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EDITED BY
Uchenna Anele,
North Carolina Agricultural and Technical State University, United States

REVIEWED BY
Solomon Mwendia,
International Center for Tropical Agriculture, Kenya
Dayal Nitai Das,
National Dairy Research Institute (Southern Regional Station), India

*CORRESPONDENCE
Bayissa Hatew
b.hatew@cgiar.org

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Synergies of feed, management trainings, and genetics on milk production of dairy cows in the tropics: The case of Ethiopian smallholder farmers

Bayissa Hatew[1*], Francisco Peñagaricano[2], Mulubrhan Balehegn[3], Chris S. Jones[4], Geoffrey E. Dahl[3] and Adegbola T. Adesogan[3]

[1]Feeds and Forage Development, International Livestock Research Institute, Addis Ababa, Ethiopia, [2]Department of Animal and Dairy Sciences, University of Wisconsin-Madison, Madison, WI, United States, [3]Department of Animal Sciences, University of Florida, Gainesville, FL, United States, [4]Feeds and Forage Development, International Livestock Research Institute, Nairobi, Kenya

Efforts made so far to increase milk production of indigenous cattle by upgrading with exotic genotypes through crossbreeding under smallholder farmer conditions in Ethiopia have resulted in limited improvement. This study was conducted to determine if combining improved feed and management-related trainings with Holstein genetics will synergistically increase the milk production of dairy cows, and to examine the degree to which the increase or improvement is related to the level of exotic genetics involved. A total of 96 smallholder dairy farmers were purposively selected and allocated to one of three treatments reflecting differing degrees of capacity building support: (1) no training and no material support (Control); (2) training provided by another project (PAID) but without material support; (3) enhanced training plus material support (Feed-Mgt). Sixteen extension development agents and eight livestock experts were selected to provide training and weekly on-farm data collection, monitoring, technical support, and messaging reinforcement visits. Enhanced training addressed a broad range of topics related to feed and feeding, improved forage production, milk production and handling, construction and use of improved dairy housing, disease control, and dairy farm record keeping. Material support was in the form of formulated dairy concentrate feed and improved forage planting materials (seeds/seedlings). Data collection included variables describing animal performance, management practice adoption, and milk and butter quality. Tail hair samples for genetic profiling of breed makeup were also collected from all cows in the study. Results showed that there was a very significant effect of treatment ($P < 0.001$) on milk production, as well as treatment by week interaction ($P = 0.034$), with the effect of treatment markedly increasing over time ($P = 0.032$). That is, cows in Feed-Mgt group had up to 26.6% greater milk production compared to those in the Control group. Region and region by treatment interaction have no effects. Cows used in the experiment had varying proportions of Holstein-Friesian genome that ranged between 0 and 100%, suggesting prevalence of indiscriminate crossbreeding. Cows with a high proportion of Holstein genetics in treatment 3 produced more milk as compared to those in control group. Besides, supplemental feed improved body condition, reduced number of services per conception and resulted in higher lactation length of cows on treatment 3 compared with those on treatments 1 and 2 (P < 0.001). Overall, our findings suggest that an integrated approach of improved feed, feeding practices, and management training for smallholder dairy that goes beyond the improvement of genetics will increase milk production, improve milk quality and body condition, and resulted in higher length of lactation.

KEYWORDS

feed, genetics, training, smallholder, dairy cows, ethiopia

Implications

- To benefit from the genetic interventions implemented on smallholder farms, there is a need to optimize feed and management training programs
- Findings from this study could help government to enhance trainings so that smallholder dairy farmers can feed and manage productive cows in a sustainable and profitable way

1 Introduction

Dairy production in Ethiopia is predominantly undertaken by subsistence farmers, with a relatively small number of small and medium commercial dairy farms, and is characterized by low production and productivity. However, the increase of human population, urbanization and rising living standards of people are increasing demand for milk and milk products (Alexandratos and Bruinsma, 2012). This increase in demand for dairy products is becoming the main driver for changes in the dairy sector and may offer opportunities for smallholder dairy farmers to increase milk production and improve their income, livelihoods and create employment. Consequently, increasing the milk production of smallholder dairy farms is a high priority of the Ethiopian government as indicated in Growth and Transformation Plan II (National Planning Commission (NPC), 2016) and, more specifically, the Livestock Master Plan (Shapiro et al., 2015). Genetic improvement of indigenous cattle through cross breeding has been proposed as the most efficient and quickest ways of improving the productivity of local dairy herds. Various studies have shown that crossbred cows have greater milk yield and reproductive performance compared with local breeds in Ethiopia (Getahun et al., 2019; Getahun, 2022). As such, different interventions have been made by government, development partners, research institutions, and non-governmental organizations on the introduction of improved genetics into the nation's dairy herd through crossbreeding over the past five decades (Brannang et al., 1980; Schaar et al., 1981).

Milk production of these crossbred cows is yet to completely realize its full potential and produce enough milk and dairy products to meet the domestic demand. To fully achieve the milk productivity potential of the crossbred cows, commensurate improvements in management and feeding are needed (Tekeba et al., 2014). However, as illustrated by Haile et al. (2009), this is typically not the case with smallholder dairy farmers in Ethiopia. These authors reported that despite the potential for greater milk production with higher intervention levels, typical smallholder management and feeding practices are generally considered inadequate to sustainably support the greater productivity potential of crossbred cows. Similarly, Tekeba et al. (2014), based on a review of studies to assess the interaction of genetic potential and plane of nutrition, found that across studies and management systems, supplementation of conventional diets fed to cows with energy and protein-rich concentrates resulted in increased daily milk production. They also found that crossbred cows benefited substantially more than indigenous cows from better nutrition not only in terms of milk yield but also in maintenance of body condition, an important variable related to reproductive performance.

