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Cluster-based Improved Sorghum Production and Commercialization in Nyangatom Woreda of South Omo Zone, Southern Ethiopia

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Abstract: Cluster-based improved sorghum (Melkam variety) production and commercialization was demonstrated in Nyanghtom Woreda of the South Omo Zone for one year (2021) to improve agro-pastoralists' awareness, enhance the adaptation of full-package production technologies, and increase the economic visibility of improved sorghum cultivation. The production was started in a single kebele with a 7-hectare area of coverage. Twenty-five purposively selected direct beneficiaries and twenty-five randomly selected indirect beneficiaries from a neighbor were involved in the production. Direct beneficiaries cultivated sorghum on 0.28 hectares of land. At various stages of crop growth, monitoring, evaluation, and fieldwork were done by both beneficiaries and indirect beneficiaries. Face-to-face interviews with sorghum producers and non-producers were undertaken. Simple descriptive statistics were used to examine quantitative data, like grain yield, whereas the Likert scale was used for qualitative data such as agro-pastoralists perceptions. The result revealed that 30 quintal sorghum grain yield per hectare was obtained from improved sorghum (Melkam variety). The average return obtained from the sale of sorghum grain per hectare was 120,144 ETB. Agro-pastoralists' perception result revealed that the "Melkam" variety is a higher yielder, and early matured as compared to local. Therefore, cluster-based sorghum production should be promoted for local sorghum growers in order to improve sorghum production sustainability and also seed system should take into account the provision of improved Melkam variety seed.

Keywords: Cluster-based; Sorghum; Grain; Agro-pastoralist preference

1. Introduction

"Sorghum (Sorghum bicolor (L.) Moench) is a member of the Poaceae family and is the fifth most significant cereal in the world, behind wheat, maize, rice, and barley". It emerged in semi-arid tropical Africa and is now one of

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the most significant cereal crops farmed in arid and semi-arid regions of the world. Sorghum is a crop that is best suited for arid climates and countries with unpredictable rainfall because of its tolerance to drought. It may be cultivated in a variety of ecological circumstances, including ones that are adverse for most cereals [1]. Various domestic uses exist for sorghum grain such as making porridge, Nefro, baby food, syrup, and regional drinks like Tella and Areke for humans. "Moreover, its leaf and stalk are also used for animal feed and further the stalks are used for the construction of houses and fences and as fuel food".

South Omo Zone is one of the arid and semi-arid areas of Ethiopia and sorghum is the major crop produced in the area. The area coverage of sorghum in the zone is around 15,739.02 ha, the total production is 33,686.6 tons and the average productivity of sorghum is 2.1 $t \cdot ha^{-1}$ [2]. However, the productivity achieved is a lower yield that can be obtained under ideal management conditions (4.5 $t \cdot ha^{-1}$ to 5.0 $t \cdot ha^{-1}$) [3]. This yield gap needs research to improve production and productivity in the area. In response to this Jinka agricultural research center has conducted sorghum varieties and agronomic management experiments at Nyangatom and Dasenech woreda of the south Omo zone (2019 and 2020) cropping seasons and Melkam sorghum variety and its agronomic management which gave higher yield (3.3 $t \cdot ha^{-1}$ to 5.4 $t \cdot ha^{-1}$) were recommended for further production in the area. And other previous works by different scholars (Tekle and Zemach [4]; Fuad et al. [5]; Abebe et al., [6]; Melese [7]) focused on performance evaluation of sorghum varieties in arid and semi-arid areas to enhance productivity. However, less emphasis has been given to commercializing sorghum production as compared to other cash crops like cotton and banana. This might be due to a lack of awareness about the importance of producing sorghum at the commercial level. Therefore, the present study was conducted (1) to demonstrate improved sorghum variety and create awareness of a cluster-based approach along with its improved package and (2) to determine the profitability of Melkam sorghum variety production under irrigation conditions in South Omo zone, Ethiopia.

