support for beekeepers who share the equipments and accessories, knowing the correct time of honey harvesting is important.

The main harvesting periods of the three agro s of Gubalafto District were October to November, where October being a peak harvesting month to obtain the largest quantity and quality of honey. The harvesting periods correlate with availability of moisture and peak flowering period for many honey plants including pulse and oil crops. In highland and mid altitude agro-ecological zones, honey harvesting starts in October and ends in December. In lowland areas, honey harvesting starts in September and ends in the beginning of December, while October is a peak harvesting period.

Table 1. Productivity of different hives in different agro ecologies

		Average honey yield per year (kg)		
Agro ecology		**Traditional hive**	**Transitional hive**	**Box hive**
Dega	Mean	11.2	19.5	14.7
	SD	5.89	7.44	7.23
Weynadega	Mean	8.7	13.2	12.2
	SD	4.57	6.16	6.27
Kola	Mean	10.6	13.8	13.0
	SD	6.18	5.89	7.38
Total	Mean	10.3	16.0	13.1
	SD	5.66	7.26	6.93
	Minimum	3.0	3.0	3.0
	Maximum	30.0	32.0	40.0

Marketing of beeswax

About 39.3% of the sample respondent beekeepers (4.3% from Dega, 11.1% from Weynadega and 23.9% from Kola) do not know that beeswax was a salable product. Consequently, they cut and throw empty combs or chewed wax obtained from different hives or give for their dogs. The major reason was lack of knowledge about its uses and absence of demand for wax in the local market (32.5%). Recently the beekeeping cooperatives are providing awareness on the value of beeswax for farmers. They have started to undertake semi-processing of honey (separate honey from wax) before sale. Generally, the attempt of the cooperatives in processing of honey and beeswax is a good start in value adding as well as creating awareness for beekeepers to collect the wax, which is useful for frame hive foundation.

Challenges

High price for equipments: The beekeeping equipments are expensive relative to the purchasing power of the beekeepers. A single box hive is about 1560 birr with its full internal materials.

Lack of good beekeeping management knowledge: Beekeepers lack knowledge about feeding and foraging behavior of honeybees, feeding, and watering of colonies at dearth periods, and harvesting of beeswax and use it as input for the foundation sheet making. \

Limited cultivated bee forage: - About 36.3% of respondent beekeepers practice planting some locally selected honeybee forage species; however, the rest 63.3% do not practice planting be forages around apiaries. There are no recommended honeybee forages in the study area. Thus, there is lack of attention to introduce potential honeybee forages.

Marketing of extracted / strained honey: The pure extracted honey from box hive or strained honey from transitional hive in the market is seen as sugar adulterated and resulted ultimate blame and loss of credibility of beekeepers.

Opportunities

Though there are many challenges in the study area, there is still huge potential to increase honey production using improved beekeeping technologies to improve the livelihood of the beekeepers. Thus, the major opportunities are:

Beekeeping training: over 88.3% of the respondents have participated in simple beekeeping trainings. If problems are identified and training is organized on those issues, beekeepers in the study area will be well benefited.

Bee flora: The *Woreda* has diversified Acacia and shrubspecies and there are also different kinds of forage trees (*Wanza (Cordiaafricana)*, *Girawa(Vernoniaamygdalina)*, Eucalyptus, cactus, coffee and cultivated pulse and oil crops) which flower at differenttimes of the year that assures a constant supply of feed for bees. However, since such plants, which flower at dry season, are small, there is feed shortage at dry season. There is also enough supply of water. The *Wereda* has 13,231 hectare of land covered with forests shrubs and bushes, which are potential bee floras of the study area.

Access to road: the *wereda* has public transport road access in all of the three directions to Addis Ababa, and other regional capital cities: Bahir Dar, Mekele, and others.

Experience of beekeepers: 83.4% of interviewed beekeepers have long traditional experience greater than five years with maximum of on beekeeping. This can help extension and development agents to achieve the required objectives with less effort.

Proximity to research center: The *wereda* is in the mandate area of Sirinka Agricultural Research Center (SARC) and SARC can assist and facilitate improved beekeeping technology usages and identification of major beekeeping challenges.

Rainfall distribution: The rainfall distribution of the area is bimodal and this helps natural plants or crops to flower two times a year relative to those, which has one long unimodal rainfall.

Access to market and high market demand for honey and honeybee colonies.

Encouraging policy of improved beekeeping

Conclusion and Recommendations

Even though there are adequate natural endowments and a long tradition and culture of beekeeping practices in the study area (mainly because of lack of proper technological inputs, trained manpower and different bee enemies) the beekeeper households have not been sufficiently benefited from the sub sector. Yet, despite all the challenges currently facing the beekeeping sub sector, there is still enormous opportunities and potentials to boost the production and quality of hive products specially honey in the area. There is availability of natural honeybee flora from forest and shrub covered areas as well as cultivated crops at biannual rainy seasons.

The Zander frame hives should be provided with its full packages and availing all the required accessories; the queen excluder should be inserted on recommended time scale and better to use plastic queen excluder than aluminum queen excluder. The aluminum queen excluder has an effect of damaging the wings of honeybees. The top bars for transitional hive should be provided to produce these.

Establishing on farm demonstration site and supporting with sufficient and regular training programs for farmers about beekeeping management (feeding, watering, inspection, transferring, supering, multiplying, honey and wax harvesting and handling, bee forage gardening) and providing necessary technical supports, since majority beekeepers have not participated on improved beekeeping demonstration.

To sustain improved beekeeping technology, local crafts men manufacturing top bars specified top bar hives, swarm boxes, protective, veils, smokers, queen cages and other equipments should be facilitated and trained in addition to training beekeepers and giving loan to start their own hives.

The beekeeping experts at District should get proper training on beekeeping management to provide appropriate training and technical assistance for development agents at grassroots level.

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Evaluation of Adaptability and Yield of Different Strains of Eri Silkworms / *Samia cynthia ricini B.*

Kedir Shifa[1], Metasebia Terefe[1], Ahmed Ibrahim[1], Abiy Tilahun[1], Kassa Biratu[2], Samuel Menbere[3].
[1]Ethiopian Institute of Agricultural Research Center, Melkassa Agricultural Research Center, P.O. Box-436, Melkassa, Ethiopia. [2] Jimma Agricultural Research Center, Wondogenet Agricultural Research Center

Abstract

*Eri silkworms, Samia cynthia ricini B.**,** is one of the silkworm races under utilization in Ethiopia. However, it has several strains with wide variation in their commercial traits and selection and utilization of best suited strains of this eri silkworm race that adapt to different agro-ecologies will help to increase silk productivity and profitability. In this experiment, one Vietnamese (Eri-3.4) and three Indian (Eri-yellow, Eri-green and Eri-marked) eri silkworm strains were evaluated in different locations (Melkassa, Hawassa, Wondo-Genet and Jimma) which represents different agro-ecologies of Ethiopia. The experiment was laid out in Completely Randomized Design (CRD) in six replications. Thus, different silkworm strains showed statistical significant silkworm characteristic ranges in different locations which include egg hatchability (62.61% to 89.00%), larval duration (20.67days to 25.83 days), total life cycle duration (50.49 days to 74.00 days), single weight of larva (4.427 grams to 8.155 grams), effective rate of rearing (60.11% to 93.67%), single cocoon weight (1.848 grams to 2.903 grams), single shell weight (0.251 grams to 0.418 grams) and silk ratio (13.06 to 15.05%). However, a Vietnamese eri silkworm strain known by Eri-3.4 have showed an outstanding performance compared to other strains in all the locations especially in cocoon parameters. Therefore, it is recommended for future research and development efforts on eri silkworms in Ethiopia.*

***Key words**: Eri silkworm, strains, races, performance, agro-ecologies*

Introduction

Silk is a functional term used to describe protein fibers that are secreted by arthropods. It is a natural protein fiber and is very soft, lustrous, smooth, strong and durable (Chowdhury, 2006). The practice of silk production involves diverse activities from the cultivation of host plants to silk processing, which engage people of all spectrums. Further, the by-products also find uses ranging from fertilizers in rural areas to pharmaceutical industries which could be tapped to increase income of the farmers and other societal groups in the long term (Legay, 1958; and Sannappa et al., 2004). Silk production has the potential to make a significant contribution to the economy of many countries where there is surplus labor, low-costs of production and a willingness to adopt new technologies (Hajare *et al.*, 2007).

Silk has strong affinity to the people of Ethiopia starting from ancient period of country's civilization. However, the silk yarns used were imported from India, Arabia and China (Spring and Hudson, 2002). Currently, Ethiopian is the second populous country in Africa. There is a general trend of increasing unemployment. Therefore, sericulture, an agro based labour intensive and environment friendly cottage industry, can become an efficient and effective agricultural endeavor for the country. The business holds a

ray of hope at village level for Ethiopian citizen migrating to cities searching for jobs (Kedir *et al*., 2014). As a result, silk production from eri silkworm is practiced bits in bits in different parts of the country especially by poor farmers as an additional income source through efficient use of family labor (Metaferia *et al*., 2006).

Eri-silkworm, *S. c. ricini*, is one of the most exploited, domesticated and commercialized non mulberry silkworms. It has many generations per year and feeds on several host plant species (Singh and Das, 2006; Chakravorty and Neog, 2006; Bindroo *et al.* 2007). It is a domesticated silkworm and can be reared in doors (Joshi, 1992). It feeds on several host plants. Among all host plants, castor (*Ricinus communis* L.) is the most preferred host plant for eri-silkworm (Sannappa *et al*., 2004; Kumar and Elangovan, 2010). Moreover, about 25-40% of castor foliage can be defoliated (removed) and used for feeding eri-silkworm without affecting oil seed production (Raghavaiah, 2003). Castor grows widely and abundantly in many parts of Ethiopia. In addition to cultivated castor on cultivable lands, it is also found wild in waste places, fallow fields, along road sides, farm borders and irrigation canals among others. It is dominantly used for oil seed production; however, it is also used for rearing of eri-silkworms especially in the rift valley areas and southern region of Ethiopia (Metaferia *et al*., 2006).

However, rearing of improved silkworm strains that adapt to the local environment is an important method for improving cocoon quality, increasing cocoon yield and enhancing economic benefit (Nguku *et al*, 2009). Differences in climatic conditions of different agro-ecological regions, including the significant distinctions in temperature, humidity and the significantly different silkworm-rearing environment in different seasons, require that the silkworm variety should be both high yielder and adversity resistant (Basavaraja *et al*, 2005). An extensive study has been made in India on performance of eri-silkworm starins. Priyanki and Jorgen (2013) carried out a comparative study on eri silkworm strains and have got significant variation in morphological and productivity parameters among strains. Debraj *et al.* (2001) stated phenotypic diversity and characterization of strains of eri silk worm will be useful for selection of breeding components for developing high silk productive breeds of silk worm. Hence, it can be recognized that evaluation of eri silkworm strains is an important beginning for future breeding and improvement efforts and for sericulture inclusive development endeavors. However, the differential performance of eri-silkworm strains has not been researched and documented in Ethiopia. There was no recommended silkworm strain for silk production in the country. As a result, this experiment was initiated with an objective to introduce and evaluate different eri silkworm strains for adaptability and silk yield in Ethiopia.

Materials and Methods

Description of the study area

The experiment was conducted at Melkassa, Hawassa, Wondogenet and Jimma Agricultural Research Centers (ARCs) of Ethiopia. These locations represent some of the agro-ecologies of the country assumed suitable for silkworm development and productivity.

Lay out and rearing

As per the rearing recommendations of silkworms by Rajan and Himantharaj (2005), the silkworm rearing room and equipments were cleaned, washed and disinfected with 2% formalin solution at the rate of 800ml per $10m^2$ before the commencement of the experiment (rearing). Different eri silkworm strains viz… Eri-3.4 /Vietnamese White plain strain named 3.4/, Eri-Yellow /Indian Yellowish White Plain/, Eri-green /Indian Greenish Blue Plain/ and Eri-marked /Indian White Zebra/ were used as treatments for the experiment. The experiment was designed in a Completely Randomized Design (CRD) and the treatments were replicated four times. In each replication, 200 worms were used and allowed to complete their life cycle. The primary food plant, castor (*Ricinus communis L.*), was used as feed source for these silkworms. Tender leaves of castor were fed four times a day until the larvae ends II instar stage and semi tender leaves to III instar larvae, while more matured leaves were fed to IV and V instar larvae.

Data Collection and Analysis

As adopted by Kedir *et al.* (2014), egg count was made larval hatching. On the sixth day of spinning, the cocoons were harvested, counted and weighed. Data like larval and total life cycle duration (in days) and mature larval weight (in grams) were recorded. The cocoon weight (with pupa) and cocoon shell weight (without pupa) were documented. The following formulae were used for analysis of egg hatchability (%), effective rate of rearing (ERR %) and silk shell ratio (%) calculations.

$$Egg\ hatchability\ to\ larva = \frac{Number\ of\ normal\ eggs - Number\ of\ nonhatched\ eggs}{Number\ of\ normal\ eggs}$$

$$Shell\ ratio - \frac{weight\ of\ the\ cocoon\ shell}{weight\ of\ the\ whole\ cocoon} x\ 100$$

$$ERR = \frac{Number\ of\ cocoon\ yield}{Number\ of\ larvae\ brushed} x100$$

Finally, data were analyzed using SAS software at 5% level of significance (SAS, 2000). Significant means (p<0.05) were separated using Least Significant Difference (LSD).

Results and Discussion

Experimental findings of the present study depicted variations in respect of growth and cocoon characters of eri silkworm strains, *Samia cynthia ricini*. Data on growth, rearing performance and cocoon traits of eri silkworm strains *viz*., egg hatchability (%), larval and total life cycle durations (days), larval weight (g), effective rate of rearing (%), cocoon weight (g), shell weight (g) and shell ratio (%) of different strains are depicted below.

Egg Hatchability

Egg hatchability of eri silkworm strains to larval stage was ranging from 62.608% to 89.0%. Statistically significant variation in egg hatchability among eri silkworm strains was observed only in Melkassa area.

In Melkassa, Eri-3.4 race showed higher egg hatchability (75.665 %) followed by Eri-Yellow (72.998 %) and Eri-Green (71.330 %). The least egg hatchability was recorded on Eri-Marked strain (62.608 %).

Table 1: Variations in egg hatchability among eri-silkworm strains

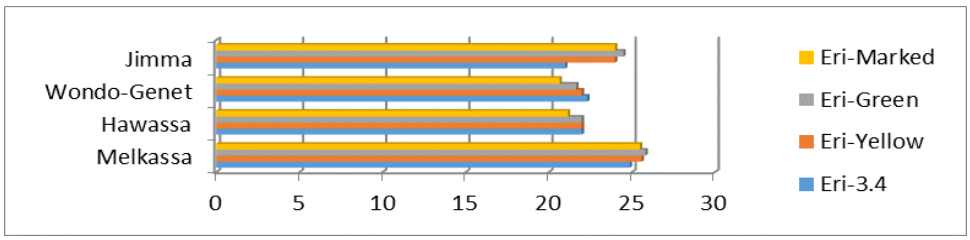
Treatment	Melkassa	Hawassa	Wondo-Genet	Jimma
Eri-3.4	75.665 [a]	80.000 [a]	82.333 [a]	82.000 [a]
Eri-Yellow	72.998 [ba]	77.333 [a]	83.223 [a]	85.500 [a]
Eri-Green	71.330 [b]	79.833 [a]	83.447 [a]	82.500 [a]
Eri-Marked	62.608 [c]	79.000 [a]	80.667 [a]	89.000 [a]
Pr	<.0001	0.1839	0.7318	0.3169
CV	3.9567	1.862258	4.007033	5.612477

Means followed by the same letter within a column are not significantly different from each other at 5% level of probability.

Larval and total life cycle duration

Larval duration was ranging from 20.667 days to 25.833 days in general. Larval duration of eri-silkworm strains showed significant difference only in Jimma area. However, there was no significant difference in other locations. In Jimma, the shortest larval period was noticed in Eri-3.4 strain /21.0 days/ compared to other strains. On the other hand, duration of the total life cycle was generally ranging from 50.487 days to 74.0 days. However, statistically significant total life cycle duration was recorded only in Hawassa area where Eri-Green strain exhibited the shortest stage of 56.5 days.

a) Larval duration (in days)



b) Duration of the total life cycle (in days)

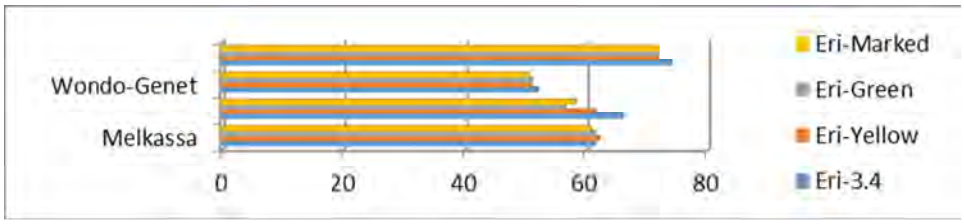


Fig. 1. Larval (top) and total life cycle (bottom) (in days) duration of different eri-silkworm strains

ERR (%): The experiment revealed a general range of ERR (Effective Rate of Rearing) from 60.111% to 93.667%. Eri silkworm strains showed significantly variable ERR in all locations except Wondo-Genet

area. Among the strains, Eri-3.4 strain revealed the highest ERR in all locations. The lowest ERR was seen from Eri-marked strain in Jimma area.

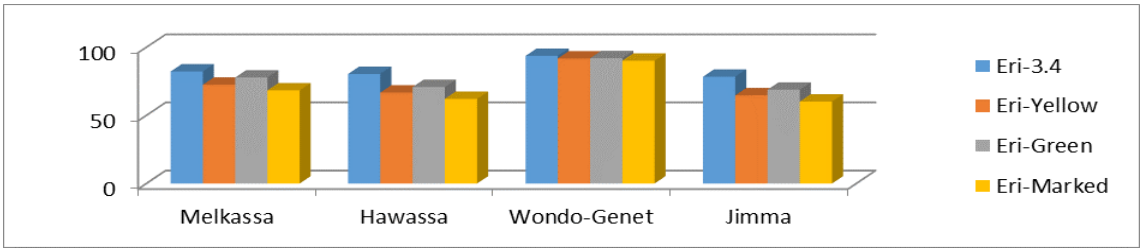


Fig. 1. Variability of different eri silkworm strains in effective rate of rearing

Matured Larval Weight

Weight of a single matured silkworm larva was significantly different among eri silkworm strains in all locations. However, there was no significant variability among strains in Jimma area. The experimental findings revealed that larval weight was significantly highest in Eri-3.4 strain in Melkassa (7.606 g). This strain also depicted higher larval weight in Hawassa and Wongo-Genet areas compared to other strains. The least record of larval weight was obtained from Eri-Yellow strain (4.636 g) in Hawassa area.

Table 2: Variations in larval weight (in grams) of different eri silkworm strains

Treatment	Melkassa	Hawassa	Wondo-Genet	Jimma
Eri-3.4	7.6062 [a]	7.1333 [a]	5.38333 [a]	6.6083 [a]
Eri-Yellow	8.1548 [a]	4.6367 [b]	5.35567 [b]	7.1617 [a]
Eri-Green	6.4076 [b]	5.1250 [b]	5.38900 [ba]	7.2800 [a]
Eri-Marked	6.2545 [b]	5.4983 [b]	5.12667 [c]	7.0433 [a]
Pr	0.0004	0.0009	0.0046	0.3084
CV	10.246	8.266093	2.215526	6.078834

Means followed by the same letter within a column are not significantly different from each other at 5% level of probability

Cocoon Traits

With respect to cocoon traits, maximum and significantly different single cocoon weight was recorded from Eri-3.4 strain in Melkassa (2.639 g). The lowest cocoon weight (1.848 g) was obtained from Eri-Yellow strain in Hawassa. In addition, eri silkworm strains showed variation in their single cocoon shell weight in different locations. The highest was 0.418 g from Eri-Green strain in Jimma but the lowest was 0.251 g from Eri-Yellow strain in Hawassa. However, the shell ratio which will indicate the quantity of silk that can be spun from cocoons was no significantly different among eri silkworm strains in all the locations (Table 3).

In general, the different silkworm strains showed variations in silkworm characters at $p<0.05$ in different locations which include egg hatchability (62.61% to 89.00%), larval duration (20.67days to 25.83 days), total life cycle duration (50.49 days to 74.00 days), single weight of larva (4.427 grams to 8.155 grams),

effective rate of rearing (60.11% to 93.67%), single cocoon weight (1.848 grams to 2.903 grams), single shell weight (0.251 grams to 0.418 grams) and silk ratio (13.06 to 15.05%). Similar findings carried out by Priyanki and Jogen (2013) confirms such differences among eri silkworm strains. In addition, Singh *et al.*, 2011 carried out study on morphological characters of eco races and six strains of eri silk worm and find out their rearing performance variations but they recommended Yellow Zebra as the best strain in terms of rearing performance, which is not introduced to Ethiopia until today. These differences are justifiable in that rearing performance of silkworms is affected by ecological, biochemical, physiological and quantitative characters, which influence growth and development, quantity and quality of silk they produce in different geographical locations (Virk *et al*, 2011; Anandakumar and Michael, 2012; and Reddy *et al*, 2012). Majorly, the ability of silkworms to produce is affected by temperature and humidity, as verified by the silkworms reared in the all locations. In addition, it has been well established that efficiency in silkworm production is often lower during and after the hot season. One reason for the reduction in their productive performance in some locations might be elevated ambient temperatures, which induce heat stress (Scriber and Slansky, 1981). Moreover, the nutritive value of leaves especially the moisture content may also vary to contribute to variability in performance and productivity of silkworm strains at different agro-ecological zones (Jayaramiah and Sannappa, 1998).