Apart from feed, it has been reported that training on dairy husbandry practices increased milk production, volume of milk processed, and milk income by about 21.7%, 56.5%, and 22.5%, respectively, relative to the untrained group (Seble et al., 2020). Other studies have also shown that training on dairy farming has a positive and significant relationship with the adoption of improved dairy husbandry practices in Ethiopia (Dehinenet et al., 2014; Samuel et al., 2016). In alignment with this, a study undertaken in another tropical country, Malawi, revealed that training improved the milk yield of dairy cows and the technical competence of dairy farmers (Kazanga, 2012). The Malawi study involved small scale dairy farmer members of six milk bulking groups (MBG) untrained and trained (three MBG replicates per treatment) in the proper management of water, feed, milk handling, animal welfare, farm hygiene and disease control. All farmers were milking cows with at least some degree of Holstein-Friesian genetics. Training was found to have a positive impact on farmer behavior with respect to improving water and feed availability, cleaning of milking equipment and utensils as well as barn facilities. These changes were, in turn, associated with increased milk yield and reduced rejections of milk by buyers. In contrast, the untrained dairy farmers continued to register low milk yield and to practice unhygienic milk handling with consequent high milk rejection rates.

Though crossbreeding of indigenous cattle with exotic breeds is established as an option commonly used by dairy cattle producers in milk-producing areas of the tropics, the national recommendation for optimum exotic genetics for high milk potential under favorable environmental and management conditions in Ethiopia is 50% (Haile et al., 2009; Hailu, 2013). However, previous research has suggested that the current genetic makeup of the Ethiopian dairy herd is highly variable, ranging from the incorporation of very low to very high levels of exotic genetics (Melku et al., 2017), implying that management skills and supportive resources required for cows to express their genetic potential also vary widely. This study will first test the hypothesis that increased knowledge and consequent changes in practices because of training in feeds and management will synergize with ongoing interventions in genetic improvement of dairy animals to further increase the quantity and improve quality of milk in Ethiopia. Secondly, we also hypothesize that level of genetic improvement will impact the response to level of nutrition. Hence, this study was conducted to investigate if the combination of improved feed and management-related trainings with exotic (Holstein) genetics would synergistically increase milk production and improve the health of dairy cows, and to explore the degree to which the increase or improvement is related to the level of exotic genetics involved.

2 Materials and methods

2.1 Study location

This study was conducted at the farm level in the primary milk shed areas in four regions of Ethiopia, namely Oromia, Amhara, Tigray, and Southern Nations Nationalities and Peoples' (Figure 1). The study specifically focused on smallholder farms that had been targeted and were close to those targeted by the Feed Enhancement for Ethiopian Development (FEED[1]) I and II projects implemented by ACDI/VOCA and were a subset of those involved in the African Dairy Genetic Gains (ADGG) and Public Private Partnership for Artificial Insemination Delivery (PAID) projects. The ADGG and PAID participants were targeted because of the opportunity to leverage the training, registration and recording of pedigree and performance data introduced through these projects. Proximity to the FEED I and II woredas (second smallest administrative unit in Ethiopia, equivalent to a district) allowed leveraging of the FEED project farmers' cooperative unions and extensive resource provision and capacity building in these woredas. In addition, other selection criteria such as possessing at least two cross-bred dairy cows (milking and/or pregnant cows), male and female headed household, proximity to the farmers' cooperative unions (FCUs), farmers who were, or intend to be, market oriented and are early adopters to serve as disseminators, farmers trained earlier by different projects (like FEED II, PAID and ADGG), untrained previously, and location (proximity for data collection, follow up and assessment) were also used.

Two woredas in each of the four regions, two kebeles (smallest administrative unit in Ethiopia, equivalent to a ward) in each woreda, and six farms in each kebele were purposely selected, resulting in a total of 96 smallholder dairy farms. The study protocol was reviewed and approved by Institutional Research Ethics Committee (IREC) of International Livestock Research Institute (ILRI). Written informed consent was obtained from the owners for the participation of their animals in this study.

2.1.1 Baseline study

After the research farms were selected a baseline study was conducted to assess feed resources and availability, feeding practices, and various aspects of dairy farm milk management on the farms. The survey and key participant interviews targeted small-scale dairy farmers and extension workers to inventory and catalogue their feeds and feeding practices, and milking management and milk handling practices.

2.1.2 Extension staff recruitment

Livestock Experts (LEs) for each woreda and Development Agents (DAs) for each kebele were recruited to support project activities in the study areas. Specifically, the DAs were selected for a Training of Trainers (TOT), assisted in the support and monitoring, participated in data collection, and conducted outcome assessments. Support and monitoring visits were scheduled so that each farmer was visited by the assigned DA once per week. This weekly visit was intended to reinforce the management practice lessons covered during the training. Monitoring included a survey of farmers to assess adoption of practices, quantity and quality of milk produced, practices used at the milk collection centers, and soliciting feedback on potential improvements. Specific variables of interests included milk production, milk quality assessment from the cooperative (including rejection rates), animal health, feed intake, and adoption rates of feed and management techniques.