2. Materials and Methods

2.1 Study Area

The study was carried out in Nakriaman kebele, Nyanghtom district of South Omo Zone. The district is bordered on the south by Omo Kuraz, on the west by the Ilemi Triangle (claimed by Ethiopia, Kenya, and Sudan), on the northwest by the Bench Maji Zone, on the north by Salamago, and on the east by Hamer. The Omo River is flowing along the northern and western border of Nyanghtom. The district is located at 5°05'-5°21' North latitude and 35°55'-36°14' East longitude and the altitude lies between 380 and 497 meters above sea level. The total population of the district is estimated to be 11375 of those 11187 were male and 22562 were female [8]. "The majority of economic activity that has prevailed in the study area is low-input/low-output livestock and small-scale sorghum, maize, and banana production using flood irrigation from the Omo River". Cattle, sheep, donkeys, and goats are the main indigenous livestock species that have been kept in the study area.

2.2 Agro Pastorals Selection and Cluster-based Approach

A basic criterion to select a host kebele was land accessibility, irrigation facility, and agro-pastoral interest in growing sorghum for home consumption and seed production for future use. Consequently, Jinka agricultural research center established one improved sorghum-producing pastoral and agro-pastoral research and extension groups (PAPREGs), which contained about 25 direct beneficiaries and 25 indirect beneficiaries from Nakriaman kebele in collaboration with the district Pastoral and Agro Pastoral Affairs Office and Agriculture and Natural Resource Management Office. Of the total fifty agro-pastoralists, twenty-five were selected purposively as they were experimental units on which the experiment was conducted whereas the rest twenty-five were randomly selected from a neighbor so as to share experiences with direct beneficiaries.

Cluster farming represents horizontal and vertical interactions between related and neighboring farmers/agro-pastorals in agricultural production, processing, and marketing, and these interactions promote institutional innovations in support to reinforce farmers/agro-pastoralist in facing constraints; hence they achieve productivity improvement and are key for creating brand identities [9,10]. And also, cluster farming is important for smallholder farmers to use agricultural mechanization, supply inputs collectively, and create output market linkage, and has effects on some agricultural crop's commercialization in terms of productivity [11].

2.3 Site Selection and Agronomic Management

Each member of the pastoral and agro-pastoral research and extension group has allocated 0.28 ha of land, and a total of 7 ha of land per group were cleaned, plowed, disked, harrowed, and ridged 75 cm using tractors and corrected by laborers of the members. Sorghum seed was sourced from Jinka Agricultural Research Center and

sown by drilling with a seeding rate of 15 kg/ha at a 25 cm interval between rows. The use of improved input is one means of increasing agricultural production and productivity such as seeds, fertilizer, and chemicals. Thus, 50 kg/ha of NPSB and 50 kg/ha Urea at planting and 50 kg/ha Urea at knee height, 4 liters of Diaznole @5%, and 1 liter of Karate @5% were used for this demonstration activity. Besides, agronomic management such as thinning, weeding, irrigating, pest management, harvesting time, and post-harvest handling was conducted timely by the pastoral and agro-pastoral research and extension group with intensive follow-up of researchers and experts.

2.4 Training and Awareness Creation

Practically, on-farm training was given to agro-pastoralists, members of PAPREGs, and development agents of kebeles to create awareness and improve the associated skill gap on improved sorghum production. Mainly was provided on proper site selection, land preparation, sowing/drilling the seed, chemical application, fertilizer rate, irrigation frequency and time of application, and all agronomic practices.

2.5 Monitoring and Evaluation

Monitoring was conducted starting from land preparation till up to the final yield harvesting. During monitoring frequent contact with participant agro-pastoralists and kebele development agents, getting feedback, and providing technical advice were done. "A discussion was held among the stakeholders on the way forward, and some additional roles might be identified, and roles and responsibilities were shared for the next contributions along the production chain of improved sorghum production and cluster-based demonstration".