Table 3: Differences in cocoon traits among eri silkworm strains

Treatments	Melkassa			Hawassa			Wondo-Genet			Jimma		
	Single cocoon weight (gram)	Single shell weight (gram)	Silk ratio (%)	Single cocoon weight (gram)	Single shell weight (gram)	Silk ratio (%)	Single cocoon weight (gram)	Single shell weight (gram)	Silk ratio (%)	Single cocoon weight (gram)	Single shell weight (gram)	Silk ratio (%)
Eri-3.4	2.6389[a]	0.3721[a]	14.106[a]	2.335[a]	0.3185[a]	13.649[a]	2.6420[a]	0.3890[a]	14.719[ba]	2.569[b]	0.3393[b]	13.2260 [a]
Eri-Yellow	2.4074[b]	0.3334[b]	13.855[a]	1.848[b]	0.2507[b]	13.569[a]	2.5400[b]	0.3823[a]	15.048[a]	2.903[a]	0.3840[ba]	13.2213 [a]
Eri-Green	2.4381b	0.3362b	13.796a	2.061b	0.2685ba	13.055a	2.3443c	0.3243b	13.839b	2.893ba	0.4180a	14.4097 a
Eri-Marked	2.4804[ba]	0.3471[b]	13.999[a]	2.055[b]	0.2869[ba]	13.867[a]	2.2590[c]	0.3343[b]	14.819[ba]	2.813[ba]	0.3907[ba]	13.8987 [a]
Pr	0.0314	0.0123	0.7329	0.0156	0.1606	0.8327	<.0001	0.0001	0.0952	0.1475	0.1498	0.3306
CV	5.3318	5.7475	3.7585	6.5508	11.9039	8.1940	1.9443	3.0062	3.6280	6.2720	9.6453	6.3205

Means followed by the same letter within a column are not significantly different from each other at 5% level of probability

Conclusion and Recommendations

In the experimental findings of the study, the different eri silkworm strains exhibited important variability among themselves in different locations. Thus, identification of eri silkworm strains that adapt to multiple agro-climatic conditions or diversities and of high yielding ones is confirmed to be very essential practice for future involvements.

From the study, A Vietnamese white plain eri silkworm strains known by Eri-3.4 have showed an outstanding performance compared to other strains in all the locations especially in cocoon parameters and effective rate of rearing. These parameters are very important in respect to commercial terms. The race was also at par or close to equivalence level with other strains in other silkworm performance parameters. Therefore, this study revealed a Vietnamese white plain eri silkworm strain known by Eri-3.4 as the best strain in terms of growth and cocoon characters. As a result, it is now recommended to be reared in bulk and to be utilized for research and development efforts on eri silkworms in Ethiopia. On the other hand, a single cocoon weight up to 2.90 grams that was recorded from the present study is lower compared to the recent findings of Priyanki and Jogen (2013) who achieved up to 3.83 grams from improved strains. Therfore, further reserach and improvement works needs to be carried out on eri silkworm strains to compete at international levels.

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Assesment of Pre Slaughter Hide and Skin Quality Management in Asela and Sagure Towns: East Arsi, Oromia Regional State, Ethiopia

Abainesh Jarso Mojo

Abstract

The study was conducted in Tiyo and Tijo /digeluweredas, Arsi zone, Oromia regional state on pre slaughter hide and skin quality management. 10 kebeles from each woredas was selected randomly and number of farmer in each kebeles was taken proportionally.100 households from each woredas were interviewed and animals belongs to each house hold were observed for hide and skin defect. In addition to this, all butchery and 20 middle men from both woredas were interviewed for about handling practice of the animal. Visual observation was also carried out on 25% of existing intensive and semi intensive farm in both woreda of study. Key informant on agricultural office of the zone and woreda was also interviewed to cross check the data obtained from all sources. Collected data were put in SPSS version 20 soft ware for analyze. As result of this study indicate majority of house hold interviewed 72.5% use hide and skin to make utensil while 66% use as source of cash income. On the other hand the major mechanical and pathological factors affecting hide and skin quality in study area were identified. Of mechanical damage horn rake, whip lash, thorny plant and branding were mentioned by farmer and they account (40.6%), (38.9%), (17.7%) and (2.8%) respectively. Ectoparacite and skin disease like sheep pox, nodule, swelling, and alopecia were also found and they account about (56%), (12.6 %), (12%), (9.7%) and (8.6%) respectively. Almost all the variables had not significant difference except horn rake which was more serious in Tiyo woreda. Both middle men and butchery interviewed mention horn rake as major factors affecting animal along transportation rout. In addition to these each and every animal belongs to farmer was observed, most of them have pure hide and skin. Of 1677 cattle and 981 sheep under observation, 123(7.33%) cattle and 16(1.63) sheep were affected by mechanical damage. While 64(%) and 15(%) show sign of skin disease.

Key words: *hide, pre-slaughter, quality, skin, management*

Introduction

Hides and skins are important livestock products providing income for the poor people living in the rural areas of Ethiopia. They are supplied to domestic and foreign markets. Since they have significant economic importance, much effort is needed to improve the quality and increase the quantity so that there will be effective and efficient utilization. Hides and skins are meat by-products and there is still little consideration given to the care required for the collection and processing of the hides and skins in to high quality leather (adugna, 2004). The pre-slaughter operations that affect the quality of the hides and skins available to the tanning industry are principally the result of the quality of the husbandry applied by those who looked after the animals-herders, farmers, ranchers, feedlot staff, veterinarians, hides and skins merchants and transport operators (Abdi, 2000). Limited studies were conducted regarding the extension and quality of the byproducts. However, there is no detail study on pre slaughter management raw materials. Of all the constraints (problems) hindering development of the leather sector, the low quality of basic raw materials is the pressing issue in need of an immediate solution. The study is important to

smallholder farmers, animals-herders, veterinarians, transport operators, butchers and live stock trader to enable them reduces damage of hide and skin before the animal is slaughtered. It also contributes to better understanding of the quality of livestock by products (hide and skin) and its effect on the quality of end product. Hence, the research findings will inform the government to give training for animals-herders, farmers, rancher, veterinarians, butchers and transport operators how to reduce pre-slaughter damage of hide and skin like branding, scratch and tearing, deferent ectoparacite infestation, several pathological disease, nutrition deficiency that seriously damage hide and skin quality with the objectives of assessing pre slaughter factors affecting the quality of skin and hide and indicate possible measures in the study area.

Material and Methods

Study Area

The study was done in two districts namely ***Tiyo*** and ***Tijo and Digelu*** found in the Eastern Arsi zone, Oromia region. The great majority of farmers are smallholder livestock keepers in traditional husbandry system (Agricultural office of the zone). Overall zebus are the main cattle breed with crosses making up to 14% of the cattle population.

Study Design and Population

Cross sectional study design were employed to assess pre-slaughter factors affecting quality of hides and skins and ante mortem hides and skin management methods around the study area. The study populations were smallholder farmers and farm holders found in and around Asela and sagure town, middle men and butchery and key informant in both wereda of study and study units were randomly selected households and middle men, farm holders, all butchery men and key informant.

Questioner and personal observation were used to collect primary data. The questionnaire generally includes data on animal feeding, management, identification, transportation, perception of respondents on the value and quality of hide and skin. Observations were made on any pre slaughter factor affecting hide and skin quality, and housing of animals. Data collection sites were households, middle men, butchers and intensive or semi-intensive farms. For the households, five Peasant kebels (four from rural and one from town) from each Woreda were randomly selected from the list provided by Woreda Offices.The list of households from each selected kebele was obtained from woreda office. The number of house hold in each kebele was taken by proportion depending on number of house hold in each kebele and households to be interviewed were taken randomly. A total of 100 respondents were selected from each Woreda. The sample size was determined by using the formula recommended by

Ashra (2007) for formal survey studies as follows:
Sample size formula=
$N = 0.25/SE^2 = 100$
Where N=sample size
SE= standard error
Assuming the standard error of 5% at a precision level of .0.05 and the confidence interval of 95%.

On the other hand, 25% of all intensive or semi intensive farms were visited within each selected woredas. Moreover, cattle corresponding to each farmer and farm holder were observed for any skin/hide defects affecting their quality. All butchers found in each woreda and some live stock trades were also interviewed. Appropriate data was collected from individual farmers and stored in Microsoft Excel spread sheet. Data analysis was carried out by using SPSS 20 software. Descriptive statistics such as mean and percentage and standard deviation were used to present the results.

Results and Discussion

Livestock holding

The livestock herd in the studied households was composed of local cattle (53.8%), cross breed (9.36%) and sheep (36.9%). As indicated in Table 1, the overall mean and standard deviation of livestock holding per household was for local cattle (6.38 ±4.822), sheep 4.05± 5.372) cross cattle 1.04 1.556%). Cattle holding was significantly higher in Tiyo woreda in which Assela town is located than in Tijo and Digelu Woreda which is 25km away from Assela town (P<0.05).

Table 1: Mean ruminant livestock holding/100 sampled households in each Woreda

Livestock species	Study location			
	Tiyo	**Tijo and digelu**	**Over all**	**(%)**
Local breed cattle*				
N	597	831	1428	53.8
Mean ±SD	6.38±4.822	8.31±4.817	7.345±4.8195	
Sheep				
N	405	576	981	36.9
Mean ±SD	4.05±5.372	6.26±5.808	5.155±5.59	
Crossbreed cattle				
N	104	145	249	9.36
Mean ±SD	1.04±1.556	1.45±1.648	1.245±1.602	

*= Means show significant difference in the two woredas, n= total livestock (for each species) SD= standard deviation

Purpose of Keeping Livestock and Advantage of Hide and Skin in Study area

According to the respondents, cattle were kept to fulfill multipurpose functions. These include milk, drought power and cash income and also as sign of wealth. The majority (96%) of the households in Tijo and Digelu woreda keep ruminant for milk production, while some of them 80% kept for draught power and cash income, only few of them 29% responded to keep livestock as sign of wealth. Also, in Tiyo most farmers 85% keep ruminant for milk production which is followed by drought power 72% and cash income 71%. There is no significant difference (P>0.05) in the purpose of keeping ruminant livestock between the two woredas. Moreover, the importance of hide and skin is appreciated almost similarly by respondents from both sites. 73.3% and 80.8% of both cattle and sheep owners rank hide as more important than sheep skin in Tiyo and Tijo and Digelu woredas respectively. Most (72.5%) farmers interviewed use hide and skin to make utensils while 66% of them use them for cash income (Table 3). On the other hand, most respondents use cattle hide at home for different purpose such as for making

utensils like ‘kurbet’, ‘wenber’ and also to cover different hand tools than sheep skin. In addition to these, culturally people who have many locally modified sheepskins at their home are seen as rich.

Table3. Relative importance and use of hide and skin in the study areas

Use of hide and skin	Tiyo N=100	Tijo and Digelu N=100	Over all N=200
1. Make utensil	67	78	145
2. Cash income	59	73	132
3. Not so important	8	5	13

Pre slaughter Factors Affecting Hide and Skin Quality

Based on the findings of the assessment, Respondents ascertained that ectoparasite (56%) was a major pre-slaughter factor affecting hide and skin quality which was followed by horn rake (40.6%) and whip lash (38.9%). The effect of thorny plant, skin lesions like nodules, small pox, alopecia, swelling and branding occupied (17.7%), (12%), (12.6%), (9.7%) ,(8.6%) and (2.8%), respectively (Tables 4.1-4.2 and Annex1) . Almost all the variables had not significant difference except horn rake which show significance different (P>0.05) among the woredas. In both woredas of the study, ticks were the major problem mentioned by the farmer. Mite and lice was also seen rarely. Most farmers said that a plant called ‘sindedo’ was major source of tick and it was seasonal because it was seen during rainy season than dry season. Horn rake was a major mechanical factor affecting hide and skin quality. According to the respondents, horn rakes as a result of fighting between animas (Figure 1) occur commonly during grazing as in most instances large animals are tethered individually at night. In the rural part of study site, oxen and bull were used for drought power like ploughing. At this time, most farmers beat oxen on their shoulder and cause rope marks or whip lash called ‘sember’ by Amharic, which ultimately changes to permanent wound gradually.

Table 4. Pre slaughter factors affecting hide and skin quality (manmade or associated factors)

Mechanical factors	Tiyo N=91	Tijo and digelu N=84	Over all N=175
Horn rake	42(46.1%)	29(34.5%)	71(40.6%)
Thorny plant	18(19.8%)	13(15.5%)	31(17.7%)
Branding	2(2.2%)	3(3.6%)	5(2.8%)
whip lash	29(31.9%)	39(46.4%)	68(38.9%)

Table 5 Pre slaughter factors affecting hide and skin quality (skin diseases or associated lesions)

Skin diseases	Tiyo N=91	Tijo and digelu N=84	Over all N=175
Ectoparacit	48(52.7%)	50(59.5)	
Swelling	8(8.8%)	7(8.4%)	15(8.6%)
Nodule	12(13.2%)	9(10.7%)	21(12%)
Sheep pox	12(13.2%)	12(14.3%)	24(13.7%)
Alopecia	11(12.1%)	6(7.1%)	17(9.7%)

Figure1. Severe horn rakes on cattle

Moreover, thorny plants such as (Echinocactus plantycanthus) “kulkal” (Figure 2) are responsible for causing damage to skin and hides. It has two species, the first one has no thorn, but it produces white latex that can affect animal hide and skin by gluing the hairs to the skin and hardening. The second one has thorn which causes scratches and wounds. Most of farmer use this plant as a fence around their homes and farm yards.

Branding was also another factor affecting hide and skin quality (Figure 3). But very few farmers practice it on cattle for different purpose like disease treatment, herd identification and to check whether the animal is properly castrated or not and for each purpose they brand on different part of body. The zonal agricultural office reported that branding on the neck region has been allowed by animal heath extension workers and veterinarians to treat some diseases that cause smelling on that part of the body.

Figure 2: Branding on the different parts of the animal practiced in the study area

Other Pre-slaughter Factors Affecting Hide and Skin Quality

Most farmers (43%) confine their animals in the house during night time with smooth earth floor (figure 4B) while 24% keep them in the house with earth floor done made with stones (Figure 4A). In contrast to this, some farmer leave their animals outside in a simple fenced pen (Table 6). Most of farmer 74% confined large ruminant and small ruminant independently, while 26% of them keep the two species together in one pen.

Table 6: Animal housing practice during night time

Housing during the night	Tiyo	Tijo and digelu	Over all	
	N=100	N=100	N=200	%
In house with stony floor	20	28	48	24.0
In house with smooth earth floor	48	38	86	43.0
In house with rough earth floor	11	7	18	9.0
In fenced pen with rough earth floor	15	18	33	16.5
Fenced pen with smooth earth floor	0	2	2.0	1.0
Unfenced plot with rough earth floor	6	7	13	6.5

Figure 4: different type of housing system

Production system and type of feed

Of the ten kebeles included in the study, eight of them were from rural areas; in General extensive production system was the common production system found 88% and the rest reported a semi-intensive system especially in towns. Crop residue (87%) and free grazing (79%) were the dominant feed sources in the study sites. Barley straw, wheat straw and grass forage were provided for animals. In addition to this few of them (20.5%) fed homemade alcohol distillation byproduct called 'atela' and concentrate. Concentrate supplementation was limited in the town sites only. Most (63%) farmers in Tijo and Digelu woreda and 36% of interviewed farmers from Tiyo woreda reported feed shortages during dry season. At this time, most of animals show signs of emaciation and are more exposed to different diseases such as ectoparacitism. In areas where water is available during the dry season, the quality of the water become poor and farmers believed that this predisposes them to diseases although the impact of water shortage on hide and skin quality is not known by the farmers.

Pre-slaughter hide and skin problem management practices

Majority of farmers (82%) interviewed have ascertained that they get veterinary services in their closest proximity. Moreover, 47.45% of the farmers practice treating their animals by buying medicines from pharmacy while 37.3% of them treat their animals at nearby veterinary service station and 21.18% use traditional type of treatment. Despite the presence of veterinary services, no extension agent working on pre-slaughter hides and skin quality management as a focus area exists. So, farmers do not get any advice about feeding, housing system and general management system rather than their own indigenous knowledge. Contrary to this opinion of farmers, key informants interviewed in the Woreda Agricultural offices argue that farmers are getting advices or consultations on Pre-slaughter hide and skin quality management

Table7: Place where farmer treat their animal

	Woreda					
Where do treat diseased animal	**Tiyo**		**Tijo and digelu**		**Total**	
	N=60	**%**	**N=58**	**%**	**N=118**	**%**
Vet clinic	24	40	13	22.4	37	31.4
Buy medicine and treat my self	27	45	29	50	56	47.5
Usetraditional treatment	9	15	16	27.6	25	

Other management practices

In the study area, farmer treat animals affected by tick by buying medicine from pharmacy and spray on their body and some of them treat traditionally in their home by adding 'kerosene' on affected part. Farmer thought that though the effect of ectoparacite is low, it reduces animal productivity if it is around teat and reduce animal work power if on their leg. No one took animal to veterinary station for ectoparacites except for other skin problems.

Dehorning is not a practice in the study areas. So, most farmer manage horn rake by tethering each animal individually and by culling aggressive animal from the herd.

Observations on Skin lesions and Wounds affecting Hide and Skin Quality

All ruminant livestock owned by the 200 interviewed study participants were e xamined for the presence of skin problems. Of the total 1677 cattle and 981 sheep under observation, 123 (7.3%) cattle and 16 sheep (1.6%) were found to have been affected by mechanical factors on their skins (Table 6). Among the animals with mechanical damages on their skin, contamination with dirt and horn rake is the major problems. The major problems identified on skin of sheep were dirty hair coat (81.25%) and wounds of unidentified causes (18.75%) among sheep identified with skin problems. In addition to these, gross lesions as sign of skin diseases were observed on 64 cattle (3.8%) and 15 sheep (1.5%). Among animals identified with skin disease problems, scab, nodule and ulcers were the dominant problems in cattle whereas scab, ulcer and sheep pox were common in sheep.

Table7: Maltreatment and skin disease indicators observed on animal

Skin problem indicators	**Animal species**			
	Cattle		Sheep	
	N	%	N	%
Mal treatment indicator				
Horn rake	30	24.4	_	
Rope mark	15	12.19	_	
Yoke mark	10	8.13	_	
Branding	3	2.40	_	
Wound	17	13.80	3	18.75
Dirt and contamination	48	39.00	13	81.25
Disease indicators				
Scab	24	37.50	6	40.00
Ulcer	15	23.40	4	26.70
Nodule	17	26.60	2	13.30
Sheep pox			3	20.00
Alopecia	8	12.5	_	_

Butchers animal Handling Practice vis-à-vis Hide and Skin Quality

Of the 48 butchers interviewed, 79.2% slaughter cattle and 18.8% slaughter sheep. The sources of animal for most of butcheries were local market 93.8%. They buy either from market of the same woreda or any market of the zone. Where ever the source of animal, they transport them up to slaughter house on foot. So, it may take days to arrive from their source to slaughter house. Most butchers (60.4%) select animals with good look and smooth skin for slaughter. One of their reasons was to sell the hide and skin to hide and skin collectors/traders at good price. On the contrary, 39.6% of them do not consider quality of the skin because their main purpose is meat and payment they earn by selling hide and skin is very little and not seen as source of income. Hence, the reject the animal only if it is deeply wounded and when they think that this affects the quality of meat.

Factors affecting hide and skin quality along transportation rout

Most of animals were exposed to horn rake 95.7% and rope mark 73.9% along transportation route, because a number animal transported and stayed in one pen during night, this increase the severity of the problem. They beat animals frequently on their leg 89.4%, shoulder 54.2%and rarely horn 14.6% and cause a great damage to the animal occasionally (Table8).

Table 8: Factors affecting hide and skin quality along transportation rout and body part of beaten frequently

Variables	Tiyo N=9	%	Tijo and digelu N=14	%	Over all N=23	%
Horn rake	9	100	13	92.9	22	95.7
Rope mark	6	66.7	11	78.6	17	73.9

Part of body	Tiyo N=19	%	Tijo and Digelu N=29	%	Over all N=48	%
Leg	15	78.9	26	89.7	41	85.4
Shoulder	10	52.6	16	55	26	54.2
Horn	2	10.5	5	17	7	14.6

Place where the animal stay until they are slaughtered

Most butchers 62.5% do not take animal to their home; animals go directly from market to abattoirs. If they have to stay, there is a place prepared for this service only, so, they pay some money per animal and the animal stayes there during night. It is a fenced pen which have smooth earth floor done from soil , but here a lot of animals are expected to be confined together in one pen which may predispose them to horn rakes. Only some butchers take the animals to their home when they want to keep and fed them for some time. Those butchers kept their animal in fenced pen with rough earth floor 16.7% and in house in smooth earth floor 14.6% as it is indicated in below table. Very few of them keep in house with concrete earth floor 6.3% which done from stone.