2.2 Research design

The research design consisted of three treatments reflecting differing degrees of capacity building support: 1) no training and no

1 FEED was implemented with support from the USDA Food for Progress program, and PAID and ADGG projects were funded by Bill & Melinda Gates Foundation.

external support (Control), 2) training delivered by another project (PAID) but without material support, and 3) received enhanced training and material support (Feed-Mgt). In addition to their previous training by different projects (like FEED II, ADGG, etc.) or government extension services, farmers on treatment 3 were provided with enhanced trainings on feed production and feeding, dairy management, hygienic milk production, milk handling and processing, animal health, and record keeping plus support on formulated concentrate feed (Table 1) and supplied with improved forage seeds/seedlings to produce forage during year 1 followed by continuous advice, follow up and monitoring until the end of year 3. Control group farms received no training and no other support. Farmers on treatment 2 received training from the PAID project in year 1 or had previously as a standard part of the program. Persistence in animal performance improvement and farmer behavior change were monitored and data were collected for all treatments through to the end of year 3. To avoid heterogeneity of supplied formulated concentrate feed, all experimental feed required for the research was manufactured at the same feed mill and distributed to the 32 farmers (treatment 3) across the four regions. Supplied seeds/cuttings were oats (*Avena sativa*), vetch (*Vicia sativa*) and elephant grass (*Cenchrus purpureus*) that were acquired through FEED II affiliated nurseries. However, these planting materials were not supplied to all farmers in treatment 3 since some did not have a plot of land or were hesitant to allocate a plot of land to grow these forages.

A farm was considered the experimental unit. Due to the variability inherent in comparing different levels of crossbred cows, at least 32 farms per treatment were required to have an 80% chance of detecting a 20% difference in daily milk production (2 liters/day; P < 0.05). Based on previous training history, selected farmers per kebele were allocated to the three treatment groups. Farms were selected from different villages to avoid possible spillover effects likely to occur between farms within the same village.

TABLE 1 Ingredient and nutritional composition of concentrate feed.

Ingredient composition (%, unless otherwise stated)	
Ingredient	**Composition**
Wheat bran	19.5
Noug seed cake	48.0
Corn/maize grain	27.0
Molasses	2.0
Limestone	2.0
Salt	0.5
Premix Intraco Ruminant 1%*	1.0
Nutritional composition (%, unless otherwise stated)	
DM	90.6
Ash	8.3
CP	21.5
NDF	32.6
ADL	7.4
ADF	22.0
IVOMD	57.9
ME (KJ/kg)	8.1

*Contained per kilogram of premix: 2,000,000 IU of vitamin A; 400,000 IU of vitamin D3; 3,775 IU of vitamin E; 3,758 mg of Fe; 3,932.3 mg of Cu; 14,939.8 mg of Zn; 10,259.2 mg of Mn; 200. 9 mg of Co; 385. 0 mg of I; 52. 3 mg of Se.

2.2.1 Feed, management-related trainings, and genetics interaction

After the farm selection and baseline study were completed, and DAs were recruited training modules on feeds, feeding, and different dairy husbandry practices were developed or adapted from previously developed materials to reflect the local conditions

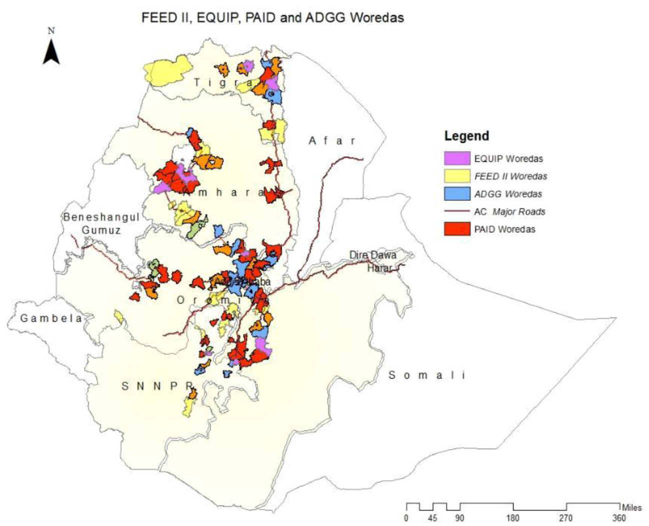

FIGURE 1
Study areas (the current study is represented by EQUIP).

and address the specific educational needs of the farmers. The training was divided into two levels. The first level of training was a Training of Trainers (ToT) targeting DAs and woreda livestock experts who were directly linked to farmers and supervise the DAs, respectively. This training lasted for 4 days, and an interactive training approach was used. In this approach, trainers were first exposed to basic information about the different training modules (Table 2) in a formal setting followed by guided assessment of actual dairies and development of a consulting report for producers to apply the knowledge gained in the formal setting. This method is believed to enhance the learning by trainers, but also to be a model for them to use in training producers at the farm level.