2.6 Field Day and Agro-pastoralist's Perception

At the end of the field activity (crop maturity stage) was conducted to further promote the sorghum production technology. As field day is means of agricultural extension events to accelerate the popularization of new or improved agricultural technologies to agro-pastorals, development agents, and key stakeholders. "A total of 148 agro-pastoralists (44 men and 104 women), 6 development agents and 19 experts from woreda agricultural offices, 12 researchers, and 37 different stockholders from federal and regional offices participated in field day". Besides, the field day program was transmitted on the news program by Debub television to disseminate information to the wider public. "A total of 250 leaflets were distributed to the participants which describe the production, agronomic practices, and overall management of improved sorghum varieties". Finally, at the end of the field day, a group discussion was held to grasp agro-pastoralists' feedback on the strength and weaknesses of the improved sorghum variety (Melkam variety). Besides, the demand for the Melkam sorghum variety has been created and most of the agro pastorals raised a timely supply of seeds. Moreover, the perception of participant agro-pastoralists was collected to know their awareness towards the improved sorghum production. Accordingly, agro-pastoralists' interest in the production of the Melkam sorghum variety was high mainly because of its uniformity, yield advantage, and early maturity characteristics. Data were collected by face-to-face interviews with 25 PAPREGs members who produced sorghum and 25 non-producers or research extension group using structured questionnaires prepared for this purpose.

2.7 Method of Data Analysis

Both qualitative and quantitative data were collected from early plantation to final seed harvesting and threshing. Qualitative data such as the agro-pastoral perception towards improved sorghum production and their varietal preference was collected. Quantitative data such as the cost of input items used and the amount of seed produced were collected. "The collected data were analyzed using simple descriptive statistics (percentage and mean) and the Likert scale. A benefit and cost ratio was used to analyze the cost of production and profit from the business enterprise".

3. Results and Discussion

3.1 Household and Socio-economic Characteristics of Pastoral and Agro-pastoral Research Extension Members (PAPREGs)

The household and socioeconomic characteristics of PAPREGs in the study area are presented in Table 1. The result on household characteristics revealed that the majority (52%) of sorghum producers were female-headed, while about 48% were male-headed agro-pastoralists. "It is obvious that in agro-pastoral areas of South Omo, the females are more involved in agricultural activities like planting, weeding, harvesting, and threshing than the males, aside from house routine activities such as preparing dishes, clearing house and barn, caring for children, fetching water and firewood". "This is because, culturally, males were paid more money during marriage time than female families, and they were considered slaves, allowing females to be more involved in agricultural activities than males". "They reported that most of the time, males

were involved in plowing land and herding cattle rather than planting, weeding, and harvesting". "Similarly, the studies reported by Hidosa & Ayele [12] from pastoral and agro-pastoral areas of Hamer and Bena-Tsemay districts in South Omo have shown that most of the time, females were involved in agricultural activities like planting, weeding, and planting, in addition to house routine activities, while the cattle were herded by males".

Concerning education level, the mean grade the sampled PAPREGs attained was grade two with minimum illiterate and a maximum grade of nine. This indicates that the education level of sampled PAPREGs is low and there is a dominance of illiteracy in the area as the study is a remote area. The minimum and maximum family sizes of households were three and nine. The average mean family size of the respondents who were involved in sorghum production in the study area was 6. The minimum was 3 and the maximum was 12. The maximum family size might be due to the polygamy practice of marriage in the area. Large family size in a family household contributes significantly to labor contribution during sorghum production and there is no labor shortage problem in the study area. The study by Adane et al. [13] reported that the average family size of 6.19 persons per agro-pastoral household in the Bena-Tsemay district of the South Omo zone. "Regarding sorghum production experience in the area, the findings of this study indicated that the minimum year of experience for agro-pastorals who have been involved in sorghum production was two years, while the maximum was 20 years, and on average about 4 years".

According to the study's findings, agro-pastoralists are not new to the production of sorghum, but successful production and getting profit from the production may depend on the availability of training and vigorous promotion. There could be up to five family members working together to produce sorghum, with two being the minimum and three being the norm. In order to conduct various farm management operations like irrigation, weeding, and harvesting to share among them, family participation in the production of sorghum is essential. The participation of family members in the sorghum production process is also crucial to expand employment options for unemployed household members, producing money, and reducing the number of unemployed family members, improving their means of livelihood.