Table 9: Place where animal stay during night

Where animal stay during night	Frequency	Percent
In house with concrete floor	3	6.3
In house with smooth earth floor	7	14.6
In fenced pen with rough earth floor	8	16.7
In fenced pen with smooth earth floor	30	62.5
Total	48	100.0

Source of Animal and their Species for traders

In Tiyo woreda, the source of animal for majority of trader (75%) were local market and some of them (50%) buy from farmer by directly going their home. In Tijo and digelu no trader bought animal from farmer, all of them bought from other middle men. Of 40 middle men interviewed, 75% trade cattle and 45% of them trade sheep (annex5). Most of traders (57.5%) see quality of hide and skin in addition to body condition and health of the animal when they buy animal, but (17.5%) of them do not consider quality of hide and skin. In addition to these (25%) see the color of animal also. All traders said that qualities of hide and skin have great effect on price because any mechanical damage and skin disease can decrease animal price.

Damage frequently seen on animal

Most of traders in Tijo and digelu (75%) rejected to buy animal due to defect on hide and skin. branding (66.7%) were a serious of all factors, which was followed by horn rake (60%) and rope mark (40%), because Sagure (town of the woreda) have a big live stock market so, animal was come from different market of the zone other than those woredas under study. Those reject due to wound, sheep pox and ectoparacite were 26.7%, 26.7% and 13.3% respectively. While in Tiyo, most of trader observed horn rake which was followed by wound (30%) sheep pox (20%), ectoparacite (20%) and branding (15%) (Table10).

Table 10: Damage observed on animal

Factors	**Tiyo**		**Tijo and digelu**		**Over all**	
	N=20	**%**	**N=15**	**%**	**N=35**	**%**
Horn Rake	9	45	9	60	18	51.4
Rope Mark	2	10	6	40	8	22.9
Branding	3	15	10	66.7	13	37
Dirt & Contamination	1	5	1	6.7	2	5.7
Ectoparacite	3	15	2	13.3	5	14.3
Wound	6	30	4	26.7	10	28.6
Sheep Pox	4	20	4	26.7		22.9

Transportation and housing system

Most of traders (90%) transport their animal from market to market on foot, while (10%) take by track (table11). Where ever they sold their animal, they didn't take directly from their source to market. All of them take to their home and kept for some day. During this time 27.5% and 27% confined them in house and fenced pen which have smooth earth floor respectively while 25% and 15% confined in fenced pen and in house which have rough earth floor respectively. Only 5%of them confined their animal in house with concrete earth floor .

Table 11: Transportation means

Means of Transport	Tiyo N=20	%	Tijo and digelu N=20	%	Over all N=40	%
On foot						
By track	18	90	18	90	36	90
	2	10	2	10	4	10

Majority of trader 62.5% beat their animal along transportation rout. The entire beat on their leg without damaging skin of the animal while 28% of them beat on their shoulder, because as it is indicated above, in order to sell the animal to either butcher or other middle men it have to be free from any defect. Most of trader said that hide and skin have no any advantage for them.

Key informant in both woredas of study said that, they try to give training for both middle men and butcheries; but none of them were willing to participate on training, because the training was given without any payment, in addition to these majority of them do not bother for hide and skin quality.

Table12 part of body beaten frequently

Part of body	Tiyo N=11	%	Tijo and Digelu N=14	%	Over all N=25	%
Leg	11	100	14	100	25	100
Shoulder	4	36.4	3	21.4	7	28

Farm Observation

In both woredas of study, some intensive and semi intensive farm were exist. Of existing farm 25% of them were observed for pre slaughter factors affecting hide and skin quality. In Tiyo woreda, the intensive farm had conversional housing system with proper drainage though hide of all animals in the farm were contaminated by feces and urine. Wound and skin disease indicators like scab and scar were also observed on animal body. While in semi intensive farm, proper house was prepared only for milking cow (figure5 C). Heifer and calf confined in house with concrete earth floor prepared from stone (figure A and B). Hide of the animal was contaminated by feces and also mechanical damage like wound was observed on animal.

Figure 5: Housing for different group of animal in the farm

In the second wereda, Tijo and Digelu, one intensive farms (sheep fattening) and one semi-intensive farm (cattle fattening) were observed. In the intensive one has 180 male sheep; they have different house for day and night. During night they confined in house which have smooth earth floor while during day time they stay in fenced pen. No skin defect was seen on the sheep skin. Semi intensive one has cross breed bull. Majority of the animal have pure hide but horn rake were seen on few of them. They are confined in house which have rough earth floor.

Figure 6.housing system for sheep fattening

Conclusion and Recommendations

Based on the facts discussed in this work, the results of this study showed that majority farmers use hide and skin in home for different purpose rather than selling to market. And as a result, several hide and skin were unable to rich the tannery. From results of this study, it is concluded that, the most important pre slaughter factors affecting hide and skin quality mentioned by the farmers in the study area were ectoparacite, horn rake, whip lash, thorny plant and branding in decreasing order. Some skin diseases were also mentioned by farmer. Farmers treat ectoparacite and skin disease in different way. Majority of farmers buy veterinany for the treatment and some practice traditional treatments for the external parasites. It was observed that several mechanical and pathological factors can affect hide and skin quality before the animal is slaughtered. As pre slaughter period cover greater part of animal life, exposing animal to those factors lead to poor quality of hides and skins after the animal is slaughtered. Therefore, from this study, the following recommendations should be undertaken to improve hide and skin quality in the study area:

There should be regular extension service by the responsible bodies on keeping the quality of skin and hide.

Training should be given for traders, butcher and rancher on housing, feeding, transporting method that can be damage hide and skin of the animal.

Feeding system of animals should be supported with concentrate supplementation through purchasing of concentrates especially in rural area farms.

Communal grazing land both in urban and rural areas should be utilized through cut and carries system to reduce damage occurred during grazing.

To reduce the impact of ectoparasites, appropriate and strategic control measure should be applied by animal health service.

The excess forage could be conserved in the form of hay at the end of the main rainy season. Thus training of the interested farmer in hay making techniques and providing them with appropriate tools or any logistic support would contribute to alleviation of the problem of feed shortage during the dry season.

Watering points should be prepared for animal to reduce problem of water shortage during dry season.

Transportation method have to be improved for middle men and butchers, this can reduce damage occurred during transporting the animal on foot.

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Animal Feeds and Nutrition

Studies On Daily Feed Consumption Rate and Feeding Frequencies of Eri and Mulberry Silkworm at Melkassa Agricultural Research Center, East Shoa, Ethiopia

Ahmed Ibrahim*, Abiy Tilahun, Metasebia Terefe and Kedir Shifa
**Ethiopian Institute of Agricultural Research, Melkassa Agricultural Research Center, P.O. Box-436, East Shoa, Melkassa, Ethiopia*
Email: ibrahimyuya02@gmail.com

Abstract

The study was conducted at Melkassa Agricultural Research Center, in sericulture research laboratory during 2011-2013. Prior to experimentation daily feed consumption rate were determined for both Eri and Mulberry silkworms. Based on daily feed consumption determined, five different feeding frequencies (one, two, three, four and five times feeding per day) were evaluated to determine number of possible time of feeding according to laboratory environmental conditions. Ply wood made feeding tray which are having the sizes of 90 cm x 60 cm were used to conduct the experiment. On each feeding tray 400 hundred larvae's were put to evaluate the number of feeding times. The treatments were laid out in randomized bock design with four replications. Daily temperature and relative humidity were recorded during the experiment. Silkworm mortality percentage in each instars (1st, 2nd, 3rd, 4th and 5th), larval period, weight of matured larvae, average filament length and silk ratios were used to evaluate the feeding frequencies. Significantly higher silkworm larval mortality was observed in one times feeding per day for 2nd , 3rd and 4th instars larvae followed by two times feeding per day for both eri and mulberry silkworms. Maximum larval growth period, lower weight of matured larvae, lower length of spinning thread and silk ratios were recorded in one and two times feeding per day than the other treatments for both eri and mulberry silkworm. Their fore, it can be conclude that two times feeding per day for 1st instar and 3-4 times feeding per day for 2nd, 3rd, 4th and 5th instar larvae of castor feeding silkworms were recommended during all cropping seasons. Similarly, two times feeding per day for 1st instar larvae and 3-4 times feeding per day for 2nd, 3rd, 4th and 5th instars larvae of mulberry feeding silkworms were recommended from December to May cropping season. However, two times feeding per day for 1st instar and three times feeding per day for 2nd, 3rd, 4th and 5th instar was recommended for mulberry feeding silkworms from June to November.

Key words: Feeding time, Temperature, Relative humidity, silkworm larvae, Mulberry and *castor leafs*

Introduction

The quality and quantity of feed plants can play an important role in growth and development of silkworm, particularly during adult and larval stage, which in turn influence the expression of cocoon productivity traits. This also leads to the increase in body size and dry weight of cellular mass which are dependent on the rate of metabolism, absorption of nutrients, and stage of development. In recent times, there has been a remarkable improvement in the production of silk by domestic silkworms (Hanifa *et al.*, 1988). Success of silkworm crops depends upon spacing given, feed quality, frequencies feeding and environmental conditions in each instars in the rearing bed. Feeding frequency/time and overcrowding in rearing bed affects the economics of cocoon crop significantly as over feeding leads to leaf wastage and higher leaf cocoon ratios while overcrowding in rearing bed leads to insufficient consumption of feeds, poor growth and higher incidence of disease, resulting in low cocoon yield of inferior cocoon quality (Krishnaswam *et al.,* 1977).Superior quality of silkworm feeds should be feeds to late age and young larvae. Quantitative differences in feed influence both the larval growth and cocoon character in the silkworm's *B. mori* and *F. saturinidae.* It is known that silkworm consumes 14% and 80% of the total quantity of leaf required in IV and V instars, respectively. As per the environmental conditions of different seasons, feeding is given two times per day in rainy season, while three times per day in rainy season, while three times during winter season and summer seasons (Krishnaswam *et al.,* 1978)

Different feeding schedules are followed in different agro climatic zones of the world in which silkworm rearing would be practiced. If the temperature and humidity can be maintained at the desired level , 4 feeding per day in case of leaf feeding method for late age and 3 feedings per day in case of young age larvae system are advocated in summer season, while two feeding per day in rainy and winter seasons. However, it is desirable to increase or decrease the feeding frequency in rainy and summer seasons after observing the weather condition without affecting the quantum of feed required at a particular instars, failing which the cocoon quality will be affected considerably (Krishnaswam *et al.,* 1978). The production of silk from lepidopteron insects in Africa, particularly in Ethiopia is still infant stage in comparison to other developing countries like China, India and other European Countries. The major cause for the underdevelopment of silk production in Ethiopia is lack of extension and management practices to produce quality silk. In Ethiopia production of silk was started during the Italian invasion and discontinued when the Ethiopian heroes drove out the Italian invaders. The production of silk was started again in 1990 by Melkassa Agricultural Research Center and since then, even though the production of silk is very slow compared to other crops, the activity had been underway with some major constraints. One of the major problems of silk production in the areas was lack of package of management practices. Among those management practices, determination of quantity of feed per day and feeding frequencies are some of the basic factors that hindering the production of silk. Therefore, it is very crucial to determine quantity of feed required/day for each instars of silkworms and number of feeding frequencies according to environmental conditions of the our area. As a result, this experiment was proposed with an objective to determine quantity of feed required and feeding frequencies for castor and mulberry silkworms according to the environmental conditions of the area.

Material and Methods

The experiments were conducted at Melkassa Agricultural Research Center, in sericulture and apiculture research laboratory during 2011-2013. Prior to experimentation daily feed consumption rate were determined for both Eri and Mulberry silkworms. To determine the quantity of feed for each instar, five feeding trays which are having equal amount of larvaes were used and equal amount of feeds were given. The feed/leaf was added for each treatment immediately after they finished during the larval growing period for both day and night until all the larvaes moved to spinning. Rearing bed space and silk ratios were taken to evaluate the daily quantity of feed determination. Based on daily feed consumption determined, five different feeding frequencies (one, two, three, four and five times feeding per day) were evaluated to determine number of possible time of feeding according to laboratory environmental conditions. Ply wood made feeding tray which are having the sizes of 90 cm x 60 cm were used to conduct the experiment. On each feeding tray 400 hundred larvae's were put to evaluate the number of feeding times. The treatments were laid out in randomized bock design with four replications. Daily temperature and relative humidity were recorded during the experiment. Silkworm mortality percentage in each instars (1st, 2nd, 3rd, 4th and 5th), larval period, weight of matured larvae, average filament length and silk ratios were used to evaluate the feeding frequencies. During the determination of daily feed consumption rate experiment, any dead larvae's observed during data collection were replaced from the larvae's of the same age and species types maintained in the other feeding trays and the collected data in the tables (Table1- Table3) are the average of five observations. Data for the feeding frequencies were subjected to SAS 6.12 soft ware.

Results and Discussions

Daily feeding quantum required and bed space for both mulberry (bivoltine, multivoltine) and Eri-silkworm (Eri India and Eri 3.4) for each instars are indicated from Table1 to Table 3. After daily feed consumption rate was determined, different feeding frequencies were evaluated for both Eri and Mulber silkworm to determine appropriate feeding time based on the environmental condition of the area. Eri and Mulberry silkworm larval mortality significantly ($p<0.01$) higher in one and two times feeding/day for all instars, except in the 1st instars of the two times feeding/day (Figure1and Figure 2). However, larval mortality significantly lowers in three, four and five times feeding per day for all instars and non significant differences were recorded among them(Figure1and Figure 2). Significantly ($P<0.01$) higher larval period, lower weight of matured larvae, lower length of single cocoon thread and silk ratios are observed in one and two times feeding per day(Table4 and table5). However, significantly lower larval period, higher weight of matured larvae, higher length of single cocoon thread and higher silk ratios were recorded in four and five times feeding per day followed by three times feeding/day (Table4 and Table5). Our studies agree with different authors from different areas. Krishnawami *et al.* (1977) reported that, three - four times feeding/day for Eri silkworms resulted in higher larval weight, lower larval mortality and shorter larval durations than two times feeding /day. Similarly, According to Das *et al.* (1994), both Eri and mulberry feeding silkworm larval duration considerably extended in one and two times feeding/ day than 3, 4 and 5 times feeding/day. On the other hands, Krishnawami *et al.* (1977) reported that, silkworms larval mortality was significantly very high in one and two times feeding/ day compared to 3 ,4 and 5 times feeding/day, nevertheless, 5 times and above feeding/day did not have marked differences with that of 3 and 4 times feeding/day except wastage of feeds.

Table 1. Recommended quantity of mulberry leaf required/day and rearing bed space required for each instars of 100 larvae of Bivoltine silkworms (Average of five treatments).

Instars	days	Quantity of mulberry (kg/gm)	Rearing bed space (sq.m)	
			At the beginning	At the end
I	1	0.0040kg=4.0gm		
	2	0.0056kg=5.6gm		
	3	0.0069kg=6.9gm	0.0027 sq. m	0.0058 sq. m
	4	0.0019kg=1.9gm		
	5	0.0015kg=1.5ggm		
	Total	19.9gm		
II	1	0.0125kg=12.5gm		
	2	0.0175kg=17.5gm	0.0058 sq. m	0.0150 sq. m
	3	0.005kg= 5gm		
	Total	35.0gm		
III	1	0.035kg=35gm		
	2	0.055kg=55gm		
	3	0.054kg=54gm	0.0150 sq. m	0.0350 sq. m
	4	0.0175kg=17.5gm		
	Total	161.5 gm		
IV	1	0.07kg=70gm		
	2	0.13kg=130gm	0.0350 sq. m	0.0689 sq. m
	3	0.155kg=155gm		
	Total	355 gm		
V	1	0.21kg=210gm		
	2	0.3kg=300gm		
	3	0.45kg=450gm		
	4	0.55kg=550gm		
	5	0.69kg=690gm	0.0689 sq. m	0.1392 sq. m
	6	0.4kg=400gm		
	7	0.2kg=200gm		
	Total	2800 gm		
Grand Total		3.37 kg		

Significantly higher silkworm larval mortality was observed in four and five time feeding per day than the other treatments for 1st instars larvae . Similarly, higher larval mortalities were obtained in two, three, four and five times feeding/day for 2nd instar. However, significantly higher mulberry feeding silkworm larval mortalities were recorded in one and two times feeding per day for 3rd, 4th and 5th instars than the other treatments. Das *et al. (*1994) also reported that, higher mortalities and lower silk ratios were recorded in one and two times feeding/day than three and above feeding time/day. Our studies are also in the conformity with Krishnaswami *et al*. (1977) who observed more matured larval weight in 2 times feeding /day with plucked leaves in the young age and 3, 4 and 5times feeding/day with matured leaf from third instar and onwards throughout larval period. Likewise, feeding frequencies of 3 and 4times/day was superior to the others and it resulted in increased larval weight (Das *et al*., 1994; Chandrashekar, 1996). Rearing of silkworms with different feeding regimes caused marked influence on late age larval duration and total larval duration but had lower effect on young-age worms. According to Haniffa *et al.* (1988),

when the numbers of feeds were restricted from 4 to 1times feeding/day, the larval period was extended. Krishnaswami *et al*. (1978a; 1978b; 1980) also observed that, prolongation of larval period as a result of under feeding. The larval duration in the present study has almost followed the trend observed by the previous workers (Das *et al*., 1994; Chandrashekar, 1996). According to Anonymous (1987), shorter silkworm larval duration, higher larval weight and good quality were recorded in 3 and above feeding/day than one time feeding/day of mulberry silkworms. In addition, our study confirmed that the number of feeding times per day increased from 3 to 4 times per day and from 2 to 3 times per day during *bega* cropping season for late and young age larvae's, respectively. Whereas 3 and 2 times feeding per day during *kiremt* cropping season for late and young age larvaes, respectively. This is for the reason that of higher leaf moisture losses during *bega* cropping season and lower moisture losses from the leaf during *kiremt* cropping season.

Table 2. Recommended quantity of mulberry leaf and rearing bed space required for 100 larvae of Mulberry mulivoltine silkworms (Average of five treatments).

Instars	days	Quantity of mulberry (kg/gm)	Rearing bed space (sq.cm)	
			At the beginning	At the end
I	1	0.002kg=2.0gm		
	2	0.0036kg=3.6gm		
	3	0.0049kg=4.9gm	0.0024sq. m	0.0049 sq. m
	4	0.002kg=1gm		
	5	0.0015kg=1.5ggm		
	Total	**13.0gm**		
II	1	0.011kg=11gm		
	2	0.0145kg=14.5gm	0.0049 sq. m	0.0143 sq. m
	3	0.002kg= 2gm		
	Total	**27.5gm**		
III	1	0.015kg=15gm		
	2	0.035kg=25gm		
	3	0.024kg=24gm	0.0143 sq. m	0.0339 sq. m
	4	0.0135kg=13.5gm		
	Total	**77.5gm**		
IV	1	0.04kg=40gm		
	2	0.21kg=210gm	0.0339q. m	0.0649 sq. m
	3	0.15kg=150gm		
	Total	**400 gm**		
V	1	0.21kg=210m		
	2	0.22kg=220gm		
	3	0.35kg=350gm		
	4	0.45kg=450gm		
	5	0.59kg=590gm	0.0649 sq. m	0.1289 sq. m
	6	0.5kg=500gm		
	Total	**2320 gm**		
Grand Total		**2.84 kg**		

Table 3. Recommended quantity of castor leaf and rearing bed space required for 100 larvae of Eri-India and Eri-3.4 silkworms (Average of five treatments).

Instars	days	Quantity of mulberry (kg/gm)	Rearing bed space (sq.cm) At the beginning	At the end
I	1	0.0038kg=3.8gm		
	2	0.0053kg=5.3gm		
	3	0.0066kg=6.6gm	0.0037 sq. m	0.0069 sq. m
	4	0.0034kg=3.4gm		
	5	0.0025kg=2.5ggm		
	Total	**21.6 gm**		
II	1	0.0321kg=32.1gm		
	2	0.0345kg=34.5gm	0.0069 sq. m	0.0254 sq. m
	3	0.0061kg= 6.1gm		
	Total	**72.7 gm**		
III	1	0.06874kg=68.74gm	`	
	2	0.075kg=75gm		
	3	0.078kg=78gm	0.0245 sq. m	0.0458 sq. m
	4	0.0569kg=56.9gm		
	Total	**278.64 gm**		
IV	1	0.097kg=97gm		
	2	0.242kg=242gm	0.0458 sq. m	0.0856 sq. m
	3	0.285kg=285gm		
	Total	**624 gm**		
V	1	0.450kg=450gm		
	2	0.640kg=640gm		
	3	0.750kg=750gm		
	4	0.59kg=590gm		
	5	0.94kg=940gm	0.0856 sq. m	0.2457 sq. m
	6	0.68kg=680gm		
	Total	**4050 gm**		
Grand Total		**5.045kg**		

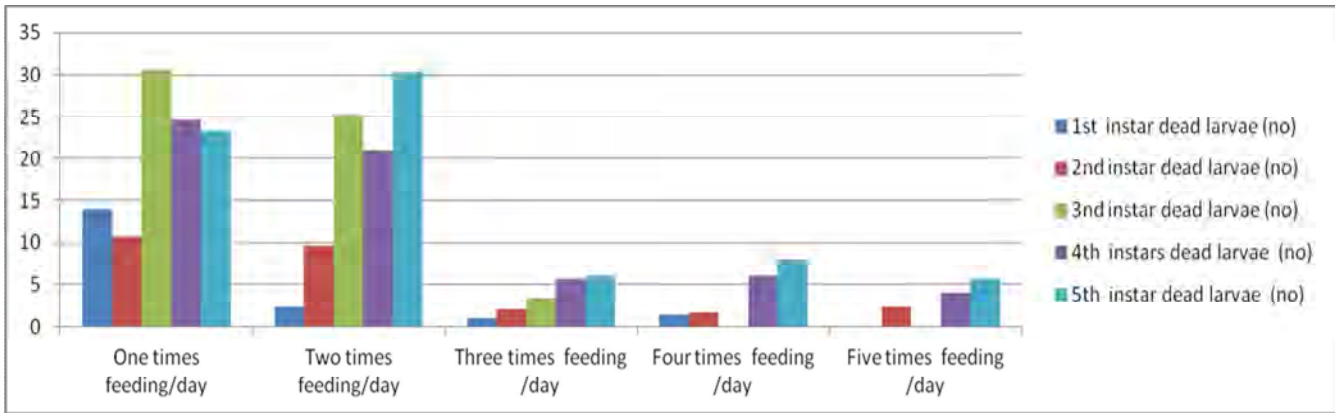

Figure 1. Effects of different feeding frequencies on different instars of Eri-silkworm larval mortality during ***kiremt*** and ***Bega*** **cropping seasons.**

Table 4. Effects of different feeding frequencies on larval period, weight of matured larvae, length of spinning thread and silk ratios of Eri - silkworm during *Kiremt* and *Bega* cropping seasons.