The second phase of training was given to farmers and lasted for 6 days. The curriculum for smallholder farmers was the same as that which was presented to DAs during the ToT. However, farmers were not asked to develop consulting reports; rather they were guided through specific improvements on their farms by the trainers. These training courses aimed at equipping farmers with knowledge, skills and practices in basic feeding and dairy management, health, and data recording, so that they could achieve higher milk yields with higher quality. This phase of the training was supported by modules, posters, brochures, and short videos. All the training materials were prepared in three local languages, namely Amharic, Afan Oromo and Tigrigna. Farmers were first exposed to the theoretical understanding of the module materials, posters and brochures followed by discussion and a short video presentation and finally practical show. At the end of the training farmers took the flyers and posters to their home to be used as a reference. The venue for this second phase of the training was at the respective farmer's home thus creating an opportunity for all family members of the household to be trained and to avoid the need for one or two members of the household to travel away from their home for such training. The ratio of trainer to trainees was one DA per household family member. The training in this research was more comprehensive with more detailed feed and management components included and more frequent (weekly) farm support visits and this is deemed as an enhanced training approach.

2.3 Data collection

During the study, DAs made visits to each farm per week. The visits were intended to provide advice and reinforce the improved practices and guide farmers in implementation of better feeding, data collection and other management practices covered during training to fully realize the genetic gain of animals. The monitoring also included a survey of farmers to assess the adoption of practices, quantity and quality of milk produced, and for soliciting feedback on potential improvements. Data collection on-farm included variables describing milk production, milk quality, and cow health. Each farmer was supplied with locally available and socially acceptable equipment to measure daily milk production of each cow. Besides, all farmers were also provided with paper forms at the beginning of each month to record daily milk production and quantity of supplemental concentrate fed. Then, training on data recording was offered to all farmers. Records were performed by farmers and checked by DAs during their weekly visit. Supplemental concentrate feed was either bought by some farmers in Control and PAID groups (treatment 1 and 2) and in this study

TABLE 2 Training modules used for the training of trainers (ToT) and smallholder dairy farmers.

Module 1. Feeds and feeding including feed troughs	Module 2. Keeping cows breeding and healthy	Module 3. Milking and milk post-harvest	Module 4. Dairy farm record keeping and housing
1. Fodder production & utilization • Fodder production strategies • Planting and managing forages • Selected improved forages and their recommended best practice • Division of family labor and role of gender in feeds and feeding	1. Natural mating versus artificial insemination • Selection of cows for breeding • Nutrition • Body condition score	1. Clean milk production and handling techniques • How to produce high quality milk? • Milk contaminants	1. Essential information for farm record keeping
2. Feed conservation • Hay making • Silage making	2. Detecting heat signs	2. Handling the milk • Milk equipment cleaning • How to keep milk cool	2. Calving and calf management • Calving • Calf management • Heifer management
3. Crop residue treatment	3. Keeping cows healthy • Mastitis • Milk fever • Vaccinations • Diarrhea and pneumonia in calves • Worm prevention • Tick control • Hoof problems	3. Small scale milk processing • How to make butter • How to take cream from milk • Preparation of cottage cheese • Roles of gender	3. Housing dairy cows • How to construct dairy barns
4. Concentrate feed mixing • Milking cows concentrate feed mixing options • Heifers and dry cows ration formulation • Calves and growers ration formulation			
5. Feeding dairy cows • Feeding roughage to cows • How to feed concentrate feeds to dairy cattle • Timely feeding of cows			

supplied for Feed-Mgt group (treatment 3). Though milk composition analysis was not done due to lack of laboratory facilities at or close to the study sites, quality was assessed based on organoleptic tests (visual inspection/appearance, and smell), hygienic characteristics (cleanliness and quality). It is established that good-quality raw milk must be free of debris and sediment, free of off-flavors and abnormal color and odor. Furthermore, butter quality was assessed based on indicators such as color, smell and consistency though there are no formally established standards and grades to determine the quality of butter.

2.3.1 Estimation of breed composition

Tail hair samples for genetic profiling were collected from all experimental cows and reference breeds, including samples from Arsi, Fogera, and Ethiopian Boran, all considered local indigenous breeds. Hair samples are easily collected and are amenable to long term storage at ambient temperature, making them the ideal sample for our purposes. All samples were sent to Neogen GeneSeek Operations (Lincoln, Nebraska, USA) for genotyping using the GeneSeek® Genomic Profiler™ Bovine 100K array that includes roughly 100,000 genetic markers.

Genotype data for 95,236 single nucleotide polymorphism (SNP) markers across the entire genome were generated for all the experimental cows and the reference breeds, i.e., both pure indigenous cows and pure Holstein cows. SNP markers with a minor allele frequency of less than 1% or with a calling rate of less than 95% were removed from the dataset. After quality control, a total of 86,957 SNP markers were retained for subsequent genomic analyses. The Genetic Relationship Matrix (GRM) was computed using the R package “gaston” by the formula XX’/q, with X the standardized genotype matrix and q the total number of SNPs. Note that the GRM is a symmetric square matrix of dimension equal to the number of individuals and each entry can be interpreted as an estimated kinship coefficient between individuals. The breed composition of the experimental cows was determined using Principal Component Analysis (PCA) executed in the R package “FactoMineR”. The PCA plot shows that the experimental cows cluster between the two reference breeds (indigenous breeds and US Holstein), and scores from the first principal component were used to calculate the exact Holstein composition of each experimental cow (between 0% and 100%).