3.2 Benefit of PAPREGs-based Sorghum Production

The advantages of being cluster-based sorghum-producing PAPREGs members are revealed by the response of beneficiaries. As indicated in Figure 1, about 32% of respondents said that growing sorghum, belonging to a cooperative, or being a member of PAPREGs allows them to earn a high income, while about 28% said that joining a cooperative is essential to exchange irrigated sorghum production practices and other experiences. Whereas about 24% replied that being in a cooperative is vital to share seed with other agro-pastorals or with each other and become seed sources for further sorghum production in the area. The remaining 16% of agro-pastoralists said that cultivating sorghum in PAPREGs gives them access to irrigation and other new technological access like chemicals and fertilizer inputs. "Several empirical studies have shown that agricultural cooperatives raise farm output by encouraging the use of productivity-enhancing technological options and thereby enhancing their collective bargaining power, which reduces the market risks they may face. Furthermore, they provide member farmers/pastoralists with financing options that raise productivity ceilings and are essential for the distribution of agricultural products like chemical fertilizers, seeds, and other inputs" [14,16,17].

Table 1. Household and socioeconomic characteristics of PAPREGs.

Characteristics of respondents	Minimum	Maximum	Mean	Std. Dev.
Age of household (year)	25	50	36.08	8.02
Family size (number)	3	12	6.44	2.18
Education level (grade)	0	9	2.24	3.31
Experience in sorghum production(year)	2	20	4.32	3.67
Member of household engaged in sorghum production (number)	2	5	3.22	1.08
		Frequency	Percent	
Sex of household	Male	26	52	
	Female	24	48	

Source: Own survey, 2022.

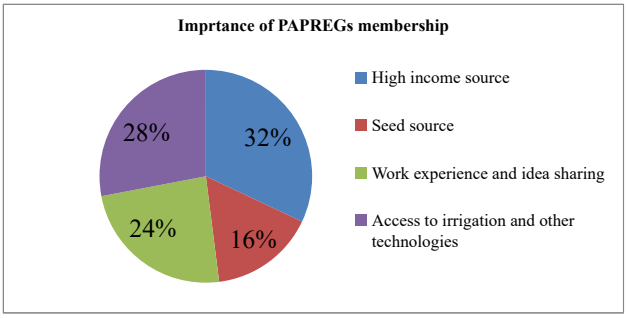

Figure 1. Importance of PAPREGs membership.

3.3 Status of Improved Sorghum (Melkam Variety) Production

Even though agro-pastorals had a long year experience

of in sorghum production, they hadn't used improved sorghum (Melkam) variety and only cultivate local sorghum variety which did not give better yield compared to improved variety. Recently Jinka agricultural research center introduced improved sorghum (Melkam variety) to enhance sorghum productivity thereby benefiting agro-pastorals in the area and the initial slow expansion of production now becomes accelerated. As from key informant discussion with woreda experts improved sorghum production had spread in the area and were incorporated into development plans by local governments (Agriculture and Natural resource management), Research Center (Jinka Agricultural Research center), NGOs (LLRP and FAO) and other development projects. PAPREG members who were involved in sorghum production were asked to reveal the lack of seed and about 52 percent of respondents revealed there are occurrences of lack of seed for production but not now. On the other hand, 8 and 40 percent of respondents reported lack of seed occurs sometimes and is not recently solved. Overall, it indicates lack of seed is not a problem now for the PAPREG members for their sorghum production but they revealed there is a yield reduction from year to year. Moreover, the main source of improved sorghum seed was Jinka Agricultural Research Center (76%), NGOs such as LLRP, FAO, and others who are working in the area (12%), and the rest 12% improved seed was supplied by Woreda Agriculture & Natural resource management office. This implies that Jinka agricultural research center is a highly contributing seed for agro-pastorals besides the demonstration of the improved sorghum variety in the area.