No.	Treatments	larval period (Days)	Wight of 10 matured larvae 6 days after 4th molt (gm)	Length of the cocoon thread (m)	Silk ratio %
1	One times feeding/day	29.00 ±0.00a	48.67 ±5.48c	4.45 ±0.05e	9.91 ±0.24b
2	Two times feeding/day	30.33 ±0.88a	52.64 ±2.96c	5.49 ±0.12d	9.33 ±0.13c
3	Three times feeding /day	24.66 ±0.33b	66.66 ±3.71b	6.70 ±0.12c	11.03 ±0.17a
4	Four times feeding /day	25.00 ±0.57b	83.68 ±2.40a	8.53 ±0.08b	11.50 ±0.14a
5	Five times feeding /day	23.66 ±0.33b	85.36 ±3.30a	8.99 ±0.24a	11.41 ±0.16a
CV%		**3.74**	**9.91**	**2.79**	**2.83**

Means followed by the same letter within a column are not significantly different from each other at 1% level of probability (Student-Newman- Keul`s Range Test).

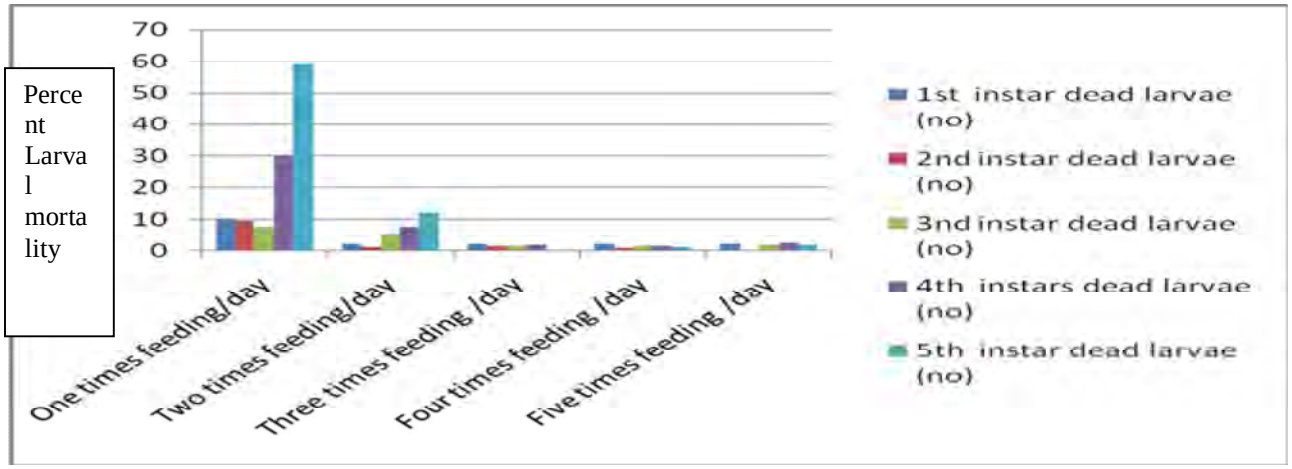

Figure 2. The rate of mortality on mulberry silkworm affected by different feeding frequencies (December – May)

Table 5. Effects of different feeding frequencies on different parameters of mulberry silkworms (December – May)

No.	Treatments	larval period (days)	Wight of 10 matured larvae 6 days after 4th molt (gm)	Length of the cocoon thread (m)	Silk ratio %
1	One times feeding/day	29.65 ± 0.31 a	28.69 ± 1.56 b	659.50 ± 63.00 b	19.73 ± 0.44 b
2	Two times feeding/day	29.31 ± 0.30 a	33.35 ± 2.33 b	561.50 ± 61.00 b	19.38 ± 0.46 b
3	Three times feeding /day	26.33 ± 0.86 b	43.03 ± 1.94 a	680.20 ± 11.35 b	21.74 ± 0.65 a
4	Four times feeding /day	23.25 ± 0.34 c	45.76 ± 0.79 a	970.20 ± 36.02 a	22.75 ± 0.39 a
5	Five times feeding /day	23.54 ± 0.30 c	44.51 ± 0.74 a	967.51 ± 36.02 a	22.48 ± 0.51 a
CV%		**3.48**	**7.19**	**18.03**	**4.58**

Means followed by the same letter within a column are not significantly different from each other at 1% level of probability (Student-Newman- Keul`s Range Test).

Table 6: Effects of different feeding frequencies on mulberry silkworm larval mortality (June-November)

No.	Treatments	1st instar dead larvae (no)	2nd instar dead larvae (no)	3nd instar dead larvae (no)	4th instars dead larvae (no)	5th instar dead larvae (no)
1	One times feeding/day	11.33 ± 0.30b	1.78 ± 0.00b	2.14 ± 0.16a	11.00 ± 0.58a	22.00 ± 0.16a
2	Two times feeding/day	3.12 ± 0.31c	1.10 ± 0.15c	2.13 ± 0.13a	10.00 ± 0.56a	11.66 ± 1.20b
3	Three times feeding /day	15.45 ± 0.52a	1.11 ± 0.16c	0.00 ± 0.00b	0.00 ± 0.00b	1.65 ± 0.30c
4	Four times feeding /day	16.00 ± 0.51a	2.00 ± 0.00a	0.00 ± 0.00b	0.00 ± 0.00b	2.00 ± 0.00c
5	Five times feeding /day	18.00 ± 0.52a	2.20 ± 0.10a	0.00 ± 0.00b	0.00 ± 0.00b	1.32 ± 0.32c
CV%		8.15	11.49	16.71	14.08	19.10

Means followed by the same letter within a column are not significantly different from each other at 1% level of probability (Student-Newman- Keul`s Range Test).

Conclusion and Recommendations

Their fore, it can be concluded that two times feeding per day for 1st instar and 3-4 times feeding per day for 2nd, 3rd, 4th and 5th instar larvae of castor feeding silkworms were recommended during all cropping seasons. Similarly, two times feeding per day for 1st instar larvae and 3-4 times feeding per day for 2nd, 3rd, 4th and 5th instars larvae of mulberry feeding silkworms were recommended from December to May cropping season. Likewise, two times feeding per day for 1st instar and three times feeding per day for 2nd, 3rd, 4th and 5th instar was recommended for mulberry feeding silkworms from June to November cropping season.

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Women Based Demonstration of Broilers Using Locally Made Feed In Bahir Dar Zuria District of Amhara Region

[1]Fisseha Moges, [2] Alemayehu Amare, [3]Muhammed Nega, [4]Kegne Yismaw, [5]Dawud Ibrahim
[1]Bahir Dar University, College of Agriculture and Environmental Sciences
[3,4]Andassa Livestock Research Center
[2,5]Ethiopian Institute of Agricultural Research, Debre Zeit Agricultural Research Center
Contact e-mail: fismog2@yahoo.com

Abstract

Pre-extension demonstration of broilers was conducted in Bahir Dar Zuria district of Amhara Region during the years of 2013/14. The major objective of the demonstration was to introduce broiler chicken breed in the area and evaluate their performance using locally made feed. The trial was done at Bahir Dar Zuria district at Andassa. A total of 420 Hubbard JV broiler breed day old chicks were purchased from Debre Zeit Agricultural Research Center and used for the study. Four jobless women were participated in this trial and each participant received 105 broiler day old chicks. Brooding was done by using electrical brooder. Finished broilers were sold live after six weeks of age. The average weight of day old chicks was 41.4g. The average weight of birds at end of 1st, 2nd, 3rd, 4th, 5th and 6th weeks were 130g, 213.72g, 291.25g, 599.7, 849.9g and 1293.9.6g, respectively. The average final weight was 1293.6g (ranged 1237.1g – 1349.3g). The total number of birds died in the entire period was seven (1.75 birds/HH). The average cumulative mortality percentage was 1.7%. The average daily feed intake/bird and cumulative feed intake/bird during the entire period was 79.4g and 3335.9g, respectively. The total average feed conversion ratio (FCR) was 2.3. The partial budget analysis result indicated that broiler production was profitable with a net benefit of 20.41 ETB per live bird. The lower mortality rate and profitability of birds revealed that broilers could be reared at smallholder level using locally made feed. The result of the trial showed that broiler producers should give a due attention in preparation of good quality feed so as to bring broilers to marketable weight within six weeks of growing period.

Key words: *Broilers, Hubbard JV, small holder producers*

Introduction

The poultry sector constitutes a significant contribution to human livelihood and food security of poor households (Abdelqader, 2007). In Ethiopia, chickens are the most widespread and almost every rural family owns chickens, which provide a valuable source of food and cash income (Tadelle, 2003). The total chicken population in the country is estimated to be 52.3 million; with native chicken representing 96.9% from it (CSA, 2013). The production system is based mainly on scavenging where birds are allowed to scavenge for major parts or all of their feed (Tadelle and Ogle, 1996). Similar to the national system, the major proportion (>95%) of chicken production in Amhara region is a traditional sector from which almost the whole chicken meat and egg production is produced. According to CSA (2013); the total chicken population of the region is estimated to be 14.6 million, accounting to 27.9% of the national chicken population.

In Ethiopian, like many African countries, attempts have been made at various times to improve village chicken production systems through introduction of exotic chicken breeds (Alemu and Tadelle, 1997). Distribution of layers and duals purpose breeds has been one of the livestock extension packages accomplished by the Regional Bureau of Agriculture since the last 20 years aiming at improving chicken production and productivity. Despite this huge distribution of exotic chicken breeds, the contribution of improved chicken in the current production system of the region is believed to be very low mainly due to high mortality rate of chicks. A recent study on the adoption of exotic chicken breeds in the highlands of Ethiopia indicated that adoption has been limited by a set of factors such as lack of strong extension follow up, lack of complimentary inputs, disease outbreak, lack of appropriate breed, unavailability of credit services, seasonal feed shortage and marketing problems (Tekelewold *et al.*, 2006). In addition to the above constraints; lack of alternative and productive chicken breeds like broilers has been one of the major problems which limit the supply and availability of chicken meat in the region. Currently there are few commercial poultry farms which are evolved in production and marketing of broilers in and around Addis Ababa.

Some big hotels and super markets found in Bahir Dar city had no any opportunity to get broiler meat other than these commercial farms until 2012. Small holder chicken producers found in the region were not aware about the breed and its productivity. The introduction of broiler in the region was made in 2011 for the first time at Bahir Dar and Gondar cities. Currently there are few broiler producers in these cities and are providing broiler meat for big hotels and supermarkets. Most of these chicken producers use commercial feed purchased from private feed producers found around Addis Ababa. There was no any information if this breed could survive and grow using locally made feed or not. Therefore evaluation of this chicken breed in different areas using locally made feed was mandatory to enhance the production throughout the region.

Materials and Methods

Study area and participants

This trial was done at Bahir Dar zuria district, Amhara Region. A total of four participants were selected for the trial in collaboration with Bahir Dar City Urban Agriculture Office. Practical training was given to all participants on management of birds (feeding, health care, housing, etc), chicken house construction and data collection. After the training, each participant prepared a small-scale chicken house designed for 100 chicks and equipped with necessary husbandry equipments like feeders, drinkers, brooder and brooder guard. The feed was prepared by participants using locally available materials.

Experimental Birds and Management

A total of 420 day old chicks of Hubbard JV breed were purchased from Debre Zeit Agricultural Research Center and transported to Bahir Dar. Deep litter housing system was used and the litter was disinfected with formalin before receiving the day old chicks. Brooding was done using infra-red lamp for at least 4 weeks of age. Data collection formats were prepared and given to each participant to record all relevant data.

Disease prevention and control

Routine vaccination against Newcastle and Gumborro diseases were given as recommended by the manufacturers. On top of this strict bio-security measures were employed during the entire rearing period. Treatments for other diseases like coccidiosis were given as it was occurred. Feed was supplied three times a day as recommended by the management guide of the breed.

Data management and statistical analysis

The qualitative and quantitative data-sets were analyzed using appropriate statistical analysis software (SPSS, 2002). More specifically descriptive statistics and General Linear Model (GLM) were used for this study. The following linear model was used during analysis of quantitative data:

Model statement regarding the effect of age on mortality: $Y_{ij} = \mu + m_i + \varepsilon_{ij}$;

Where;
Y_{ij} is the chicken performance parameter estimate for bird *j* in ages *i*;
μ is the overall mean;
m_i is the fixed effect of age in weeks (*i*=6; week1, week 2, week 3, week 4, week 5, week 6) and
ε_{ij} is the residual error.

Data collected

The following data were collected from the trial: weight of day old chicks (g), weekly and cumulative mortality percentages, daily and weekly feed intake, cumulative feed intake, weekly and total body weight gain/bird (g), final weight of chicks (g), weekly and total feed conversion ratio (FCR), market price per

chicks (live and processed), variable cost, total revenue (Birr), total gross margin (Birr), perception of participants and end users.

Result and Discussion

Growth performance

The average weight old day old chicks at arrival was 41.4g (ranged 41.1g – 41.7g). The average final weight of chicks was 1115.6g (Table 1).

Table 1. Average weight of birds at end of each week (g)

Group of households	No of DOC received	Wt. of DOC	Av.Wt at 1st week	Av.Wt at 2nd week	Av.Wt at 3rd week	Av.Wt. at 4th week	Av.W. at 5th week	Av.Wt. at 6th week
1	105	41.1	98	260.8	455.5	710.0	899.4	1156.4
2	105	41.3	102	259.0	377.4	540.0	815.7	1140.2
3	105	41.3	126	232.6	348.0	500.0	831.7	1095.8
4	105	41.7	114	212.7	417.2	580.0	863.9	1070.1
Mean ±SD	105	41.4± 0.26	110± 27.88	241.3± 23.0	399.5± 46.9	582.5± 91.1	852.7± 37.7	1115.6± 28.3

The final weight obtained was lower than the genetic potential of intensively managed final hybrids (2592g), (Table 2). However, the result obtained in this trial was very promising under smallholder level, which fulfills the weight requirement of our end users (1kg-1.5kg carcass weight). The average weight gain of birds at end of each week is presented in Table 2. The minimum and maximum weights gain of birds at end of the trial was 1028.4 and 1115.3g, respectively. The highest weight gain was recorded at the end of the trial period, mainly at 5th week. The weight gain recorded at some participants in the final week was below the expected due to feed shortage.

Table 2. Average weight gain of birds at end of each week (g)

Group of households	Av.wt. gain end of 1st week	Av.wt. gain end of 2nd week	Av.wt. gain end of 3rd week	Av.wt. gain end of 4th Week	Av.wt. gain end of 5th week	Av.wt. gain end of 6th week	Total Wt. gain (g)
1	56.9	162.8	194.7	254.5	189.4	257	1115.3
2	60.7	157	118.4	162.6	275.7	324.5	1098.9
3	84.7	106.6	115.4	152	331.7	264.1	1054.5
4	72.3	98.7	204.5	162.8	283.9	206.2	1028.4
Mean	**68.65**	**131.275**	**158.25**	**182.975**	**270.175**	**262.95**	**1074.275**

Mortality of Birds

The result of the current study indicated that the total number of birds died from all participants in the entire period was seven. The minimum and maximum numbers of birds died were 0 and 4, respectively

(Table 3). The highest mortality rate (1.5%) was recorded at the first week of the rearing period. The average cumulative mortality percentage of birds recorded in this trial was 1.7% (ranged 0%-1.5%). According to the results, significantly ($p<0.05$) higher mortality percentage (1.5%) was recorded at the first week growing period. Mortality level up to 5% is expected in big poultry farms and accepted as normal. This low mortality is might be the result of timely application of vaccines /medications/ and better management of birds by participants. This low mortality percentage (<5% mortality) is a very promising result and it showed that broilers could be reared at smallholder in peri-urban areas using locally available feed.

Table 3. Number of birds died at each week and cumulative mortality

Group of households	Number of birds died at 1st Week	Number of birds died at 2nd week	Number of birds died at 3rd week	Number of birds died at 4th week	Number of birds died at 5th week	Number of birds died at 6th week	Total number of birds died at entire period
1	2	0	0	0	0	0	2
2	1	0	0	0	0	0	1
3	3	1	0	0	0	0	4
4	0	0	0	0	0	0	0
Mean±SD	^{a}1.5 ±1.3 (1.5%)	^{b}0.25 ±0.5 (0.24%)	^{b}0 (0%)	^{b}0 (0%)	^{b}0 (0%)	^{b}0 (0%)	1.75±1.7 (1.71%)

^{a,b} *Least square means with different superscript within a column are significantly different (P < 0.05)*

Feed intake of Birds

The average daily feed intake of birds is presented in Table 4. Accordingly, the average daily feed intake of birds during the entire period was 89.2g.

Table 4. Average daily feed intake of birds at each week (g)

	Daily feed intake at 1st week	Daily feed intake at 2nd week	Daily feed intake at 3rd week	Daily feed intake at 4th week	Daily feed intake at 5th week	Daily feed intake at 6th week	Daily feed intake at entire period
Mean	19	34	66	95.5	112.5	124.50	54.5

The average cumulative weekly feed intake is presented in Table 5. The total average cumulative feed intake of each bird was 3765.7g. The daily, weekly and total feed intake of birds recorded in this trial was lower than the genetic potential of the breed. This might be due to many factors including; the feed quality, housing condition, water intake, temperature stress and general management of birds.

Table 5. Average weekly feed intake of birds (g)

	Cumm. feed intake at 1st week	Cumm. feed intake at 2nd week	Cumm. feed intake at 3rd week	Cumm. feed intake at 4th week	Cumm. feed intake at 5th week	Cumm. feed intake at 6th week	Cumulative feed intake at entire period
Mean	133	238	462	669	788	872	133

Feed Conversion Ratio (FCR)

The average feed conversion ratio (FCR) recorded each week is presented in Table 6. Accordingly, the total average FCR recorded in this trial was 2.25. It was higher than the genetic potential of the breed, which was 1.74. This relatively higher FCR (low efficiency) could be related to the feed quality, feed preparation, and environmental stress, type of chicken management, feed wastage and water quality and consumption rate of birds. According to the results, significantly higher feed conversion efficiency (low FCR) was recorded at the second week of growing period. The lower efficiency (higher FCR) was recorded at the 6th week of production period and this indicated that the quality of feed prepared by participants was deteriorating from time to time.

Table 6. Average weekly feed conversion ratio (FCR)

Participant's code number	Average FCR at 1st week	Average FCR at 2nd week	Average FCR at 3rd Week	Average FCR at 4th week	Average FCR at 5th week	Average FCR at 6th week	Average FCR at entire period
1	2.72	1.39	2.37	2.63	2.73	8.96	2.17
2	2.27	1.50	3.9	4.11	2.11	6.87	2.29
3	1.22	1.92	4.0	4.40	1.82	8.38	2.30
4	2.28	2.11	2.26	4.11	2.06	8.17	2.23
Mean	2.12	1.73	3.13	3.81	2.18	8.10	2.25

Economics of broiler production using locally made feed

Partial budget analysis

Finished broilers were sold in live weight (per head) after 42 days of growing period. They were purchased by small holder broiler processors living at Bahir Dar city. Labor was provided by family as side line activity and the cost was not considered in the analysis. The economic analysis result showed that the average selling price of finished broilers was 50 Birr per head (Table 7). Partial budget analysis result indicated that smallholder broiler production was profitable with a net benefit of 10.75 ETB /head and 19.33 ETB/kg, respectively. Semi processed broiler meat suppliers fetched 8.56 ETB/kg more than those who supplied live birds. In addition, the return could also be increased by 4.30 ETB/head when the day old chicks and formulated feed supplied in the locality. The result of the current study indicated that the cost of feed for broiler production covered more than 70% of variable cost. Opara (1996) also agreed that feed accounts for 70-85% of the production cost of modern poultry production.