3 Statistical analysis

Average milk production per week was analyzed using a linear mixed model implemented with the R package “nlme”. Note that in this first analysis farm was considered as the experimental unit. The statistical model included region, lactation, treatment, the interaction of region by treatment, week, the interaction of treatment by week, and farm as explanatory variables. An autocorrelation structure of the order 1 was used to model the residual variance-covariance matrix. Moreover, to evaluate the synergistic effects of breed composition and treatment on performance, average milk production per cow per week was also analyzed using a linear mixed model implemented with the R package “nlme”. Note that in this second analysis cow was considered as the experimental unit. The model included region, lactation, treatment, breed composition, the interaction of treatment by breed composition, week, the interaction of treatment by week, and cow as explanatory variables. Again, an autocorrelation structure of the order 1 was used to model the residual variance-covariance matrix.

4 Results and discussion

Demographic and some baseline farm characteristics of smallholder dairy farmers are presented in Table 3. The data

TABLE 3 Demographic and some baseline farm characteristics of the smallholder dairy farmers.

Parameter	Treatment		
	Control	PAID	Feed-Mgt
Age (year): Mean ± SD	47.7 ± 12.96	47.3 ± 13.20	47.5 ± 11.09
Gender: Number (%)			
Male	15 (22.4)	16 (23.9)	19 (28.4)
Female	8 (11.9)	3 (4.5)	6 (9.0)
Household family size (mean)	6.4	5.5	6.0
Education: Number (%)			
Primary school	11 (16.4)	7 (10.4)	13 (19.4)
Secondary school	5 (7.5)	9 (13.4)	8 (11.9)
College/university	2 (3.0)	0 (0.0)	0 (0.0)
Read and write	4 (6.0)	2 (3.0)	2 (3.0)
Illiterate	1 (1.5)	1 (1.5)	2 (3.0)
Family income from dairy farming: Number (%)			
Most important	9 (13.4)	9 (13.4)	13 (19.4)
Very Important	10 (14.9)	4 (6.0)	5 (7.5)
Important	4 (6.0)	4 (6.0)	5 (7.5)
Fair	0 (0.0)	0 (0.0)	2 (3.0)
Least important	0 (0.0)	2 (3.0)	0 (0.0)
Family income from other livestock: Number (%)			
Most important	1 (1.5)	0 (0.0)	3 (4.5)
Very important	6 (9.0)	6 (9.0	3 (4.5)
Important	12 (17.9)	9 (13.4)	15 (22.4)
Fair	3 (4.5)	3 (4.5)	2 (3.0)
Least important	1 (1.5)	1 (1.5)	2 (3.0)
Pastureland ownership: Number (%)			
Yes	16 (23.9)	14 (20.9)	20 (29.9)
No	7 (10.4)	5 (7.5)	5 (7.5)

given in this table show the percentages of the respondents interviewed, unless otherwise stated. There was no significant difference in the age of respondents. Most of the respondents (38%) were found to be in the productive working-age category of 18 - 55 years. This agrees with a previous study (Yohanis and Tilahun, 2021) that reported that a large proportion of dairy producers are up to age of 50. This implies the sector can provide job opportunities and serves as an income generation for a wide range of age groups. Both male and female-led dairy farms were purposively included in this study.

On-farm feed resources, consisting primarily of crop residues (straw and stover) and native grasses were the primary feed resources used as basal diet. Grass hay of medium to poor quality, mostly overgrazed communal pasture, agro- and milling by-products, and 'atella' (spent grains from home brewed beer) are some of the other feed resources identified in the study area. This agrees with other studies such as Tolera et al. (2012) and Gizaw et al. (2017), that reported crop residues as the major contributor to total feed supply followed by grazing, and the remaining was supplied by other agricultural and agro-industrial by-products, non-conventional feeds such as 'atella', and green feeds (such as weeds, sugarcane leaves, false banana leaves, etc.). These often do not meet maintenance, let alone production requirements. Formulated concentrates have been shown to improve dairy cattle performance (Assaminew and Ashenafi, 2015). However, most farmers in the study rarely supplement their cows with concentrates, mainly because of its high price and lack of local availability. They often provide saltwater solution-soaked wheat bran and oilseed cakes mixtures at milking time, presumably to encourage intake.

However, farmers assigned to treatment 3 were provided with inputs, specifically formulated compound feed (Table 1). Also, based on willingness of the farmers to allocate a small plot of land for forage production some farmers in treatment 3 were supplied with improved forage planting materials (seed/seedlings) necessary to compliment on-farm feed resources and optimize nutrition required for greater productivity, health, and reproductive performance. Though planted improved forages contributed to the total feed basket to a certain extent for those famers in treatment 3, it was difficult to quantify area of land planted, quantity fed, and proportion included in the daily basal diet. Because the type of improved forages adopted, and adoption rate varied from region to region. For instance, farmers in SNNP preferred perennial forages whereas farmers in central highlands (such as Oromia) favored annual forage crops mainly owing to the nature of the open livestock production system. During the dry season, other groups of animals are completely dependent on grazing on arable and pasture lands. In addition, farmers were also hesitant to grow the improved forages for all seasons. This is mainly because cultivable land is prioritized for food crops over forages, as forages are assumed to be less profitable than food crops.