As seen in Table 2 below, all respondents have an awareness of the importance of improved sorghum and produce on their farmland. Agro-pastorals consider improved sorghum production as food for household consumption, livestock feeds mainly biomass and a source of income. About 80 percent of respondents reported that the benefits of producing sorghum were highly improving whereas 20 percent reported benefits slowly improving. This implies that the majority of respondents realized the importance of sorghum production as their livelihood improvement activity and food security. In addition, the Jinka Agricultural Research Center, Lowland Resilient Project, and Woreda Agriculture & Natural resource management office gave different training for the PAPREGs members and others on planting, irrigating, harvesting, threshing, and post-harvest handling. This awareness creation training helped agro-pastorals to produce sorghum and realized benefits. All PAPREGs members reported that they were taken training from Jinka Agricultural Research Center whereas about 40, 48, and 72 percent of respondents reported that they got training from Woreda Agriculture & Natural resource management office, pastoral field days, and LLRP, FAO, and other NGOs respectively. This indicates that agro-pastorals in the area are getting different pieces of training from different stakeholders.

3.4 Agro-pastoralists' Trait Preference

In the evaluation process at a different stage of the crop, both direct and indirect beneficiaries have participated. The selected traits of the sorghum variety for evaluation by agro-pastoralists were early maturity, high yielding, stalk palatability, panicle length, seed size, seed color, birds attack and plant height (Table 3). As indicated in the result, all agro-pastoralists confirmed that the improved Melkam variety is best in grain yield as compared to the

Table 2. Sorghum (Melkam) production status.

Attributes		Freq	Percent
Lack of seed	Yes it occurs often but not now	26	52
	Yes it occurs sometimes	4	8
	No, recently solved	20	40
Source of improved sorghum (Melkam)	Jinka Agricultural Research Center	38	76
	NGOs	6	12
	Woreda Agriculture & Natural resource mgmt.	6	12
Awareness of improved sorghum cultivation	Yes	50	100
	No	0	0
The benefit of cultivating sorghum	Highly improving	40	80
	Slowly improving	10	20
Training on sorghum production	Woreda Agriculture & Natural resource mgmt.	10	40
	Pastoral field days	12	48
	Jinka Agricultural Research Center	25	100
	LLRP, FAO, and other NGOs	18	72

Source: Own survey, 2022.

Table 3. Preference of agro-pastorals on improved sorghum (Melkam) with compare to local variety.

Relative weight	Grain Yield	Panicle length	Seed color	Seed size	Plant height	Early maturity	Bird attack	Salk palatability
Varieties	3	2	3	2	2	3	3	3
Melkam	4(100%)	3(100%)	4(80%)	3(80%)	3(96%)	4(100%)	0(80%)	3(88%)
Local	1(100%)	1(100%)	1(100%)	2(100%)	3(88%)	1(100%)	0(80%)	2(88%)

The total number of participants = 25 (5M & 15F). Rating of performance of a variety for selection criteria: Score for criteria 0 up to 4, 0 = similar, 1 = poor, 2 = good, 3 = better, 4 = best; Relative weight of selection criteria: 3 = very important, 2 = important and 1 = less important. The numbers in the parenthesis indicate the product of the relative weight of the selection criterion and the performance of a variety given by agro-pastoral.

local variety which has a poor grain yield. Moreover, all agro-pastoralists confirmed that an improved Melkam variety is best in early maturity while the local variety is too late and takes a long time to mature. Besides, all agro-pastoralists revealed there is no difference between improved Melkam and local variety on bird attack. This is in line with the findings of Hailemariam et al. [18], who used the same selection criteria to indicate farmers' preference for sorghum varieties traits.

3.5 Performance of Sorghum Technology's Yield and Yield Components

The result of the study revealed that the productivity of improved sorghum (Melkam variety) with its technology packages was better than the local variety with existing agro-pastoralist practice. Thus, the mean grain yield of improved sorghum was 30 quintals per hectare and the mean grain yield of the local variety was 10 quintals per hectare in similar production years in the study area (Table 4). This implies that improved sorghum (Melkam variety) had a yield advantage of 200% over the local variety. This greater yield advantage was achieved through the proper use of recommended technology packages such as the use of the improved variety, appropriate fertilizer, chemicals, seed rates, and good management practices. This yield result was in agreement with the study by Abady et al. [19], Kinfe & Tesfaye [20], and Birhane et al. [21]. The result also conformity with EIAR [22] "suggesting the positive effects of improved technology demonstrations over the existing farmer's practice towards enhancing the yield of sorghum with its positive effect on yield attributes". The minimum and maximum yield attained by each agro-pastorals from a plot area of 0.28 ha were 7.73 and 9.17 quintals whereas the mean yield was 8.4 quintals.