Table 7. Partial budget analysis of broiler production using local feed

Description	Birr/bird
Total average revenue (ETB)	**5162.5 (Ranged 5050-5250)**
Total average variable costs (ETB)	3019 (Ranged 2904 – 3235)
Day old chicken cost	600
Feed cost (starter & finisher)	1875.6
Labor cost	319.00
Electricity cost	73.75
Guard cost	68.75
Other costs (vaccine, etc)	82.00
Gross Margin (Revenue - Variable Cost)	2143.5 (Ranged 804.5 – 1287)
Average profit/bird	20.41 Birr

Sensitivity analysis

The result of the current study indicated that broiler production would result in a positive net benefit for all production situations up to 20% output price reduction and 10% input price increment (Table 8).

Table 8. Sensitivity analysis for broiler adaptation trial using local feed

Description	Price of birds and variable cost (Birr)
Average selling price of broiler	50.00
Average variable cost	29.59
Net benefit	20.41
Sensitivity analysis	
+ 5% variable cost	31.0695
- 5% selling Price of broiler	47.5
Net benefit	16.4305
+ 10% variable cost	32.549
- 10% selling Price of broiler	45.25
Net benefit	12.701
+ 15% variable cost	34.0285
- 15% selling Price of broiler	42.5
Net benefit	8.4715
+ 20% variable cost	35.508
- 20% selling Price of broiler	40
Net benefit	4.492

Producers' opinion

The survey result indicated that all participants of the trial were highly satisfied by the breed. According to the producers the breed has paramount merit than other chicken breeds they know. Some of the merits mentioned by trial participants included the following; very fast growth, high final weight, able to rear many cycles per year and rear as side activity (Table 9). All growers mentioned that they have future plan to maintain broiler production since it was highly profitable. Participants mentioned that presence of high

demands for chicken meat and low supply improved poultry breed meat were good opportunities for broiler production in the study area.

Table 9. Special merits of broilers as mentioned by growers

Special characteristics of broilers mentioned by producers	Number of respondents	Response %
Fast growth	4	100
High product (high final body weight)	4	100
Ability to do many cycles per year	4	50
Could be done as side activity	4	25

Participants were afraid to sustain the production in the future due to some constraints. The major challenge raised by all participants was lack of day old chicks in the region (Table 10).

Table 10. Challenges of broiler production as mentioned by participants

List of Constraints	Number of respondents	Response %
Lack of day old chicks	10	100
Lack of formulated feed	10	75
High feed cost	10	50
Lack of appropriate health services	10	25
Lack of knowledge (poor training access)	10	25
Lack of husbandry equipments	10	25

Conclusion and Recommendations

The result of the current study showed that there is high demand for broiler meat around Bahir Dar City and this could be considered as a good opportunity for maintaining broiler production in the area.

The Lower mortality rate (<2%) recorded in this study revealed that broilers could be produced using locally made feed at smallholder level.

The final weight and feed conversion efficiency was lower than the genetic potential of the breed. This was highly correlated with the quality of feed produced by participants and the daily amount given to birds.

The finished broilers were purchased by small holder processors found in Bahir Dar city. They bought them to fatten birds for one extra week before processing. This showed that prolonging the growing period from 6 to 7 weeks might be important to bring birds at slaughter weight if the quality of feed produced is not according to the standard.

The higher mortality rate was recorded at the early stage of the growing period and this showed that attention should be given for the first two weeks of growing period.

Provision of trainings on small scale broiler processing and packing was found to be relevant to make smallholder producers more lucrative.

Preparation of good quality feed should be given a due attention so as to fatten broilers on time and make it more profitable using locally available and formulated feed.

Fig 1. Rearing day old chicks at first week

Fig 2. Finished broilers at week six

Finished broilers at week six

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Comparison of Supplementing Urea-Molasses Block and Urea-Atela Blocks On Feed Intake and Digestibility of Male Blackhead Ogaden Sheep Fed Natural Pasture Hay

Guesh Fesaha
Adigrat University; Department of Animal Production and Technology
Email: Gueshfesaha2001@gmail.com

Abstract

The objective of this study was to evaluate the effect of supplementing feed blocks with urea molasses and urea-atela blocks on feed intake, digestibility, body weight change and carcass characteristics of natural pasture hay fed male black head Ogaden sheep. The physical and nutritional quality of the feed blocks and the economic feasibility of supplementing block made from molasses versus block made from atela were also compared. The experiment consisted of ninety days of feeding trial, seven days of digestibility trial followed by evaluation of carcass parameters. The treatments consisted of feeding of urea-molasses block ad libitum (50% of molasses: 23% wheat bran: 9% urea: 12% cement: 6% salt, T1), urea-atela block ad libitum (30% atela: 43% wheat bran: 9% urea: 12% cement: 6% salt, T2), urea-atela block ad libitum (40% atela: 33% wheat bran: 9% urea: 12% cement: 6% salt, T3), and urea-atela block ad libitum (50% atela:23% wheat bran:9% urea:12% cement :6% salt, T4). The sheep were randomly assigned to treatments following Randomized Complete Block Design (RCBD). Two kg block per week per head was given to each experimental animal. Supplementation with urea-atela block consisting of higher amount of wheat bran (T2) had significantly (P<0.001) higher daily weight gain (55.5±2.2), DM (600.45 ± 8.7) g and nutrient intakes (CP=104.2 ± 3.2) than urea-molasses block. Supplementation with T2 diet has also significantly (P<0.001) higher apparent digestibility of DM (69 ± 0.007), OM (63.2 ± 0.007) and CP (82.2 ± 0.01) than urea-molasses block. Therefore, home-made atela can fully replace molasses even with better nutritive value in areas where molasses is scarce.

Key words: *urea-molasses block, urea-atela block, body-weight gain, black head Ogaden sheep.*

Introduction

Ethiopia has a huge population of sheep serving as source of food, hair (wool), and manure. The short generation interval, the ability to give multiple births, and their smaller size make them adaptable to smallholder and mixed crop livestock production systems, whereby they contribute up to 22-63% of cash income (FAO, 2004). However, productivity of sheep is very low and mortality rate is very high particularly in the remote area such as pastoralists and agro-pastoralists. One of the major causes of low productivity and death of animals is scarcity of feed. Livestock feeding in most parts of Ethiopia is based almost entirely on fibrous feeds such as native pastures and crop residues, the quality and quantity of which is subject to great seasonal variation (ILCA, 1988). Supplementation with urea-atela or urea-molasses blocks can increase digestibility of fibrous feeds, the nutritional value, and feed intake and provide opportunity to sustain body weight of animals during the dry period and under harsh environment when access to conventional sources of supplements are difficult. Blocks are easy to make, store, transport and feed to animals. They can easily be made and used in villages. A person may make and sell blocks to farmers as a source of income. Since molasses is intensively used for production of ethanol, availability of molasses as animal feed and molasses based block preparation in the future is of great concern. Therefore, it is important to look for other alternatives such as atela. Supplementation of sheep

fed a basal diet of hay with atela was reported to improve feed intake, body weight change, and digestibility and carcass characteristics (Yoseph, 1999). Urea-atela block technology is a cost effective approach to maximize the utilization of locally available feed resources for better animal productivity during the dry season and may perhaps constitute an innovative feeding strategy for other species of livestock as well, where concentrate feeding is not a common feature, particularly in remote area, such as pastoralists and agro-pastoralists. But urea-atela block is currently not effectively utilized by small holder farmers for feeding to animal, mainly due to lack of information and experience about their potential as supplement to small ruminant. The objectives of this study were thus to evaluate feed intake, digestibility, body weight change and carcass characteristics of male blackhead Ogaden sheep fed natural pasture hay supplemented with urea-molasses block and urea-atela block, to assess the economics of supplementing block made from molasses versus atela, and to compare the physical and nutritional quality of blocks prepared from molasses and atela.

Materials and Methods

Description of the study area

The experiment was conducted at Haramaya-University. The university is located 515 km east of Addis Ababa at 9° N and 42° E. The site is situated at 1950 m above sea level and has a mean annual rainfall of 790 mm and a mean annual temperature of 16 ^oC (Mishira et al., 2004).

Experimental animals and management

Twenty four yearling intact male Blackhead Ogaden sheep with initial live weight of 12.79 ± 1.4 (mean ±SD) were purchased from Babile. The age of the animal were determined by dentition. The animals were quarantined for 21 days and during this period all sheep were ear tagged for identification. The sheep were dewormed and sprayed against internal (flat and round worms) and external (tick and mange mite) parasites, and they were vaccinated against common diseases like pasturolosis, anthrax and blackleg based on the recommendation of the veterinarian at the end of the quarantine period. Then all sheep were placed in to individual pen and offered the basal diet and supplemented with urea-molasses block and urea-atela blocks according to the treatment for another 15 days to adapt the animal to the feed and experiment procedure prior to the beginning of the actual data collection.

Experimental design and treatments

The design of the experiment was randomized complete block design (RCBD). The experimental sheep were grouped in to six blocks with four male sheep in each block based on the initial body weight. The four treatment diets were randomly assigned to sheep in each block, which resulted in to six animals per treatment and the animal within a block had equal chance to receive one of the treatment diets.

The treatments were:
T1= Urea-molasses block *ad libitum* (50% of Molasses: 23% Wheat bran: 9% Urea: 12% Cement: 6% Salt);

T2= urea-atela block *ad libitum* (30% Atela: 43% Wheat bran: 9% Urea: 12% Cement: 6% Salt);
T3= urea-atela block *ad libitum* (40% Atela: 33% Wheat bran: 9% Urea: 12% Cement: 6% Salt), and
T4= urea-atela block *ad libitum* (50% Atela: 23% Wheat bran: 9% Urea: 12% Cement: 6% Salt). Urea-atela blocks were made by varying the proportion of atela to wheat bran, other ingredients being constant.

Experimental feed preparation, block physical quality and feeding

Procedure of block preparation

The procedure for preparing the blocks required-preparation of blocks using the block maker constructed from metal sheet, mixing of atela and urea in the same container (step 1), mixing of cement, salt and water (40ml per 2kg block) in a separate container (step2), combination of the mixture in step 1 and step 2 by stirring using hand until the ingredients were fully dissolved and mixed = (step 3), addition and thorough mixing of wheat bran to the solution in step-3 (step 4). Then the mixture was put in to rectangular shape by several pressing (step 5). The pressed block was removed and put on plastic sheet spread on floor in the house and left to mature/harden for 2 days (step 6), after which it was fed to the animals. The block weighed about 2 kg.

Color and hardnes of the block

The color of the block was assessed by necked eye, and hardness of the block was estimated by pressing the block with finger or by inserting sharp object in to the block.

Feeding of hay and block

Hay purchased from Haramaya University dairy farm was used as basal diet throughout the experimental period. Wheat bran was purchased from Dire-Dawa food complex. Atela, urea, salt and cement were purchased from Harar. Atela was purchased from four tella houses in Harar throughout the experiment. According to the information obtained from producers, the tella was made from mixtures of maize, sorghum, wheat and barley, the first two ingredients making the largest proportion in all tella houses. Fresh atela was transported every five days and immediately used for preparation of the block to prevent further fermentation. The block was stored for two days in door before it was given to animals to achieve sufficient strength, so as to prevent animals from breaking the block when they lick. Then the whole block was weighed and offered to individual animal in a separate trough for *ad libitum* consumption. The block was licked by the animal for 7 successive days, after that the block was removed and weighed, and a fresh block was given to the animal. Weight of the block was taken every morning throughout the experiment to calculate daily block consumption by the animal. Hay was offered to animal *ad libitum,* common salt lick and water were available all the time to the animal.

Blocks were introduced to animals slowly and fed after animals have consumed adequate forage. That is, the block was given one hour after hay. This prevents animals from consuming too much at any one time. During the first week of adaptation, animals get access to block for only one hour, and for two hours during the second week followed by free access throughout the feeding trial. Since some animals refused eating the blocks, they were forced urea-atela block to eat by limiting access to other feeds. By doing so, all animals get accustomed to eat the block.

Palatability of blocks

Palatability of block was assessed by observing the level of acceptability of the block by the animal. That means animals consume more if the block is palatable, but animals reject if the block is unpalatable.

Duration of block remained consumable

Duration of block remained consumable was identified by observing consumable of the block. That means animals refused licking after the block was dried and lick too match before it was dried.

Feed intake and body weight measurement

Hay offer and refusal were collected and weighed daily to determine daily feed intake. Block offer was weighed daily to determine daily intake, and the amount of block remained was measured weekly at removal. The daily samples of feed offered per feed and refusal per animal were collected, bulked and sub samples were taken after mixed for determination of nutrient composition. Body weight measurement was taken every 10 days after overnight feed withdrawal. Daily body weight gain was determined as a difference between the final and the initial weight divided by the feeding days. Samples of ort for individual animal during digestion trial was separately collected, weighed and pooled by treatment for chemical analysis.

Digestibility

Digestibility experiment was carried out, after the completion of ninety days feeding trial. After adjustment period of three days to carrying of the fecal collection bag, feces was collected for seven days and each days collection of feces per animal was weighed and 20% was sub-sampled and stored frozen at -20 ^{0}C. At the end of the collection period, the composite samples were thawed to room temperature, mixed thoroughly, sub-sampled and dried at 55 ^{0}C to a constant weight. The dried samples of the feces was ground through 1 mm sieve and stored in airtight polyethylene bag until analyzed. The digestion coefficient (DC) was calculated as follows:

$$DC = \frac{\text{Total amount of nutrients in feed} - \text{Total amount of nutrients in feces}}{\text{Total amount of nutrients in feed}}$$

Carcass characteristics

After completion of ninety days feeding and seven days digestibility trial, each sheep were deprived of feed and water for 12 hours. Pre-slaughter weights were recorded and then the animals were slaughtered. The blood was collected in plastic container and its weight measured. Then skin was flayed and weighed and the leg at fetlock as well as the head was cut and weighed. The alimentary canal consisting of esophagus, reticulo-rumen, omasum-abomasum, small and large intestine were weighed with and without content. The weight of offals such as head without tongue, skin and feet and internal organs namely, liver,

heart, trachea, lungs, kidneys, spleen gall bladder, testicles, penis and kidney were also recorded. The cross sectional area of rib eye muscle between the tenth and eleventh rib were traced on transparency paper and measured. Dressing percentage was computed as a proportion of hot carcass weight to slaughter weight and empty body weight.

Feed analysis

Chemical analysis of the offered and refused feeds in the experiment as well as feces were subjected to laboratory determination of DM, OM, N and ash following the procedure of FAO (2004). The ADF, NDF and ADL component of each ingredient and feces was also determined according to the procedure described by Van Soest and Robertson (1985).

Statistical analysis

The data obtained for feed intake, body weight change, digestibility and carcass were subjected to analysis of variance (ANOVA) using the general linear model procedure of SAS (1998). The correlation between feed intake, digestibility and live body weight gain were also determined by the same software. To describe the effect of CP intake on average daily live weight gain of black head Ogaden sheep, regression analysis was done.

The model for the experiment was:

$$Y_{ij} = \mu + \alpha_i + b_j + e_{ij}$$

Where Y_{ij}= response variable, μ= over all mean, α_i = i^{th} treatment effect, b_j= j^{th} block effect, and e_{ij}= random error,

Results and Discussions

Composition of feeds

The chemical composition of individual ingredients of urea-molasses and urea-atela blocks (offered and refused) are given in Table 1. In the current study, the DM content of the treatment feeds, except molasses were above 90%. Crude protein content of urea-atela blocks was by far higher than urea-molasses block; this is because atela has higher CP content than molasses. The NDF and ADF content of urea molasses block were lower than urea-atela blocks. The dry matter content of atela (93.1%) and molasses (75.2%), but the CP content of atela was (10.2%). This is because atela in our experiment was made from low protein ingredients. The DM and CP content of wheat bran were (90.8%) and (16.8%), respectively. The CP of urea-molasses block used in the present experiment was 33.5%, but the CP content of urea-atela blocks was more than 58%, which is due to high CP content of atela than molasses.

The chemical composition of feed stuff (offered and refused) is given in Table 1. In the current study, the DM content of the treatment feeds, except molasses and atela were above 90%. Crude protein content of atela blocks was by far higher than urea-molasses block. The NDF and ADF content of urea molasses block were lower than atela blocks.

Table 1. Composition of the experimental feeds and refusals

Feed Offer	DM	Ash	OM	CP	NDF	ADF	ADL
Hay (%)	89.6	8.6	91.4	5.1	67.8	48.2	11.6
Atela (%)	93.1	3.9	96.1	10.2	32.7	16.4	5.9
Wheat bran (%)	90.8	6.2	93.9	16.8	54.2	14.6	4.1
Molasses (%)	75.2	3.1	96.9	4.1	13.6	5.4	2.3
T1 UMB (%)	95.3	31.5	68.5	33.5	15.56	7.2	2.85
T2 Atela block (%)*	96.6	32	68	62.5	37	16.4	5.2
T3 Atela block (%) *	95.6	33.7	66.3	61.5	37.1	19.4	5.2
T4 Atela block (%) *	95.7	34.5	65.5	58.5	33.7	21.6	5.6
Refusal							
Hay (%)	90.1	8.8	91.2	4.9	69.2	49.7	11.9
T1 UMB %)	95.5	32.1	67.9	32.6	13.8	7.6	2.3
T2 Atela block (%)(%)*	96.1	32	68	55	40	17.7	5.5
T3 Atela block (%)*	96.6	34.5	65.5	56.7	37.3	23.4	7.2
T4 Atela block (%)*	95.9	36.9	63.1	61.5	35.5	17.3	5.6

DM = dry mater; OM=organic matter; CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; ADL = acid detergent lignin. * = Percentage of atela block differ; UMB = urea-molasses block.

Properties of the block

The color of the blocks was dependent up on the amount of ingredients added to the block. As a result, the color of the block varies among treatments. The color of urea molasses block (T1) and T4, highest proportion of atela were dark, and more or less similar. The color of T2 and T3 urea-atela blocks were white. Blocks should be fed as a lick so that only the top surface is accessible to the animals. This requires that the block must have enough strength. This prevents animals from pushing the blocks around, breaking them up and consuming large chunks that could cause urea toxicity. When we compared urea molasses block with atela block, urea-molasses block was harder than urea-atela block. Although hardening is essential for block, quicker and extreme drying may be disadvantage as observed during the present experiment. One of the problem is it reduces intake and animals cannot consume the block after few days, but atela block was easily consumable to the animal for relatively longer period of time.

Feed intake

The mean daily DM intake is presented in Table 3. Hay and total DM intake of sheep consumed T2 diet (atela block consisting the highest level of wheat bran, 43%) was higher than the other treatments, but there were no significant difference between T1, T3 and T4. Block DM intake of T2 was higher than other

treatments. There was no significant difference between T1 and T3, but T4 has the lowest block intake compared to the other treatments. T1 and T4 blocks consists equal proportion of wheat bran in the block, but the urea-molasses block (UMB) intake was high confirming the fact that high level of atela in block depresses dry mater intake. The OM intake of sheep in T2 is higher compared to T1, T3 and T4, but there were no significant difference between T1, T3 and T4. Crude protein intake of urea-molasses block was lower than urea-atela blocks, because molasses has low protein than atela. Physical quality of the block such as hardness and palatability had direct effect on intake. The block made from atela was relatively more acceptable by the animal. This is because the amount of wheat bran added to urea-atela block was higher than the block made from molasses.

Table 2. Daily dry mater and nutrient intake of blackhead Ogaden sheep fed hay supplemented with urea-molasses block and urea-atela blocks

Nutrient	T1	T2	T3	T4	SEM	SL
DMI						
Hay (g/d)	476.6^{b}	494.6^{a}	480.1^{b}	488.2^{b}	7.77	***
Block (g/d)	103.86^{b}	105.85^{a}	103.73^{b}	95.25^{c}	1.66	***
Total (g/d)	580.47^{b}	600.45^{a}	583.89^{b}	583.45^{b}	8.74	***
TCPI (g/d)	63.63^{d}	104.2^{a}	94.06^{b}	86^{c}	3.18	***
TOMI (g/d)	560.86^{b}	584.23^{a}	561.7^{b}	563.2^{b}	8.4	***
TNDFI (g/d)	377.62^{c}	433.82^{a}	403.47^{b}	402.96^{b}	6.91	***
TADFI (g/d)	264.2^{c}	296.53^{a}	279.35^{b}	284.13^{b}	4.59	**
DMI(%LW)	3.8	3.9	3.9	4.1	0.33	ns
g/Kg $w^{0.75}$	74.4^{d}	78.2^{a}	76.5^{c}	77.5^{b}	0.3	***

DMI = dry mater intake; OMI = organic matter intake; CPI= crude protein intake; NDFI= neutral detergent fiber intake; ADFI= acid detergent fiber intake; ADL= acid detergent lignin; mbw = metabolic body weight, TCP I= total crude protein intake, TOMI = total organic matter intake, TNDFI = total neutral detergent fiber intake, TADFI = total acid detergent fiber intake.

Feed intake in all treatments increased steadily throughout the experiment period, but remained high in T2 (Figure 1).