The formulated compound/concentrate feed replaced grain and oilseed byproducts like wheat bran and noug (*Guizotia abyssinica*) seed cake typically purchased individually and mixed at home in varying amounts and fed (regardless of the production level of the animal) after being soaked in a saltwater solution. It should be noted that after our intervention, farmers adopted practices, such as feeding of cows according to production level and use of feed troughs. The mean milk production for each group weeks after intervention is shown in Table 4 and Figure 2. There was an effect of treatment ($P < 0.001$), treatment by week interaction ($P = 0.034$) on milk production and the effect of treatment markedly increases with time ($P = 0.032$; Table 4). It is evident that supplementation with improved feed substantially improved milk yield. The mean daily milk yield for treatment 3 in the current study was 11.1 L/day. That is, a net benefit in milk production for farms on treatment 3 of as much as 26.6% relative to controls was observed, and region and region by treatment interaction had no significant effect. This agrees well with the production level reported by Lobago et al. (2007) who evaluated lactation performance of smallholder crossbred dairy cattle in Oromia region. In contrast, 9.6 L/day in the Tigray region (Girmay and Gebrekidan, 2014), 5.1 L/day in North Shewa zone (Mulugeta and Belayeneh, 2013), 5.0 L/day in the central highlands (Zelalem, 1999), and 7.7 L/day in the Southwestern region (Belay et al., 2012) were reported. The relatively high maximum daily milk yield recorded from crossbred cows managed under the smallholder production level in the current

TABLE 4 Effect of feed, management-related trainings, and genetics on milk production (L/d) of dairy cows under smallholder farmers.

Treatment	Week	LSM	SE	Lower CL	Upper CL
Control	1	9.6	0.37	8.8	10.3
PAID	1	9.2	0.36	8.5	9.9
Feed-Mgt	1	10.5	0.32	9.9	11.2
Control	2	9.8	0.37	9.1	10.6
PAID	2	9.0	0.36	8.3	9.7
Feed-Mgt	2	10.9	0.32	10.2	11.5
Control	3	9.7	0.37	9.0	10.4
PAID	3	9.1	0.36	8.4	9.8
Feed-Mgt	3	11.2	0.32	10.6	11.9
Control	4	9.8	0.37	9.0	10.5
PAID	4	9.1	0.36	8.4	9.9
Feed-Mgt	4	11.7	0.32	11.1	12.4
Source		NumDF	DenDF	F- value	P-value
Baseline		1	72	889.0	< 0.0001
Region		3	72	0.8	0.5030
Treatment		2	72	11.7	< 0.0001
Week		3	241	3.0	0.0320
Region × Treatment		6	72	0.9	0.4890
Treatment × Week		6	241	2.3	0.0340

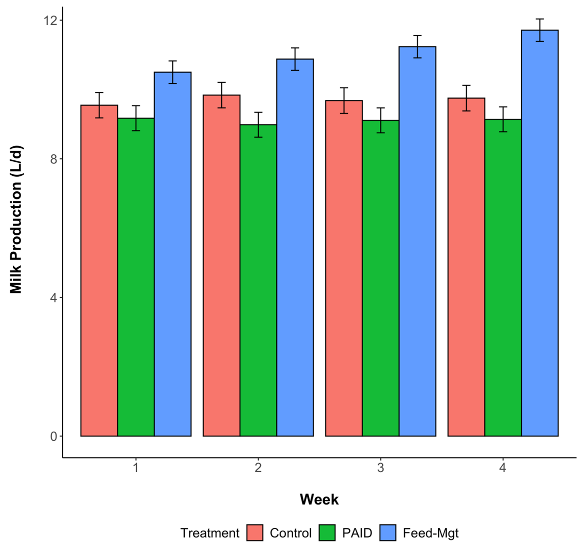

FIGURE 2
Milk production (L/d) per treatment per region weeks after intervention.

study clearly demonstrates that improved feeding and management (housing, use of feed trough and improved husbandry practices) allowed the crossbred cows to express their genetic potential to a greater extent. The results found in the current study were also higher than those reported for other tropical countries with mean daily milk yields of 6.6 L/day in Kenya (Muraguri et al., 2004) and 9.5 L/day in Tanzania (Msangi et al., 2005). The type and amount of improved feed supplemented, level of exotic genes and other management factors might have contributed partly to the difference among the studies.

Feeding 0.5 kg concentrate feed per liter of milk produced per day was cost effective if there was an increase in milk yield by at least 1.5 liter per day. On average supplementation increased milk yield by about 1.5 L/cow/d. In terms of cost, this was equal to 32 to 44.8 Ethiopian birr (ETB) at a price of 20 to 28 ETB for a liter of milk. The cost of feeding 0.5 kg concentrate feed per day was ETB 15.0 leaving a profit margin of 5.0 to 13.0 ETB which is cost effective under Ethiopian smallholder conditions. Other advantages gained by supplementation and reported by farmers were improved body condition, reduced number of services per conception in the treatment group (1 to 2 for treatment 1 versus 3 to 5 services per conception for treatment 2 and 3) and resulted in higher length of lactation as compared to other groups. Famers also indicated that the quality of butter has improved due to intervention (treatment 3). The butter becomes yellow-red which is preferred by buyers as compared to white butter in most of the study areas. This agrees well with the finding by Gebremedhin et al. (2014) who assessed butter value chain in Ethiopia. Regarding smell, farmers indicated that butter made from milk produced by cows in treatment 3 (Feed-Mgt) has got a pleasant smell.