3.6 Economic Returns and Costs of Sorghum Production in the Study Area

Biomass

The biomass of sorghum was used for a different purpose by agro-pastorals in the study area. For instance, the fresh biomass of sorghum was used for livestock feed in the study area whereas the dried biomass of sorghum is important for house and fence construction, and is also used as firewood wood. However, it is not an easy task to value the biomass of sorghum to monetary value. Besides, there is no uniform amount of biomass produced by each PAPRG member and different usage form makes it not easy to value. So its monetary value was not added to the economic return of sorghum production in this study.

Grain Yield

During the demonstration season, researchers made regular observations and monitoring of agro-pastoral fields which motivated them to actively monitor, weed, and irrigate their sorghum plot. All recommended agronomic management including sowing and weeding was done at the right periods of the season. As illustrated in Table 4, the mean grain yield of the Melkam variety was 30 quintals, which was far greater than the grain yield of

Table 4. Yield data of sorghum produced by PAPREGS.

Beneficiaries	Land coverage (ha)	Average yield Q/ha	Total yield (Q/ha)
25 agro-pastorals	7	30	210
Per agro-pastorals	0.28	8.4	8.4
Per agro-pastorals plot of 0.28 ha	Min	Max	Mean
	7.73	9.17	8.4
Local variety per ha	1	10	10

Source: Own result, 2022.

the local variety (10Q) mostly because of the early maturing period and its productivity.

Input Items and Costs

Starting from land preparation, all input items utilized on farm plots and costs were recorded by researchers on a prepared data record sheet. Input items identified for analysis were the amount of seed (Melkam), type and amount of fertilizer (NPBS and Urea), land preparation cost by tractor, fuel for tractor and water lifting from the river, chemicals (Diaznole @5% and Karate @5%) and other of costs related to labor. Labor costs such as planting, irrigating, weeding, harvesting, and threshing were included in the analysis. However, labor costs spent on storing or other post-harvesting costs were not included in this study.

Consequently, cultivating sorghum from land preparation to harvesting and threshing or until getting grain yield costs incurred were seed (15 kg/ha), NPSB (50 kg/ha), Urea (100 kg/ha), land preparation cost by tractor including fuel and operator Perdium (8000 birr/ha), fuel for water lifting from the river (9956 birr/ha), Diaznole @5% (2400 birr/ha), Karate @5% (1200 birr/ha), first and second weeding (900 birr/ha) and harvesting and threshing (750 birr/ha) (Table 5). This substantial amount of tractor operator and fuel costs for both tractor and water lifting from Omo River reflect the increased cost of production in the area. They simply practice sorghum production when the Omo river overflows and they call this system of production Omo shesh. The study also revealed that the agro-pastoralist in the study area did not practice sorghum production with improved agronomic and recommended doses of fertilizers. While urea was applied in two splits—the first half during planting and the second half a month later at the height of tillering NPSB was applied all at once during the sorghum sowing. Where there is an abundance of land to cultivate but the problem with sorghum production is how to get water from Omo river or the lifting water (fuel cost) which is currently too expensive in the country. It is without a doubt a great idea to boost yield per unit area, but yield in and of itself should only be a goal if it can be sustained by an acceptable gross margin and profit to remain competitive and continue in the farming industry.