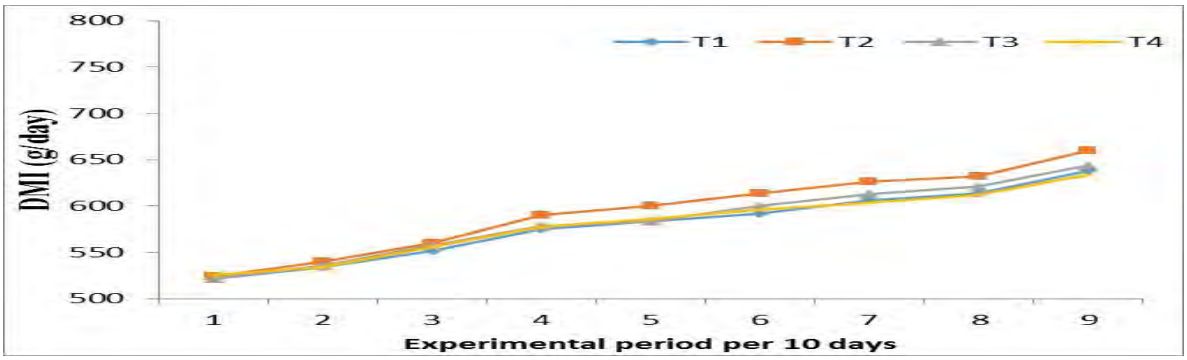

Figure 1. Trends in dry mater intake of blackhead ogaden sheep fed hay supplemented with urea-molasses block and urea-atela blocks during the experiment.

Dry matter and nutrient digestibility

The apparent nutrient digestibility is given in Table 3. The dry matter digestibility is significantly higher (P<0.05) for sheep fed T2 and T3 blocks than T1 and T4, which could be attributed to the high wheat bran in the blocks than UMB and T4 urea-atela block. There were no significant differences between T1 and T4 in DM digestibility. Organic matter digestibility in T2 was higher compared to T1 and T4, but similar with T3. The CP digestibility in T2 was higher compared to the other treatments and T1 has lower CP digestibility than T3 and T4. According to result obtained as the amount of atela increases digestibility of nutrient decreases. However, increasing the proportion of wheat bran in the block increased digestibility of nutrients.

Table 3. Apparent nutrient digestibility of blackhead Ogaden sheep fed hay supplemented with urea molasses block and urea-atela blocks

Parameter	T1	T2	T3	T4	SEM	SL
DMD (%)	65.06^{b}	68.96^{a}	67.08^{a}	62.26^{b}	0.007	*
OMD (%)	58.9^{b}	63.2^{a}	59.7^{ab}	59.5^{ab}	0.0069	**
CPD (%)	71.4^{c}	82.2^{a}	77.8^{b}	75.5^{b}	0.01	***
NDFD (%)	51.5	54.4	53.8	52.3	0.0082	ns
ADFD (%)	52.5	53.8	54.3	52.2	0.0057	Ns

DMD = dry mater digestibility; OMD = organic matter digestibility; CPD = crud protein digestibility; NDFD = neutral detergent fiber digestibility; ADFD = acid detergent fiber digestibility.

The high apparent digestibility of CP in urea-atela blocks supplemented sheep groups could be related to the high content of nitrogen supplied by atela compared to molasses.

Correlation between nutrient intake and digestibility of experimental feeds

The correlation between nutrient intake and digestibility of feed was presented in table 4. Dry matter intake was positively and significantly correlated (P<0.001) with OMI, NDFI, ADFI intake, DOM and ADG. As the total DM intake increased the other nutrients intake were also increased. The positive associations among these parameters reflect the improved fermentation and passage rate, which leads to improved intake as a result of dietary treatment. However, DNDF and DADF were negatively correlated with DDM. CP digestibility is also negatively correlated (P<0.05) with DNDF and DADF. This is because cell wall constituent reduce digestibility of CP as well as passage rate. CP intake was positively correlated (P<0.001) with intake of ADF and NDF, and digestibility of CP. But, CP digestibility was negatively correlated (P<0.05) with intake of ADF and NDF.

Table 2. Correlation between nutrient intake and digestibility

	TDMI	TOMI	TCPI	TNDFI	TADFI	DDM	DOM	DNDF	DADF	DCP
TOMI	.73***									
TCPI	.48*	.5*								
TNDFI	.95***	.7***	.68***							
TADFI	.94***	.67***	.61***	.98***						
DDM	.36ns	.36ns	.38ns	.31ns	.21ns					
DOM	.79***	.61**	.46*	.77***	.75***	.43*				
DNDF	.13ns	.061ns	-.5*	-.03ns	.01ns	-.22ns	.1ns			
DADF	.42*	.15ns	-.04 ns	.4ns	.48*	-.31ns	.34ns	.58**		
DCP	.34ns	.27ns	.73***	-.46*	-.37*	.54**	.47*	-.6*	-.17*	
ADG	.74***	.62**	.61**	.72***	.63***	.65***	.65***	-.07 ns	.06ns	.58**

ADF = ADF digestibility; ADFI = ADF intake; CPD = CP digestibility; CPI = CP intake; DMD = DM digestibility; DMI = DM intake; NDFD = NDF digestibility; NDFI = NDF intake; OMD = OM digestibility; OMI = OM intake; (**) =P<0.01; (*) =P<0.05 ;(***) = P<0.001.

Body weight change

The body weight changes and average body weight gain of blackhead Ogaden sheep fed natural pasture hay and supplemented with urea-molasses block and urea-atela blocks is given in Table 5. The higher daily body weight gain obtained by all sheep group in this study indicated that both CP and energy were adequate in the feed satisfying their maintenance nutrient requirements. The daily body weight change of sheep supplemented with urea-atela block containing high level of wheat bran (T2) was significantly higher (P<0.001) as compared to the sheep supplemented with urea-atela blocks having low level of wheat bran (T3, T4) and UMB (T1). Moreover, T3 (urea-atela block with 33% wheat bran) gained significantly higher weight. The result of the current study therefore, revealed that as the level of wheat bran in the block increased, daily body weight changes of sheep also increased. Therefore, the blocks supplied required nutrients to the rumen microorganisms and enhanced feed digestibility and intake, as a result of which animals performance improved, although the rate of growth depends upon the level of nutrients supplied by a given block. The result of the current study was agreed with that reported Salim *et al*. (2003).

Table 5. Body weight change of blackhead Ogaden sheep fed hay and supplemented with urea molasses block and urea-atela blocks.

Parameter	T1	T2	T3	T4	SEM	SL
Initial weight (kg)	13	12.9	12.5	12.8	0.29	ns
Final weight (kg)	16.5^{b}	17.9^{a}	16.5^{b}	15.5^{b}	0.33	**
Body weight gain (kg)	3.5^{c}	5^{a}	4^{b}	2.8^{d}	0.2	***
Daily Weight gain (g/day)	38.9^{c}	55.5^{a}	44.4^{b}	31.0^{d}	2.27	***
FCR	0.07^{b}	0.09^{a}	0.08^{ab}	0.05^{b}	0.004	***

^{abcd}; Means with different superscripts in the same row are significantly different at P < 0.001; ns: not significant; SEM: standard error of mean; SL: significance level.

All sheep loss weight during the adaptation period, since they did not easily accustom to the block feed and the cold (end of August) environment in the study area during this period. However, block intake increased slowly during the adaptation period and early stage of the trial after which animals showed a steady growth rate throughout the experimental period (Figure 2).

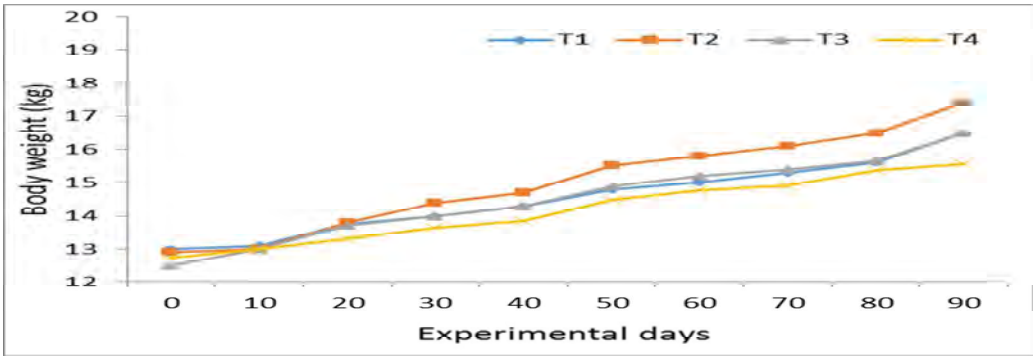

Figure 2. Weekly body weight change of blackhead ogaden sheep fed hay supplemented with urea-molasses block and urea-atela blocks.

Carcass components

The values for pre slaughter weight, empty body weight, and hot carcass weight, dressing percentage and rib-eye area of experimental sheep were given in Table 6. Pre-slaughter weight (P< 0.01), hot carcass weight, dressing percentage/slaughter and empty body weight and rib eye area (P< 0.001), follows the same trend, and are higher in T2 as compared to the other treatment groups. Tsegay (2011) Reported higher hot carcass weight and dressing percentage in blackhead Ogaden sheep than in the present experiment, which is due to the higher slaughter weight in these previous studies.

Rib-eye muscle area

Rib-eye muscle area is an indirect estimate of body musculature and amount of lean meat in the carcass. Larger (P<0.001) rib-eye muscle area was obtained in T2 as compared to the other treatments. This might be due to the efficient utilization of feeds offered for growth of useful muscle component in the former group. There were no difference in REA between the urea-molasses block, T3 and T4 urea-atela blocks.

Table 6. Carcass characteristics of blackhead ogaden sheep fed hay and supplemented with urea molasses block or urea-atela blocks

Carcass characteristics	T1	T2	T3	T4	SEM	SL
Slaughter weight (kg)	16.7^{b}	17.3^{a}	16.4^{b}	15.6^{b}	0.34	**
Empty body weight (kg)	13.4^{b}	14.7^{a}	13.0^{b}	12.6^{b}	0.33	*
Hot carcass weight (kg)	5.3^{b}	7.1^{a}	5.5^{b}	5.2^{b}	0.25	***
Dressing percentage						
Slaughter weight base (%)	31.8^{b}	41^{a}	33.4^{b}	32.9^{b}	0.74	***
Empty body weight base (%)	39.6^{c}	45.3^{a}	42.2^{b}	39.4^{c}	0.84	***
Rib eye area (cm^2)	6.9^{b}	7.3^{a}	6.9^{b}	6.7^{b}	0.09	***

^{abcd} Means with different superscripts in the same row are significantly different at P < 0.001; ns: not significant; SEM: standard error of mean; SL: significance level.

Carcass offal

Offal component of blackhead Ogaden sheep fed hay basal diet and supplemented with urea-molasses block and urea-atela blocks are given in Tables 7 and 8. In Ethiopia offal components were categorized in to edible and non- edible based on tradition and culture of the people in the area. In the present study, weight of lung, spleen, heart, kidney, total fat and blood are significantly different at (P<0.001). In the current study, kidney and abdominal fat were significantly (P< 0.001) higher in sheep fed T2 diet. This was because the diet has got high wheat bran in a block which might have promoted higher internal fat deposition.

Table 7. Response to supplementation with urea molasses block and urea-atela bocks on edible offal of blackhead Ogaden sheep fed hay

	Treatments					
Edible carcass offal (g)	T1	T2	T3	T4	SEM	SL
Blood	1032.6^{b}	1045^{a}	1024^{b}	1016^{b}	10.6	***
Liver	208.5^{b}	239.1^{a}	203.8^{b}	194.6^{c}	5.3	**
Kidney	56.8^{b}	68.5^{a}	54.3^{bc}	51.1^{c}	2	***
Heart	65.1^{b}	80.1^{a}	67.6^{b}	60.1^{c}	2	*
Tail	41.1^{b}	60^{a}	40.7^{b}	42^{b}	2.1	**
Tongue	49.5^{bc}	54.6^{a}	52^{b}	51.6^{b}	1.2	***
Kidney fat	25.6^{c}	48^{a}	30.6^{b}	29.3^{b}	2.2	***
Testis	58.3^{b}	85.8^{a}	55^{b}	46.3^{c}	3.4	***
Empty gut	1047.8^{c}	1163.5^{a}	1067.1^{b}	1048.1^{c}	10.1	***
Abdominal fat	38.3^{b}	58^{a}	39^{b}	32.3^{c}	2.4	***
TEOC	2623.6^{b}	2902.6^{a}	2634.1^{b}	2572.5^{c}	35.7	***

*$^{a-c}$; Means In the same row with different superscripts differ significantly * = (P< 0.05); **= (P < 0.01); *** = (P< 0.001); ns = not significant; S.L= significant level; SEM = standard error of mean; TEOC = total edible offal component.*

Table 8. Response to supplementation with urea molasses block and urea-atela blocks on non-edible offal of blackhead Ogaden sheep fed hay

Non-edible carcass offal's (g)	T1	T2	T3	T4	SEM	SL
Head	887.2[ab]	941.3[a]	856.3[b]	831[b]	21.7	*
Skin	940.3[c]	1224.2[a]	1205.5[a]	1015[b]	36.7	*
Feet	335.8[b]	376.5[a]	344[ab]	321.6[b]	6.6	*
Penis	40[b]	49.2[a]	40.6[b]	35.7[b]	1.7	***
Spleen	23.6[b]	32[a]	15.3[d]	18[c]	1.4	***
Gut fill	3309.7[ab]	3546[a]	3391.7[a]	3049.5[b]	97.3	**
L+T	200.5[b]	223.2[a]	195[b]	189.17[b]	5.7	*
Gall bladder	11.6[b]	13.6[a]	10.3[c]	10.7[bc]	0.4	***
TNEOC	5997[ab]	6439[a]	5858.8[bc]	5403[c]	133.9	*

[abc] *Means In the same row with different superscripts differ significantly P< 0.05 ; P < 0.01; P< 0.001; ns: not significant; S.L: significant level; SEM: standard error of mean; TNEOC: total non-edible offal component.*

Conclusions and Recommendations

The result of the chemical analysis of feeds showed that CP contents of T1, T2, T3 and T4 blocks were 33.5, 62.5, 61.5, and 58.5%, respectively. This indicated that supplementation of urea-atela blocks to be good source of protein than urea-molasses block. The apparent digestible of crude protein was significantly higher (P<0.001) for sheep supplemented with urea- atela block (82.2, 77.8 and 75.5 for T2, T3 and T4, respectively; SE=0.01) than urea molasses block, due to low protein content of molasses. The dry matter digestibility is also significantly higher (P<0.05) for sheep fed T2 (68.96 ± 0.007) and T3 (67.08 ± 0.007) blocks than T1 (65.06 ± 0.007) and T4 (62.26 ± 0.007), which could be attributed to the high wheat bran in the blocks than UMB and T4urea- atela block. The OMD is also significantly higher (P<0.01) for sheep fed (T2) urea-atela block than urea-molasses block, T3 and T4 urea-atela blocks. However digestibility of NDF and ADF were similar between supplemented treatments. Average daily gain of animals fed with T1, T2, T3, and T4 blocks were 38.9 ± 2.27 , 55.5 ± 2.27, 44.4 ± 2.27, and 31 ± 2.27, respectively. The body weight gain was significantly (P<0.001) higher in sheep fed with T2 urea-atela block. Hot carcass weight of animals fed with T1, T2, T3, and T4 blocks were 5.3 ± 0.25, 7.1 ± *0.*25, 5.5 ± 0.25, and 5.2 ± 0.25 (mean ± SE) respectively and carcass weight of T2 urea-atela block was significantly higher than other treatments. In agreement with growth and carcass performance, urea-atela blocks supplemented sheep promoted economical gain. The result showed that atela can replace molasses as a block ingredient. We observed that feeding the blocks beyond seven days is less consumable by the animals, since it becomes hard. We suggest smaller block size that is consumable within seven to eight days.

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Animal Breeding and Reproduction

Response to Selection with Multi-traits Selection Goal for Holetta Bull Dam Herds, Ethiopia

Emana Getachew, Enyew Negussie,[1] Mohamed Aliy [2]
[1] Natural Resources Institute Finland (Luke), Jokioinen , ,
Finland,Email:enyew.negussie@luke.fi
[2]Jimma University College of Agriculture and Veterinary Medicine, mohamed.derseh@ju.edu.et, Ethiopia

Abstract

A simulative prediction to determine the level of response to selection in aggregate genetic gain of indigenous breeding program of NAIC on Holstein Friesian Holetta bull dam dairy herd was conducted using the bivariate and multivariate model, that take cares of productive (305 d MY) and reproductive (AFC, CI) performance traits. The variance component analysis procedure based estimates of genetic and phenotypic parameters being derived from data captured from performance record of a total 1125 cows, 814 Dams sired by 137 in space of 35 years were used to take care of the all possible correlations and relationship among the animals. The prediction were made with the assumption of breeding plan to be implemented with selection on best aggregate merit indexed sire line and dams in the bull dam to be used as the parent to the next generation in the bull dam. The prediction model developed by Anders & Jan Philipsson (1999), for two traits breeding program and Julius. Vander Werf (2006) for three traits breeding program were employed. The response to selection by fitting 305d milk yield and calving interval, Age at calving as the target traits with 400 herd size had shown the change of 137.4 to 138.4 kg of increase in milk yield and reduction in -6.1 and -11.2 days of the CI and AFC decrement in one round selection*, respectively, with the total genetic changes of 131.6 and 129.9 Index value of combination for both 1st and 2nd scenarios respectively. The generation interval predicted in this analysis was 6.35 years, indicated poor performance for the replacement of the herd under the study. The predicted response to selection with the higher herd size using the follower herds size of 1000 to 2000 in contractual breeding scheme simulated had shown better response to selection 140.2-145.2 kg of milk yield increment with -8.4-12.2 d for CI and 13.1- 17.3 for AFC decrement. Therefore, the inclusion of more follower herds and animal evaluation on early recordable traits and on first lactation record would help to optimize the response. In this study response to selection with the three traits breeding objectives by multivariate models had indicated projection of 133.3 kg milk yield increment, -5 and -3 days decrement per* one round selection *for AFC and CI, respectively indicates possible total merit response to selection in indigenous breeding program of small herd available in the country.*

Key words: Genetic gain*, Holeta bull dam farm, ONBS, Holstein Friesian*

Introduction

Nowadays, dairy industry has an effective combination of genetic improvement tools like milk recording, artificial insemination and variance component estimation that had proven to contribute annual genetic gains of 1.5 to 2.0 % of the mean performance of a given herd through selection Robertson and Rendel (1950). This had been observed to be possible in Ethiopia situation too. The multivariate animal model evaluation study done on Holeta bull dam herd had shown that considerable genetic variability expressed in heritability on 305d milk yield (0.15), AFC (0.38) and CI (0.13) exist in the herd that would justify a selection program to be continued and implemented by NAIC. In the past three decades, milk yield has been the most important trait in the breeding goal for dairy cattle in Ethiopia. This had already caused the replacement challenge as lack of adaptation to the environment in national breeding programs. The single trait breeding goals of NAIC did not consider fertility merit of an animal to be improved in parallel with production traits, causing the slow genetic progress in the bull dam and the country at large.

Therefore, the multivariate selection objectives taking care of all possible genetic correlation was recommended to be better strategy to evaluate a given dairy animals in Holeta situation where keeping variability among the small population, and conducting selection to improve the total productivitybr while take care for fertility traits of animals is essential. Improvement in overall potential performance of livestock for all future circumstance requires to determine the amount of emphasis given to a particular trait in any selection program that justified by its economic importance, variability among the animals (heritability), plus genetic and phenotypic correlation with other traits under selection (Dickerson, 1962). To alleviate the chronic fertility and replacement challenge and optimum productivity in Holeta management situation, selection for best raking sires and dam line on aggregate genetic merit as the parent of the next generation had been proven to be more appropriate strategies to be adopted by NAIC. Prediction with more than one traits in a breeding program was not conducted anywhere in Ethiopia for this breed. Therefore, the simulation prediction model to observe the possible genetic gain based up on the nucleus and followers herd in the database of NAIC were made in this study to see how much change can be achieved within a generation or year in each traits and total merit index.

Materials and Methods

Description of the area

The Holeta bull dam is located approximately 45 km west of Addis Ababa at 38.5°E longitude and 9.8° N latitude. It is situated at about 2400 m above sea level and is delineated as one of the areas known as “the Addis Ababa milk shed”. The average annual rainfall is about 1200 mm and the average monthly relative humidity is 60.6% (Haile *et al.*, 2009).

Methodology used /assumption

Based upon the phenotypic and genetic parameters estimates obtained in the same herd (Table 1) on Production and reproduction performance of the bull dams herd. The simulation model were fitted for total number of animals currently available and actively in fertility cycles on Holeta bull dam (400) and

additional follower herds owned by the dairy farmers animals in the database ranging from 1000 to 2000 at NAIC had been taken to assumptions to come up with possible alternative strategies of the ONBS that were recommended by (Wollny, 1995) using direct prediction model of (Anders & Jan Philipsson, 1999) being used to evaluate the response to selection in one round selection and the three traits model projection were conducted according to Julius. Vander Warf (2006). The selectable sire lines and Dam line are assumed to be nominated based on the total merit index established for recommendation to NAIC on BLUP procedure based on estimates breeding value being standardized and summarized in total merit index in order to combine traits relating to reproduction and production traits.

To predict the annual genetic change achievable, assumption were used in the prediction of response in the future progenies of selectable best ranking parents in the nucleus herd, the phenotypic and genetic parameters obtained in this study (Table 1), were made using two alternatives scenario being considered for 305d milk yield versus calving interval, and 305 d MY versus age at firs calving as the target traits in breeding objective. The bull dam currently existing and being selected with 25% selection intensity and importation of proven sires used (75%) and young bulls (25%).

$$H = \left[\sum_{i=1}^{2} i_n \; c_n\right] \frac{b_{u'} G a_t}{\sqrt{b_{u'} P b_u}}$$

Where:
H= aggregate genetic gain
I_n = selection intensity in path n;
c= cumulative discounted expression for path n;
b_u= vector of selection index weights corresponding with the used set of economic weights;
at = vector of economic weights used,
G =matrix of covariance between traits in aggregate genotype and index,
P= matrix of covariance between traits in the selection index.