The number of records (number of experimental cows) in each region per treatment and per breed composition is presented in Figure 3 Plot A and Plot B, respectively. Although the national recommendation for optimum exotic inheritance for high milk potential under favorable environmental and management conditions is 50% (Haile, 2006) and Beyene (1992) reported that Friesian crosses with exotic inheritance of 50 to 62.5% were

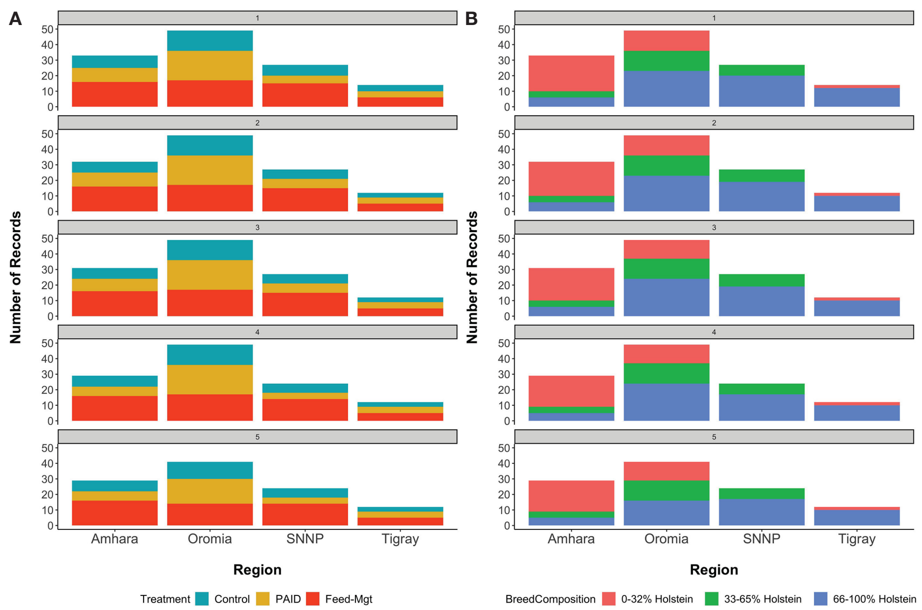

FIGURE 3
Number of records in each region per treatment (Plot A) and per breed composition (Holstein-Friesians; Plot B).

appropriate for smallholder dairy production in Ethiopia, our results revealed a large variation in breed composition, ranging from almost 0% to almost 100% Holstein (Figure 4). Of the cows involved in this study, about 33.9%, 18.6%, and 47.5% contained less than 32%, 33 - 65%, and greater than 66%, respectively, of Holstein genetics. This huge variation might be due to indiscriminate crossbreeding (Mengistu, 2019) and indiscriminate mating of indigenous cattle with exotic breeds (Alemayehu and Kebede, 2015) owing to either lack of appropriate breeding policy or binding breeding strategies (Desta, 2002; Alilo, 2019; Mengistu, 2019). Most of the cows in SNNP and Oromia regions, unlike Tigray and Amhara regions, had a large proportion (66 - 100%) of Holstein genetics (Figure 3 Plot B). This might suggest that feeding and genetic improvement for increased milk output interventions targeting smallholder dairy farmers should be implemented with breeding strategies adapted to the environment and production systems. However, it should be noted that this study did not characterize for genetics composition of cows for other exotic breeds like Simmental and Jersey.

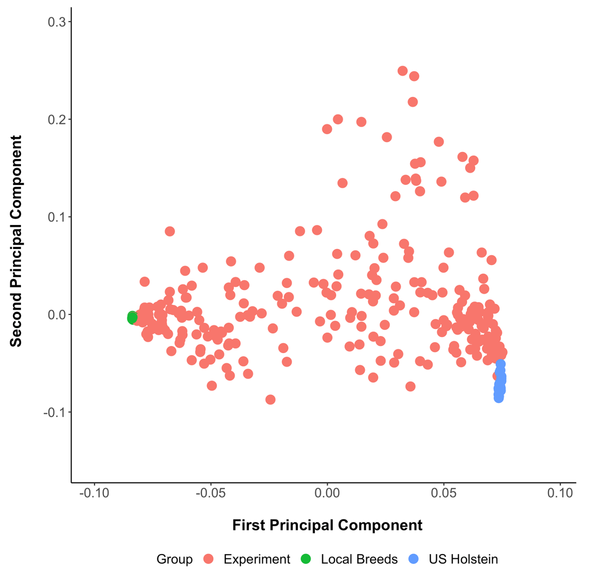

FIGURE 4
Principal component analysis looking at the breed composition (Holstein-Friesians) of cows in the study.

Daily milk production weeks after intervention per region per treatment is shown in Figure 5 and milk yield per region per breed composition is presented in Figure 6. Specially, milk production for treatment 3 in Oromia region increased 3 to 4 weeks after the beginning of the experiment as compared to the control group (Figure 7). As shown in Figure 6, at least in two regions, SNNP and Oromia, there is a clear relationship between milk production and breed composition, cows with a high proportion of Holstein genetics tend to produce more milk. This agrees with earlier studies (Tadesse and Dessie, 2003; Aynalem et al., 2009; Getahun et al., 2020) who reported that daily milk yield increases with an increasing proportion of exotic genetics. It clearly shows that there is an interaction between breed composition and training (treatment 2), and training, improved feeding, and breed