Thus, variable and fixed costs were recorded by researchers on the prepared data record sheet with the collaboration of producer agro-pastorals. To that end, the mean projected variable cost per hectare was 27856 birr. The greatest costs out of this ranged from 9956 birr/ha for fuel to pull water from the river to 9000 birr/ha for tractor fuel and operator, which account for 36% and 32% of the overall cost, respectively. Increased usage of better inputs is one way to provide greater agricultural output and productivity. In order to increase agricultural output, it is crucial to look into the cost structure of the inputs. Hence, seeds, chemicals, laborers, and fertilizers were relatively the lowest input items. For instance, since it only makes up 2.7% of the overall cost, the seed of the enhanced sorghum variety was a low-cost input. Due to the lower sorghum seed rate of 15 kg/ha, the contribution of seed to the total variable cost is incredibly low. The lowest costs were also incurred in planting, weeding, irrigating, harvesting, and threshing. This demonstrates that easy water listing technologies or solar systems need to be the focus of future research to boost sorghum output. This could be possible through the use of the effective solar system which has been practiced in other areas of Ethiopia or adopted from elsewhere.

Gross Margin or Revenue

A gross margin of a farm business is the difference between gross revenue which is the price multiplied by the yield obtained and the costs of variable inputs used. Gross margins and profit offer agro-pastoral the encouragement to admit new technologies and improve crop production and productivity. Greater gross margins and profit are the results of greater yield and better productivity, while the lesser costs per unit of products could most likely be realized through a mixture of farm input, and improved operation of inputs. Any modifications to technologies or practices depend on the financial benefit realized. Agro-pastorals who easily don't realize the innovative technologies are frightened of the financial threat that might be faced while investing in any business environment. To determine the financial feasibility of the innovative technologies in sorghum production, Melkam improved varieties along with its agronomic practices were verified and their gross margins were calculated. The amount of grain produced per hectare was one of the criteria used to calculate gross margins. All pastoral and agro-pastoral research groups confirmed that the Melkam sorghum variety gave greater grain yields and greater revenues per hectare than their local variety because it is the short maturing crop and short in size that it could be easily managed from bird attacks and minimize its costs of labor. Melkam sorghum variety gave a higher yield which is 3000 kg/ha. Thus, the result suggests that Melkam sorghum productivity in this area is a good and further expansion and availing water lifting devices to agro-pastorals are important.

Return

Return is simply the difference between the total income value of yield at normal market prices and total costs (total variable and fixed cost). In this study, variable costs included are the price of seeds, fertilizers, herbicides real amount used and the real amount of labor, fuel used for water lifting from Omo river and the fuel used for tractor and Perdium cost for tractor operator during plantation costs from the whole planting season were taken into consideration. Regular expenses known as "fixed costs" stay largely constant regardless of output level. In this study cost of land, and renting were only considered but it was not easy to calculate as other variable costs. However, we used the average current market land renting price per hectare for one year in a fixed term. Accordingly, estimated the current average market price of land in the study area is 2000 birr/ha/year. This cost estimate is 7% of total variable costs and the estimate falls out of adequate bounds of further lessons that inveterate. That fixed cost contributes 10%-15% of variable costs in smallholder farmers who operate at a low level of performance [23,24]. This might be due to ample land resources in the area and there is no land shortage problem in the area as it is a pastoral area. The mean return, which included the fixed cost, was 120,144 EB/ha. Farmers adopt new technologies and innovations, lower costs per unit of production, preserve soil fertility, and look for better marketing strategies as a result of rising farm profits [25].

Benefit to Cost Ratio

This study used benefit to cost ratio to confirm that new sorghum production technologies are appropriate and financially safe. Accordingly, the system of the input-output investigation indicates the benefit to the ratio of sorghum production technology as a beginning for its appropriate valuation and choice. The mean revenue from the sale of grain seed was 150000 birr/ha and the mean production cost was 29856 birr/ha. This implies that each household that engaged in sorghum production would get a profit of 120,144 birr/ha. Moreover, the benefit-to-cost ratio of sorghum production was 4.02:1, which demonstrates that each household gets a benefit from sorghum production nearly four times the cost of production. This result would encourage new agro-pastoralists to tend to start with sorghum production and area expansion to evaluate the costs and benefits of this profitable initiative.

Table 5. Economic returns and costs of sorghum production.