The subscript n which stands for path n and follows what Robertson and Rendel (1950). Preliminary survey was conducted, in order to allow selection of sires and dams for simultaneous improvement for both production and reproduction traits by standardize breeding values for bulls and cows were obtained using the index set up by Scandinavian country. A total of 145 dairy farmers and 122 customers of the dairy products to substantiate the index model to be adopted for Addis milk shade of Ethiopian context were selected by purposive random sampling technique for identification of traits preferences as the reflection of economic benefit of dairy cattle traits. Preliminary survey was conducted on the level of traits preferences of dairy cattle in and around Addis Abba, (Bishoftu and Holeta), in order to identify prioritized breeding goal traits for implementation of appropriate indigenous breeding program by developing relevant selection index with the participation of the Dairy farmers and customers. Accordingly,

H= **0.60***305d MY Index BV +**0.25*** AFC Index BV + **0.15*** CI Index BV 0.60,25 and 15%

Table 1: Assumption taken to Predict Genetic Change

Functional value from the study	Scenarios			
	Scenarios 1		Scenarios 2	
	305 d	CI	305 d	AFC
Overall mean	3661 kg	461d	3661 kg	1200d
Additive genetic variance	165900	1841	165900	19
Phenotypic variance	1106000	14160	1106000	49
Heritability (h_1^2)	0.15	0.13	0.15	0.38
Repeatability	**0.41**	**0.23**	**0.41**	**-**
No. of services/cow calving				

Assumption	
Proportion of young bull semen	0.25
No. of proven AI-bulls selected/year	2
No. of proven bull-sires selected/year	6
Proportion of young bulls with proven sires	0.75
Recorded population size, cows	400
No. of cows calving/year	317
	2.0
Proportion of cows used as dams	0.74
No. of candidate bull dams/young bull calf	10
Period a young bull is used (months)	24
Period a proven bull is used as bull-sire	60
Replacement rate, proportion	0.30
Culling rate, proportion	0.10

Result and Discussion

Prediction of genetic gain open nucleus breeding (ONBS)

The simulation model on response to selection if selection for female and male lines having the highest ranking in total merit index among the bull dam herd being used to produce the next generation, the response to selection per current breeding objective of (305d milk yield, age at first calving and calving intervals) by multivariate models had indicated projection of 133.85 kg milk yield increment, -5.41 and -3.83 days decrement per one round selection for AFC and CI respectively, with the precision of 96. Relatively the greater improvement of 305d M than CI and AFC is mainly because of high weightage value (0.60%) that was applied. This response to selection was lower than the report of (Chagunda, 2000) in Malawi, who reported 213.1kg,-8.02 days and -12.31day for 305d milk yield age at first calving and calving intervals, respectively for first and second scenarios. There was a relatively more expected genetic gain for all traits in bi-variate breeding program model after introduction of both reproduction (CI and AFC) and production trait (305d MY) than multivariate model prediction which was 137.4 and 138.4 kg of milk yield in both first and second scenarios respectively, whereas -6, -11 day for CI and AFC respectively. This is the rationale behind the idea of lower genetic progress when more traits are in breeding program (Julius van der Werf, 2006). The reduction in the genetic gain for milk yield by multivariate model with the optimum genetic gain by reducing the calving intervals and age at first calving is beneficial to the farmers in log run in order to optimizing the number of traits in breeding goal. The reducing calving interval and age at first calving means within a given productive life time, a cow would produce more calves than when the CI and AFC is long. This would result in more replacement in the herd as well as more lactation per productive life time of a cow which is a good opportunity to solve the problem of replacement rate and fertility problem existing in Holeta bull dam farm. This would off-set the loss that is envisaged in the reduction in milk yield per lactation which comes as a result of including CI and AFC in the selection criteria.

Table 2. Expected predicted genetic change for 305 d MY, AFC and CI

Selection criteria	S	SD	Response to selection for traits in different S					
			MYkg	CI d	AFC d	ΔG	GI	I_{Ar}
305d MY +CI	1	249	137.9	-6.1d	-	131.6	6.4	59
305d MY +AFC	2	65	138.4	-	-11.2d	129.7	6.4	62
305d MY + CI +AFC	3	72	133.3	-3 d	-5 d	115.1	6.5	95

Number of daughter per sire =10 GI=generation interval I_{Ar} = accuracy of selection ΔG =Aggregate Index S= scenario SD = standard deviation d = days

The current result of the response to selection by fitting 305 days milk yield and calving interval (first scenarios) as the target traits with 400 herd size had shown the change of nearly 137.9 kg milk per one round selection increase in milk yield and reduction in -6.1 days of the calving interval decrement in one round selection period with the total genetic changes of 131.6 Index value of combination (Table 2). The second scenario of 305 days milk yield with Age at first calving, expected annual genetic change was 138.4 kg increment of milk yield and decrement of -11.2 days of Age at calving days, with the total genetic merit index changes of 129.7 for the two traits.

The effect of herd size on the predicted genetic change

In the current study, the small herd size in Holeta bull dam had contributed to the existence of lower variability which has contributed to high homogeneity, even if the sire import from different country had been made by NAIC. The predicted response to selection simulated with the higher herd size using the follower herds and contractual breeding scheme in the breeding program simulated had shown better response to selection. The estimates of response based upon different herd size in recording scheme to selection per one round selection and selection accuracy are given in (Table 3).

Table 3. Expected predicted genetic change by herd size

Size of herd	**Response to selection for both scenario CI and AFC with 305 days MY**							
	305 d MY with Calving intervals				305 d MY with age at first calving			
	MY kg	CI	ΔG	I_{Ar}	MY kg	AFC	ΔG	I_{Ar}
400	137.4	-0.16	115.1	0.59	138.4	-0.16	129.7	0.62
1000	140.2	-0.19	125.7	0.61	141.3	-0.19	133.4	0.67
1500	142.2	-0.20	127.7	0.64	143.7	-0.20	135.3	0.71
2000	145.2	-0.21	129.7	0.68	146.2	-0.21	27.1	0.70

I_{Ar} = accuracy of selection ΔG = Aggregate Index

The annual change predicted for different herd size under the open nucleus herd and follower herds being in the data base of National Artificial insemination Center had been taken to assumptions to come up with possible alternative strategies of the open nucleus breeding schemes (ONBS) that were recommended by Wolly (1995) and other pioneer of animal breeding and genetic (Lohuis, 1998). Therefore, per the prediction from the current model we recommend the NAIC to adopt open nucleus breeding schemes using the exotic Holstein Frisian herds being owned by different stakeholder private, Government institutions that can get engaged by contractual agreement to participate in recording and allowing the test of young bulls and participate in progeny testing scheme in the country.

Since importation of foreign genetic material involves the use of foreign exchange which is extremely scarce and existence of genotype environment interaction slows down the rate of genetic progress (Mpofu *et al.*, 1993). This calls for revising the existed breeding strategy in order to assure the sustainable utilization and conservation of well adapted superior genotypes for achieving sustainable genetic improvement of dairy cattle. This is achieved by designing appropriate breeding strategies to find the best suitable and adapted bull(s) for different production systems in Ethiopia. The appropriate breeding programme for the large scale dairy farms like Holeta bull dam would be the dispersed open nucleus scheme as represented in Fig.1 by definition, in dispersed open nucleus scheme, the animals are not found in one place and this is allowance of inflow of foreign germplasm in to the system (Lohuis, 1998). As compared to the centralized closed nucleus scheme, the dispersed open nucleus scheme has more advantages.

In the proposed nucleus breeding programme, as schematically presented in fig.1, sires would be imported from abroad and their semen is utilizing in the nucleus herd (selected bull dam) then the young bull born from those sires can be disseminated to the follower herds and systematically mated with tested herds for progeny testing to prove young bulls. The performance records from the nucleus and follower herds can be transferred to the central data system. Feedback based on their performance in central data base analysis (EBVs), the young bull are selected for semen production from the nucleus and follower herds and then physically taken to NAIC. Accordingly the owner of the follower

herds can select best replacement heifers for their farms based up on the feedback from NAIC and similarly heifers would have to be selected in the nucleus herds to be the parents of the next bull dam in the nucleus. All the effective breeding and selection activities would be confined within the nucleus scheme, which would be the source of male stock in the system.

Conclusion and Recommendations

- The application of multivariate selection goal to Holeta bull dam herd being simulated had proven that reduction of AFC & CI with 5 and 3 days and increment of 133.8 kg MY per one round selection were possible within the current small herd.
- The number of animals in the follower herd have to be larger enough to get more response per selection cycle and assure accurate breeding values in selection of the parent of upcoming generation.
- The adoption of multitraits based selection goal can solve challenge on replacement to improve selection intensity and increase lifetime production of an animal.
- The longer GI and slow rate of genetic progress indicated the limitation in sire progeny testing program in small herd. Therefore, the inclusion of more follower herds and animal evaluation on early recordable traits and on first lactation record would help to optimize the response

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Genetic Association between Productive and Reproductive Traits in Ethiopian Holstein: A Multivariate Animal Model Analysis

Wondossen Ayalew Mohammed Aliy[1] Enyew Negussie[2]
Department of Animal Production and Technology, Wolkite University, P.O.Box 07, Wolkite, Ethiopia wondessenayalew9@gmail.com
[1]Jimma University College of Agriculture and Veterinary Medicine, P.O.Box, 307 Jimma, Ethiopia
[2] LUKE Natural Resources Institute Finland, Helsinki, *Finland*

Abstract

Data from Holetta bull dam farm was used with the objectives of to estimate genetic parameters for productive and reproductive traits. The data included in the study had production and reproduction records of animals that have calved between 1979 and 2013. Genetic parameters were estimated using a multivariate mixed model software DMU. Estimates for heritability of milk production traits from the three repeatability animal models ranged from 0.03±0.03 for LL to 0.17±0.04 for LMY. For reproductive traits the heritability estimates ranged from 0.09±0.03 for DO to 0.47±0.06 for AFC. Phenotypic correlation between production and reproduction traits ranged from 0.08±0.04 for LL and AFC to 0.42±0.02 for LL and DO. The genetic correlation between productive and reproductive traits ranged from -0.02±0.16 for 305-dMY and DO to 0.99±0.20 for LL and CI. The moderate heritability estimates observed for AFC indicated that in Holstein Friesian cattle faster genetic improvement for this trait is possible through selection. However, the low heritability estimates obtained for both productive and reproductive traits might be due to smaller herd size, phenotypic based selection bias and high temporary environmental variance. Therefore, effective improvement in productive and reproductive traits of Holstein Friesian could be realized mainly through improving the production environment.

Key words: *Genetic parameter, Multivariate, Holstein Friesian, Holetta bull dam farm, Productive and reproductive traits*

Introduction

Performance evaluations of locally available exotic and cross bred dairy cattle in Ethiopia have so far been analyzed mostly by using univariate models. Evaluations based on single trait models does not account for the covariances among traits. Therefore, using estimates from univariate models that did not take the relationship among traits into consideration may result inaccurate estimates of breeding values that will leads to selection bias. Today, multivariate analysis are generally used in animal breeding studies for the selecion of best replacment stock, so that the effect of selection for one would be known to affect the other in anticipated direction. In additon, using such kind of analysis has a great deal of importance to provide reliable and unbiased esimates of geneic parameters (Unalan and Cebeci, 2004). Variance covariance estimates from a multivariate data analysis in the dairy herd helps to assess the presence of genetic correlations among breeding goal traits that enables the setting up of total merit index evaluation for every animal in the herd. In general, information on the estimates of genetic parameters of productive and reproductive traits of Holstein Friesian dairy cattle particularly those with multivariate animal models are scarce in Ethiopia. Therefore this study was conducted to generate genetic parameters that would contribute to our understanding and particularly to the future design of the country's dairy genetic improvement program with the objective of to estimate genetic and phenotypic parameters for both productive and reproductive traits in Holstein Friesian herd.

Material and Methods

In this study milk production and reproduction performance of Holsteins Friesian cows calving between 1979 and 2013 were collected from individual animal cards. The data was edited in such a way that lactation milk yield less than 1000 kg and lactation lengths less than 220 and greater than 450 days were excluded based on the method adopted from Ayied *et al.* (2011). All lactation records between 21 and 320 days were standardized to 305-days milk yield by using the projection procedures of Rege (1991). Lactation greater than 321 days were adjusted by developing a regression model considering R-square and variance inflation factor for each independent variable in the model as used by Eyduran *et al.* (2010) and Khan *et al.* (2011). Reproductive traits included in this analysis were age at first calving between 18 month to 60 month with records greater than 60 month were considered as 60 month, calving interval between 300 and 900 days and days open between 21 and 500 days (Ajili *et al.*, 2007). Finally a total of 3552, 3733, 2938, 1125, 2764 and 2773 records on LMY, adjusted 305-dMY, LL, AFC, CI and DO were available for analysis.

Seasons of calving was classified into three groups based on weather and climatic conditions of the area. This included June to September as long rain season, March to May as short rainy season and October to February as dry season (Senderos *et al.*, 2004). Further, all lactation numbers were classified into three parities; 1, 2, and 3 or more. All parities above 3 were pooled together in parity three due to very few number observations. Sires used in the farm were huddled into eight groups based on their source or country of origin.

Data analysis

Estimation of (co)variance components and resulting parameters; heritability, correlations and repeatability were made using DMU package, fitting single and multiple trait repeatability animal model with Average Information Restricted Maximum Likelihood (AI-REML) algorithm (Madsen and Jensen, 2013).

To estimate (co)variances and correlations, different animal models were used for the traits studied (production and reproduction traits) depending on the nature of the data. A full multiple trait (6×6) animal model was initially tried but it was not computationally feasible. Other multiple-trait analyses were tried by reducing the number of traits one at a time from 6 but only bi-variate model resulted in logical estimates. Three different models namely, model 1, 2 and 3 were used for estimation of genetic and phenotypic parameters. In general the effects included in these models included season of calving, year of calving/birth, origin of sire and parity as fixed effects and permanent environmental effect, animal genetic effect and random residuals as random effects. Model 1 was used for the univariate analysis of AFC whilst model 2 was used for the estimation of parameters for the productive and reproductive traits fitting permanent environmental effect due to repeated records per cow. For joint analysis (bi-variate) of both productive and reproductive traits model 3 was fitted, respectively. The general descriptions of the models in matrix form are given below:

$$Y = Xb + Za + \varepsilon \quad \ldots\ldots 1$$

$$Y = Xb + Zp + Za + \varepsilon \quad \ldots\ldots 2$$

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} x_1 & 0 \\ 0 & x_2 \end{bmatrix} \begin{bmatrix} b_1 \\ b_2 \end{bmatrix} + \begin{bmatrix} z_{c1} & 0 \\ 0 & z_{c2} \end{bmatrix} \begin{bmatrix} p_1 \\ p_2 \end{bmatrix} + \begin{bmatrix} z_1 & 0 \\ 0 & z_2 \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \end{bmatrix} \quad \ldots\ldots 3$$

Where

Y = vector of observation,

X = incidence matrix of the fixed effects,

b = vector of fixed effect;

Z_c = incidence matrix of the permanent environmental (random) effect,

P = vector of the permanent environmental (random) effect,

Z = incidence matrix of the animal (random) effect,

a = vector of the animal (random) effect,

$\boldsymbol{\varepsilon}$ = vector of random residual effect

Results and Discussion

Heritability

The heritability estimates for LMY in the present study from univariate and bi-variate models ranged from 0.17±0.04 to 0.25±0.02. The current estimate from the univariate model is comparable to estimate reported by Gader *et al.* (2007) for the same breed in Egypt. It is a bit higher than those reported by Hammoud and Salem (2013) for first lactation Holstein Friesians in Egypt. However Hermiz *et al.*, (2005) reported higher estimate of 0.28 in Pakistan. The heritability estimates for adjusted 305-days milk yield from univariate and bi-variate analysis were 0.15±0.04 and 0.16±0.04, respectively. The current estimate from all models were comparable with Atil (2000); Hammoud and Salem (2013) who reported 0.13±0.05 and 0.11, respectively for the same breed in Egypt. Similarly, Dematawewa and Berger (1998) reported nearly similar heritability estimate (0.19) for the same breed in temperate environment. However, higher estimates were reported by several authors from different production environments (Rege, 1991; Kadarmideen et al., 2000 and Ojango and Pollott, 2001). Differences in the estimates are expected and are mainly a result of size of dataset, genetic variation within population, management and environmental conditions, the method used for parameter estimation.

The heritability estimates for lactation length from all models in this study ranged from 0.03±0.03 to 0.06±0.03 and the estimates correspond with those reported by Ojango and Pollott (2001). It is slightly higher than Eid *et al.* (2012) who reported heritability estimate of 0.003±0.08 in Sudan for the same breed using paternal half-sib correlation. These low heritability estimates obtained in this study could be attributable to the high phenotypic variance arising from large environmental variation. Heritability (h^2) and repeatability (r) of milk production and reproductive traits from univariate, bi-variate (with 305-dMY) as a correlated trait), repeatability analyses, respectively.

Table 1. Heritability (h^2) and repeatability (r) of milk production and reproductive traits (with 305-dMY)

Models	Univariate		Bi-variate	
Traits	**h^2**	**r**	**h^2**	**r**
305-dMY	0.15±0.04	0.42±0.02	0.16±0.04	0.41±0.02
LMY	0. 17±0.04	0.39±0.02	0.25±0.02	0.45±0.02
LL	0.03±0.03	0.12±0.02	0.06±0.03	0.12±0.02
AFC	0.47±0.06	----	0.38±0.27	----
CI	0.11±0.04	0.22±0.02	0.11±0.04	0.23±0.02
DO	0.09±0.03	0. 19±0.02	0.09±0.03	0.20±0.02

305-dMY= 305 days milk yield, LMY= lactation milk yield, LL lactation length, AFC = Age at first calving, CI= calving interval, DO= days open, h^2 = heritability and r= repeatability.

Heritability estimates for age at first calving were 0.47 and 0.38 from univariate and bi-variate models, respectively (Table 2). The high estimates of heritability for AFC in this study may be explained by weak selection in this trait in contrast to the intense selection for milk production. Those estimates were comparable with estimates of Rege (1991), Ojango and Pollott (2001) and Hermiz et al. (2005) who reported 0.467, 0.38 and 0.33 for the same breed in Kenya and Iraq, respectively. However, higher than most estimates reported for the same breed in tropics (Menjo *et al.*, 2009). Those moderate heritability estimates in the present study suggests potential for improvement of this trait through selection.

Heritability estimates for calving interval was 0.11±0.04 from univariate and bi-variate models, respectively (Table 1). The present result is lower than the estimate 0.17 reported in Iraq by Hermiz et al. (2005), but higher than the estimates reported by (Ojango and Pollott, 2001 and Zambrano and Echeverri, 2014) for the same breed in other tropical countries. This low heritability estimates for CI can be explained by large environmental influences. Therefore, improvements in nutrition and reproductive management should lead to a considerable decrease in length of CI than genetic selection (Vergara et al., 2009).

Heritability estimates for days open were 0.09±0.03 and 0.09±0.03 from univariate and bi-variate models, respectively (Table 1). The heritability estimates in the present study from all models were almost similar. Those estimates are agreed with literature estimates. The heritability estimates reported here was close to 0.082 reported by Zambrano and Echeverri (2014), but higher than 0.042 reported by Dematawewa and Berger (1998). The low heritability of days open indicates that the major part of variation in this trait is due to non-genetic factors (temporary environmental influences) and great improvement could be achieved by improving management system (Makuza and McDaniel, 1996).

Phenotypic correlation

In the present study the phenotypic correlations between milk productions traits were high. The highest phenotypic correlation was 0.84±0.01 between 305-dMY and LMY and the lowest was 0.05±0.02 between 305-dMY and LL. The highest phenotypic correlations are in agreement with Ahmad *et al.* (2001) for cross breeds dairy cattle in Egypt. However, the lower estimate between 305-dMY and LL in the present study is in agreement with Alhammad (2005) who reported 0.01. Falconer

and Mackay (1996) revealed that both genotypic value and environmental deviation cause phenotypic correlation between traits.

Phenotypic correlations between 305-day milk yield with fertility traits (AFC, CI and DO) were negative. The phenotypic correlation between 305-dMY and AFC in present study was higher than Ahmad et al. (2001) for crossbreed cattle (-0.02) and Ojango and Pollott (2001) (-0.02) for first parity Holstein Friesian. Conversely, positive phenotypic correlation was reported by (Yosef, 2006). The negative phenotypic correlation of 305-days milk yield and fertility traits in the present study indicates the possibility of improvement of fertility as milk yield increase. As a result improving feeding and reproductive management has an important factor to avoid slowing the rate of genetic gain in milk production due to an antagonistic relationship with fertility.

In the current study the phenotypic correlation between CI and DO is 0.98±0.01.This strong and positive phenotypic correlations is in agreement with results of Ghiasi et al. (2011) and Zambrano and Echeverri (2014) who reported 0.95 and 1 for Holstein Friesian cattle in different production environment, respectively. This was because one is derivative of the other. Many management factors, such as oestrus detection and other reproductive managements, contribute to the phenotypic correlation between the two traits. Therefore, any increase in those traits is usually indicative of reduced fertility.