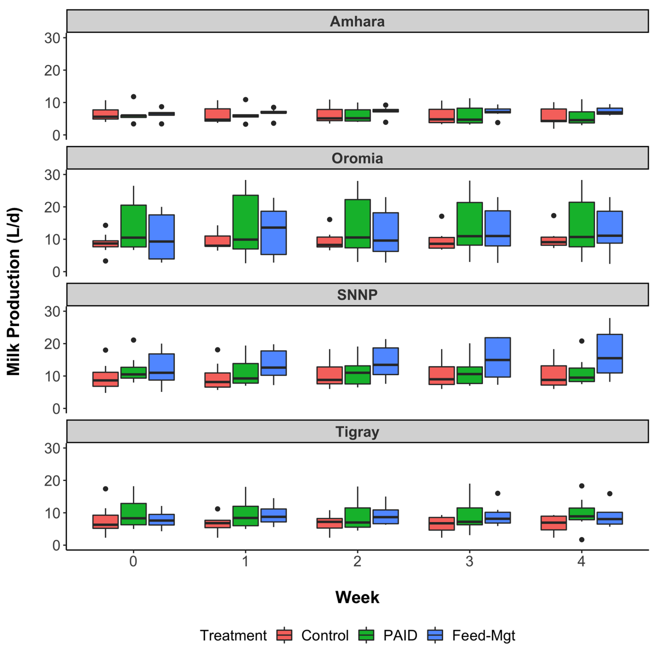

FIGURE 5
Milk production (L/d) per treatment per region weeks after intervention.

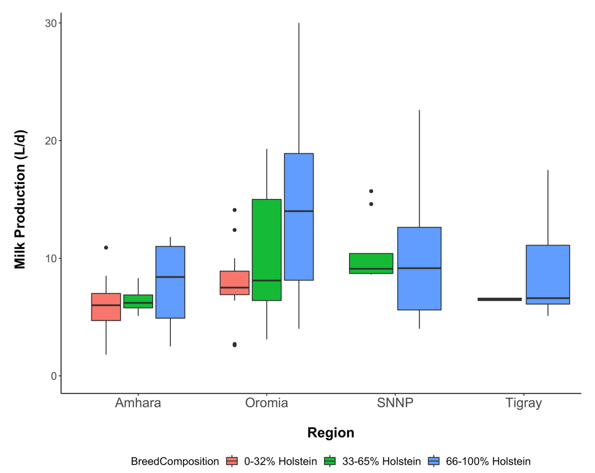

FIGURE 6
Milk production (L/d) per region per breed composition (Holstein-Friesians).

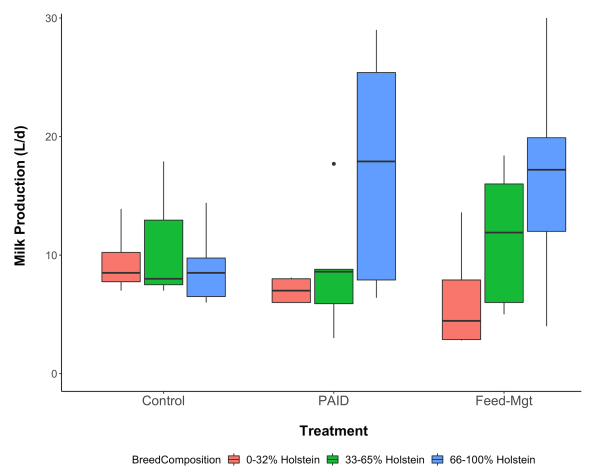

FIGURE 7
Milk production (L/d) in Oromia region 3 - 4 weeks after the beginning of the experiment.

composition (treatment 3) on the milk production. However, the reason for lack of the relationship in the other regions (Tigray and Amhara) is unclear.

Though it was observed that training and improved feeding increased milk yield and improved the adoption of practices, farmers in some study sites stated shortage of dry season forage, high cost of concentrate feed, unreliable insemination services, and low price of milk are the main limitations to improving milk production. But training of farmers in efficient feed utilization using improved feed troughs helped the farmers to reduce feed waste, feeding time and labor required to feed. Cows tended to eat more with the improved troughs because of less feed waste. However, the main challenge with the construction of improved feed troughs is lower perception of farmers about the benefits of the improved feed trough. Notably, after looking at farmers in treatment 3, other famers have approached the project team to make requests for the improved feed trough.

5 Conclusion

This study showed that improved feeding and management increased milk production of cross-bred cows. It indicates that interventions in Ethiopian smallholder dairy farms need to optimize feed and management training programs to match crossbreeding efforts to fully exploit the genetic potential of crossbred dairy cows. Findings from the current study will help extension agents as well as development project implementers to improve smallholder dairy training programs so that dairy farmers can manage highly productive cows in a sustainable and profitable way and supply both the household as well as communities with nutritious dairy foods.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material. Further inquiries can be directed to the corresponding author.

Ethics statement

The animal study was reviewed and approved by Institutional Research Ethics Committee (IREC) of International Livestock Research Institute (ILRI). Written informed consent was obtained from the owners for the participation of their animals in this study.

Author contributions

BH: Site selection, conceptualization, set up of experimental design, delivery of trainings, follow up of the experiment, data collection, and writing of original draft preparation. FP: Contributed to designing of experiment, data analysis, and revision of manuscript. MG: Project administration and revision of manuscript. CJ: Supervision, visualization, and revision of manuscript. GD: Contributed to designing of the experiment, and revision of manuscript. AA: Contributed to designing of the experiment, supervision, revision of manuscript, and funding acquisition. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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