Cost items per ha	Unit	Quantity	Unit cost (ETB)	Total cost (ETB)
Seed	kg	15	50	15*50 = 750
NPSB	kg	50	15	50*15 = 750
Urea	kg	100	13.5	100*13.5 = 1350
Diaznole @5%	Liter	4	600	4*600 = 2400
Karate @5%)	Liter	1	1200	1*1200 = 1200
Land preparation by tractor	Operator & fuel	1	80000	1*8000 = 8000
Planting	Labor per day	6	50	6*50 = 300
Irrigation (2 times per week)	Labor per week	1	50	15days/3month*1*100 = 1500
Water lifting cost from the river	Fuel per liter	400	24.89	400*24.89 = 9956
1st weeding	Labor per month	10	50	10*month*50 = 500
2nd weeding	Labor per month	8	50	8*month*50 = 400
Harvesting/threshing	Labor per harvest	15	50	15*50 = 750
Total variable cost				27856
Fixed cost	Land cost per ha	1	2000	2000
Total cost				29856
Benefits (birr/ha)				
Grain yield	Quintal (mean)	30	5000	150000
Total revenue				150000
Gross margin				122144
Profit (birr/ha)				120144
Benefit-cost ratio				120144/29856 = 4.02:1

Source: Own survey data, 2021.

3.7 Lessons Learned and Suggestions Forward

As it is true that the PAPREGs organized in the area were rarely practicing sorghum production in the area and the selected area for sorghum production at the time was bare land. But the formations of PAPREGs make them work together and learn from each other. This helped the PAPREGs members to undertake all the crop management activities. The other is the use of improved technologies such as fertilizer and row planting which were not common in the area. So the PAPREGs team spirit and the influence of group members on one another made a sense of competition between members. So, the formation of the PAPREGs group is a main to for technology adoption in the area. And now PAPREGs members were expanding their production as well as other agro-pastorals nearby are adopting the technology (Figure 2).

Sorghum production in agro-pastoral areas has a dual purpose as feed for livestock and human consumption for food with high productivity. So, the production should be scaled out widely at every time without a season limit since there are opportunities for fertile land in every flowing Omo River in the area and also a provision of a skill gap training in practicing the technology.

Figure 2. Cluster-based improved (Melkam variety) sorghum production at Nakriaman kebele, Nyanghtom woreda.

4. Conclusions and Future Implication

The result from this study revealed that the demonstration of sorghum (Melkam variety) had offered superior performance in grain yield compared with the agropastoral practices and has highly improved agro-pastoralists' livelihoods as it was used for further seed production and home consumption. Pastoral and agro-pastoral groups involved in improved sorghum production are currently able to consume and use the seed for further expansion. The result also justified that the improved sorghum variety has shown a 200% of yield increment over the local variety which agro-pastoralists practicing using Omo shesh (use of water when Omo river overflows). Besides, the mean profit from sorghum production using irrigation per hectare was 120,144 EB/ha which would inspire new agro-pastorals to have a tendency to start with improved sorghum production. The host agro-pastoralists of the cluster-based demonstration also played a crucial role as a source of knowledge and high-quality seeds in order to distribute the improved variety of sorghum (Melkam) to other local agro-pastoralists. Therefore, the district's agriculture and rural development offices should scale out the Melkam variety to agro-pastorals and it is advisable that organize seed producer's cooperatives/groups in order to continually supply the seed of the Melkam variety and to ensure sustainable production.

Author Contributions

Mr. Awoke T. wrote and edited the entire manuscript in addition to writing the proposal, securing the funding, and conducting the research and data collection. Mr. Asmera A. took part in gathering socio-economic data, analyzing it, drafting the manuscript, and formatting it following journal guidelines. Dr. Tekle Y. and Mr. Anteneh T. took part in land acquisition, preparation, planting, and monitoring activities.

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Data Availability

The accompanying materials or the main text contain all the data, and upon request, the corresponding author will provide the raw data.

Conflicts of Interest

The authors pronounce that there are no encounters of interest regarding the publication of this paper.

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