Table 2. Genetic (above the diagonal) and phenotypic (below the diagonal) correlations between milk production and fertility traits from bi-variate analysis

Traits	LMY	305-dMY	LL	AFC	CI	DO
LMY		0.99±0.01	0.91±0.08	-0.41±0.11	0.16±0.15	0.25±0.15
305MY	0.84±0.01		0.74 ± 0.19	-0.24±0.11	-0.10±0.15	-0.02±0.16
LL	0.51±0.02	0.05±0.02		-0.72±0.38	0.99±0.20	0.98±0.19
AFC	-0.41±0.11	-0.24±0.11	0.08±0.04		0.16±0.12	0.06±0.13
CI	0.15±0.02	-0.12±0.02	0.39±0.02	0.11±0.04		0.99± 0.01
DO	0.17±0.02	-0.11±0.02	0.42±0.02	0.10±0.04	0.98±0.01	

305-dMY- 305 days milk yield, LMY= lactation milk yield, LL lactation length, AFC = age at first calving, CI= calving interval, DO= days open

Genetic correlations

Genetic correlations between milk production traits were high. The highest genetic correlation was 0.99±0.01 between LMY and 305-dMY and the lowest was 0.73±0.19 between 305-dMY and LL. This is comparable with Ahmad *et al.* (2001). This high genetic correlation between milk productions traits result from pleiotropy (Falconer and Mackay, 1996). This means that genetic improvement of one milk production trait could be expected to cause similar improvement in the highly correlated trait, especially an increase in 305-dMY achieved through selection of lactation milk yield. Generally using 305-dMY and LMY simultaneously in selection goal is not economical rather genetic evaluation based on 305-dMY is quite enough.

The genetic correlation between 305-dMY and AFC was -0.24±0.11. This is in close agreement with -0.22±0.08 for the same herd reported by Yosef (2006). Conversely, higher and positive (0.54) genetic correlation was reported for Holstein Friesian dairy cattle in Kenya (Ojongo and Pallott, 2001). The negative genetic correlation between 305-dMY and AFC in the present study indicates that genes that positively affect 305-dMY would result in early onset of puberty. Similarly genetic correlation between 305-dMY and CI found to be -0.10±0.15. This result is higher than previous reports of -0.032 and 0.02 by Rege (1991) and Hussein (2004), respectively. However, Yosef (2006) and Sun et al. (2010) reported higher and positive genetic correlation of 0.29±0.01 and 0.48 for the same breed in Ethiopian and Denmark, respectively. Regarding genetic correlation between 305-dMY and DO, it was close to zero and directionally favourable (-0.02±0.16), however, positive and lower estimates were reported by Atil et al. (2001) and Hammoud and Salem (2013). On the other hand, higher and positive estimate were reported by Yosef (2006) and Sun et al. (2010). The present results indicated that selection against calving interval and days open would expected to increase milk yield. Therefore a reduction DO and CI are the desirable goal of dairymen. Similarly, Atil et al. (2001) came to the same conclusion.

In the current study positive genetic correlations between various reproductive traits were observed. This positive genetic correlation between reproductive traits indicates improvement of one trait has positive impact on the other trait. The genetic correlation between CI and DO was 0.99±0.01. This is in close agreement to Ghiasi et al. (2011) and Zambrano and Echeverri (2014) who reported a nearly perfect genetic correlation (0.99 and 0.98, respectively). The positive and strong genetic correlation in the present study suggests that these two reproductive traits are genetically equivalent; therefore, improvement of one trait will cause simultaneous improvement in other trait. However, in tropics the recording system is primitive due to different constraints. As a result, in the Holetta bull dam farm evaluation based on calving interval would be easy to handle by the available human resource and recording infrastructure than evaluation based on days open.

Conclusion and Recommendations

Selection of livestock is usualsly based on a combination of economically important traits that may be phenotypically and genetically correlated. The current study showed that heritability estimates of adjusted 305-dMY, LMY and LL are relatively low. On the other hand, the heritability estimates for reproductive traits obtained for the Ethiopian Holstein Friesian cattle are comparable to those obtained in other regions.

This low heritability estimates indicates that the major parts of variation for those traits were due to non-genetic factors. Although the heritability estimate for 305-dMY and LMY were relatively low but there is still a room for genetic improvement. The genetic correlations between 305-dMY and fertility traits (AFC, CI and DO) were negative and favourable. Therefore, it would be used to include 305-dMY, AFC and CI in the breeding goal of Holetta bull dam farm to bring simultaneous improvement of correlated traits and thereby to improve herd profitability through selection of best animals. Multivariate analysis also showed slight improvement in heritability estimates of CI than univariate analysis. This indicates that selection with multivariate model could be better than univariate model for traits more influenced by environmental factors.

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Farmers' Perception on Oestrus Synchronization and Mass Artificial Insemination in Cattle in West Gojjam and South Wollo Zones, Amhara Regional State, Ethiopia

Zeleke Mekuriaw[1], Habtemariam Assesfa[1], Teshome Derso[1], Mesfin Tefera[1], Azage Tegegne[2]
[1] International Livestock Research Institute (ILRI), LIVES Project, Amhara Region, Ethiopia
[2] International Livestock Research Institute (ILRI), LIVES Project, Addis Ababa, Ethiopia
Email: Z.MekuriawILRI@cgiar.org/mekuriawzeleke@gmail.com;

Abstract

Assessment of beneficiary farmers' perception towards ongoing oestrus synchronization and mass artificial insemination (OSMAI) program in cattle in West Gojjam and South Wollo Zones was made. For this study, a total of 86 beneficiary smallholder farmers (24 from West Gojjam and 62 from South Wollo zone) who came to oestrus synchronization campaign sites with their cows were randomly picked and interviewed. In addition, two group discussions (one group per zone) were made to complement information obtained from individual interviews. This finding revealed that smallholder farmers (100%) were enthusiastic to improve the genetic make of their local cattle for milk production by using OSMAI. The beneficiary farmers appreciated the use of hormone to induce oestrus in many of the cows at a time. They also witnessed high fertility rate of artificially oestrus induced cows when they are served by bulls. They valued the OSMAI technology since it resulted in reduced calving interval of their cows which under natural circumstance was much extended (two years and above in 53.1% of local and 44.4% of crossbred cows).However, increasing proportion of improved cattle genotype for milk production in peri-urban and rural areas was below expectations of smallholder farmers due to low pregnancy rate in oestrus synchronized and artificially inseminated cows. Possible reasons for lower pregnancy rate from OSMAI technology may be technical incapability of technicians, inadequate awareness of farmers and incorrect campaign approach. Therefore, to achieve the ultimate objectives of OSMAI program, which is increasing the proportion of improved cattle genotype for milk production in peri-urban and rural areas, further capacity development and awareness creation works are needed for smallholder farmers, AI technicians and livestock experts.

***Key words**: Artificial insemination, cattle, farmers' perception, fertility, genetic improvement, Oestrus synchronization*

Introduction

Ethiopia is known for huge cattle population standing first in Africa and ninth in the world. However, productivity of cattle in particular and livestock in general is known to be very low. For instance, average daily milk yield and lactation yield from cattle is about 1.31 and 237.6 liters, respectively (CSA, 2012/13). Similarly, reproductive efficiency of local cattle when evaluated in terms of age at first calving, average calving interval and lifetime calf production is very poor. Consequently, per capita milk consumption in Ethiopia was estimated to be less than 19 liters (MOA, 1997), which is lower than average per capita milk consumption for African countries. There are various causes for low productivity of cattle in the country; the major ones being low genetic potential, inadequate supply of feed, poor health service, and knowledge and skill gaps of producers. Indigenous cattle are reported to be very inferior to improved exotic dairy cattle breeds especially for milk production traits. Cognizant of this fact, efforts are being made to improve the genetic make-up of the local cattle. One of the focus areas to improve the genetic potential of local cattle for milk production has been crossbreeding of local cows with exotic dairy

breeds, mainly Holstein Frisian and Jersey. To this end, national artificial insemination center has been established in the capital city and gradually followed by regional artificial insemination centers.

However, the coverage of AI service in the country in general and in Amhara region in particular is still very limited. The efficiency of the service is also very poor (Desalegn *et al.,* 2009). Consequently, the proportion of improved dairy cattle breeds (both hybrid and exotic) constitutes only 1.05% of the total cattle population in the country (CSA, 2012/13). Most of those improved breeds are localized in and around capital city and in major regional towns. The majority of smallholder farmers residing in peri-urban and rural areas are not yet accessing the AI service. Those AI service beneficiaries are also very much discouraged by poor pregnancy rate of cows served artificially. To mitigate the limited coverage of regular AI service and to benefit the vast majority of smallholder farmers, Improving Productivity and Market Access for Ethiopian Smallholders (IPMS) project initiated innovative approach of genetic improvement of cattle known as Oestrus synchronization and mass artificial insemination (OSMAI).

The OSMAI protocol involves mobilization of livestock experts, AI technicians and smallholder farmers to brainstorm, coach and execute the activity in a coordinated manner in peri-urban and rural areas where regular AI service is not accessible. It is the induction of oestrus in a large number of smallholder farmers' cows at PA/village level by using prostaglandin hormone and then inseminating cows in heat with semen from improved dairy breeds. The ultimate aim of OSMAI is to increase the proportion of improved dairy cattle for smallholder farmers where regular AI service is not reaching. This initiation has been taken-up by government extension system throughout the country and the scale of operation has been dramatically increased in few years' time. However, the perception of beneficiary farmers on merits and drawbacks of OSMAI technology has not yet been documented. The involvement of beneficiary farmers on any agricultural technological interventions matters a lot on adoptability of the technology and on its sustainable use (Adesina and Jojo, 1995; Oladele, 2001; Aseidu-Darko, 2014; Rghav and Sen, 2014). The objective of this study was therefore to assess and document the opinions of end users of the technology and to take corrective measures timely on the approach and protocol of the OSMAI.

Materials and Methods

Study areas

The study was conducted in two LIVES project intervention zones (West Gojjam and South Wollo) of Amhara regional state, Ethiopia.West Gojjam zone is found in North West of Ethiopia. The Zone lies between 36^0 30' to 37^0 5' longitudes East and $10^0$16' to $11^0$54' latitudes North. Its elevation varies from 1500 to 3500 meters above sea level (m.a.s.l.). Most of the districts (75%) in the zone have ambient temperature ranging from 15-20^0C and the remaining (17%) have 20 – 27^0C. According to CSA (2007), this Zone has a total human population of 2,106,596, of whom 1,058,272 are men and 1,048,324 women; with an area of 13,311.94 km^2. The average rural household has 1.1 hectare of land (compared to the national average of 1.01 hectare of land and an average of 0.75 for the Amhara Region)equivalent to 0.7 heads of livestock/km^2.West Gojjam Zone has a population density of 158.25 and an average family size of 4.39. Similarly, South Wollo consists of a total population of about 2.5 million people. The range of altitude and temperature of the zone are1250 - 3800 m.a.s.l. and 5 - 21^0c, respectively. According to CSA (2007), South Wollo Zone has a total population of 2,518,862, of whom 1,248,698 are men and 1,270,164 women; with an area of 17,067.45 square kilometers. The average rural household has 0.7 hectare of land

and the equivalent of 0.6 heads of livestock. The zone has a population density of 147.58 and an average family size of 4.21.

Sampling procedure

Smallholder farmers who came to OSMAI campaign sites to get their cows synchronized were randomly interviewed using semi structured questionnaire. A total of 86 smallholder farmers were interviewed from two zones (24from west Gojjam and 62 from South Wollo).One group discussion per zone was also held to complement the information obtained from individual interview. The group in South Wollo Zone consisted of 5 members (2 women) who have good experience in dairy cattle production and exposure to cattle genetic improvement programs. Similarly, the group in West Gojjam Zone was made up of 6 members (all men).

Data collection

Data were collected on household characteristics of interviewed farmers such as sex, age, marital status, and family size, level of education, landholding, and cattle holding using semi-structured questionnaire. In addition, information on existing calving interval (CI) and main season of calving of cows in the study area was gathered. Besides, farmers' preference for CI and season of calving as well as their interest on OSMAI and objectives of cattle genetic improvement was documented. To complement information gathered from individual interview, group discussion was held to collect information on the current dairy production and productivity (milk yield, AFC, CI, life time calf productivity, purpose of genetic improvement, availability of improved breeds, the current AI service) in the area, the need for OSMAI and its perceived outcomes.

Data Analysis

Data were analyzed using SPSS15.0 for windows evaluation version. Descriptive statistics such as percentages and frequencies were used.

Results and Discussion

Household characteristics of respondents

The mean age of the respondents was 44.2±12.7 years, ranging from 18 - 80 years, whereas the average family size was 5.4±1.9 with the range of 2 - 9. As indicated in table 1, the majority of respondents (80.2%) were males and most of them (89.3%) were married. Regarding educational status of household heads, the majority fall under grade 5 - 8 (29.3%) followed by illiterates (19.3%). Only few of the respondents attended grades 11 and 12 (3.7%). This lower level of education of farmers might have negative effect on technological usage and adoption, and also limited their access to information.

Farmland and livestock holding of the respondents

The average farmland holding size of the respondents was 1.01 ± 0.91 hectares (Table 1) which is relatively very small. Out of this land, 19% was allocated for forage development. Though the proportion

of land allocated for forage development seems small, this is a very good start of giving emphasis to livestock feed resource development in the region which was uncommon in previous days. Similarly, the average livestock holdings of the respondent households were 2.4±1.9 for cow, 1.6±1.3 for oxen and 1.7±1.5, 2.5±4.1, 0.8±3.0 and 0.7±0.9 for calf, sheep, goats and equines, respectively. The livestock holding size especially for cows reported in this study may not be representative of the zones since respondents were picked among farmers who came to OSMAI campaign sites with their cows to get the service.

Table 1. Land and livestock holding status of the respondent smallholder farmers

Landholding (ha)	**Mean ±SD**
Crop land	1.01 ± 0.91
Private grazing land	0.19 ± 0.23
Livestock holding	**Mean ±SD**
Cow	2.4±1.9
Ox	1.6±1.3
Calf	1.7±1.5
Sheep	2.5±4.1
Goat	0.8±3.0
Equines	0.7±0.9

ha = hectare; SD = standard deviation

Respondents' interest in using OSMAI technology and its purpose

All respondent farmers (100%), regardless of their age, sex and educational status, have shown strong interest towards OSMAI technology (Table 2). The purposes of using OSMAI technology according to respondents were mainly for genetic improvement, followed by improving fertility of cows by reducing calving interval (CI). Under natural condition, the CI in the majority of local cows in the study area exceeded one year which is indication of poor fertility rate (Table 3). In some local cows, the CI has even been extended beyond 3 and 4 years. Slightly shorter CI reported in this study for crossbred cows compared to local cows might be due to preferential management practices given for crossbreds such as better feeding, healthcare and housing. And yet, considerable number of crossbred cows (more than 44%) failed to calve every year. Similarly, Belay *et al.* (2012), Ayelew and Asefa (2013) reported CI interval of 21.36±3.84 and 23±4.3 months, respectively, in crossbred cows between local and Holstein Friesian in Ethiopia. This scenario significantly affects production and productivity of the herd. Extended CI reduces cow's lifetime milk and calf crop production and negatively affects profitability of a dairy farm. Therefore, despite lower pregnancy rate recorded from OSMAI, farmers are very much interested to use the technology at least to improve fertility in local cows by reducing calving interval.

Table 2. Purpose of using OSMAI technology according to beneficiary

Farmers' view		
Purpose of respondents for using OSMAI	**N**	**%**
Breed improvement	65	75.6
Reduced calving interval only	14	16.3
Both breed improvement & reduced calving interval	6	7.0
Programmed calving	1	1.2
Total	**86**	**100.0**

N=number of respondents; OSMAI= oestrus synchronization and mass artificial insemination

Table 3. Calving interval of local and crossbred cows in the study area according to the respondents' view

Calving interval (years)	**Breed of cattle**			
	Local		**Crossbred**	
	N	**%**	**N**	**%**
1	37	46.8	10	55.6
2	37	46.8	3	16.7
3	2	2.5	5	27.8
4 and above	3	3.8	0	0
Total	**79**	**100.0**	**18**	**100**

N=number of respondents

Objectives of smallholder farmers for possessing crossbred cows

According to respondents, the aim of using OSMAI was to increase milk yield per cow (78.8%). However, the purpose of increasing milk production and productivity of cattle varied depending on farmers' location from the respective district towns. Smallholder farmers who are far away from local district towns were more interested in milk production for household consumption and butter production for sale (Figure 1). On the contrary, smallholder farmers living closer to district towns (in less than 5km) were more interested in milk production for sale followed by milk production for household consumption. This might be emanated from difficulty of selling whole milk for the smallholder farmers who are residing far away from district towns due to perishable nature of the product and lack of transportation and cooling facilities in the vicinity. Farmers who live nearby towns preferred selling whole milk to butter since selling whole milk is more profitable to selling butter according to their views. As indicated in figure 1, there still exists huge demand for milk and butter for household consumption regardless of distance from the district town. This implies that the current level of milk production by smallholder households could not even satisfy the family needs let alone supplying surplus milk and butter for urban dwellers.

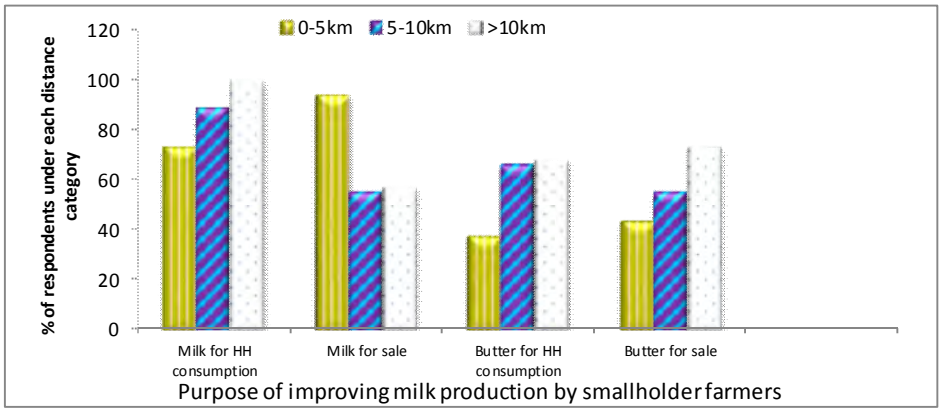

Figure 1: Objectives of improving milk production by farmers based on their relative location from district towns

Opinion of beneficiary farmers on limitations of OSM AI practice

The ultimate objective of OSMAI technology was to boost milk production and productivity of smallholder farmers by increasing the proportion of improved dairy cattle in the herd. The beneficiary farmers (100%) were happy about ability of the hormone to induce heat in cows. However, they reflected that most of the inseminated cows from synchronized oestrus failed to conceive. In line with this, smallholder farmers during group discussion pointed out perceived challenges that lowered pregnancy rate from OSMAI. One of the challenges they mentioned was short duration of stay of AI technicians on specific campaign sites. According to their views, a quick shift of AI technicians from one camp to the next affected the chance of re-inseminating cows which come on oestrus after three days of hormone injection and/or which return to oestrus. As an alternative option, farmers used local bulls to mate cows that returned to oestrus and/or come to oestrus after the third day of hormone injection. Reportedly, fertility of cows significantly improved when served by bulls. The second bottleneck according to farmers was wrong choice of season for OSMAI. Farmers in both zones shared their experience that most of the natural mating in cattle takes place from September to November. However, OSMAI was conducted during the months of December, January, February and March which are periods of serious feed shortage and high ambient temperature. Cows were in poor body condition by the time OSMAI was conducted.

The third route cause for reduced pregnancy rate might be due to knowledge and skill gaps of AI technicians. For instance, some AI technicians were giving fixed time appointment to the farmers to bring their cows for insemination after hormone injection. It has been reflected that regardless of oestrus status of cows, farmers were told to bring their cows for insemination at 48 hours after hormone injection. This might be one of the causes for poor conception rate since some of the cows might have come on heat prior to or after 48 hours of insemination. Furthermore, location of OSMAI sites have been commented by farmers as possible causes for reduced pregnancy rate. Most of the beneficiary farmers trekked their cows for long hours before and after insemination due to long distance from OSMAI sites to farmers' villages. This might have been one of the causes for fertility failure or early embryonic death. Above all, farmers were not given adequate awareness how to manage cows prior, during and post insemination. Due to lack

of awareness, some of the farmers used their cows for threshing crops after insemination. This might have induced stress on the cows and resulted in embryonic mortality.

The above stated challenges are reflections from smallholder farmers during group discussion and during individual interviews. Many more shortcomings might have also existed from AI technician side and from overall approach of OSMAI which require further investigation.

Conclusion and Recommendations

Smallholder farmers are enthusiastic to improve genetic make of their local cattle for milk production. The respondents appreciated the OSMAI technology for its ability to induce oestrus in many of the cows at a time. They also liked the technology for improving the fertility of cows when they are mated with bulls. However, their expectation to get crossbred calves from OSMAI technology was not met because of lower pregnancy rate. And yet farmers want the technology for the benefit of reduced calving rate in their cows. However, to achieve the ultimate objectives of OSMAI, which is increasing the proportion of improved cattle genotype for milk production in peri-urban and rural areas, further capacity development works are needed for smallholder farmers, AI technicians and livestock experts.

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