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## RESEARCH ARTICLE

# Demonstration of Improved Banana (William-1 Variety) Production and Commercialization in Nyanghtom District of South Omo Zone, Southern Ethiopia

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**Abstract:** A demonstration of improved banana production and commercialization was conducted in the Nyanghtom district of the South Omo Zone to enhance the livelihoods of pastoralists and agro-pastoralists in the area. One improved banana variety (Wiliams-1) was used for the demonstration and planted on one hectare of land after training was given for purposively selected 25 trial pastoral agro-pastoral research and extension groups and 7 nontrial agro-pastorals from land preparation to harvesting. Relevant data through individual interviews and measurement of agronomic parameters were collected. The collected data were analyzed by descriptive statistics and Likert scale measurement of agro-pastoral preference. Based on the results, the mean banana fruit produced was 28.4 ton ha<sup>-1</sup> under agro-pastoral management and also agro-pastoral preference indicated that the variety Wiliam-1 was the first choice of agro-pastorals in all parameters except drought resistance. Cost-benefit analysis results indicated that the average net income obtained from banana production was 209,647 Ethiopian Birr ha<sup>-1</sup>. The cost-benefit ratio of 2.95:1 indicated that the benefit of production was nearly three times higher than the cost of production. However, agro-pastoral raised the frequent breakdown of water pumps, lack of operation and maintenance skills, and the high cost of fuel to operate generators and tractors were major bottlenecks to sustaining production. Therefore, strong efforts of respective stakeholders are needed to resolve irrigation water access problems for sustainable banana production and commercialization to ensure food security and improve the livelihoods of women and agro-pastorals.

**Keywords:** Banana; Agro-pastoral; Demonstration; Preference; PAPREG

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## 1. Introduction

The Banana (*Musa paradisiacal var. sapientum*) is one of the most popular monocotyledon herbaceous fruit plants which are grown throughout tropical humid areas<sup>[1]</sup>. In 2020, the world production of bananas was 120 Mt from the cultivating land of 5.2 million hectares<sup>[2]</sup>. It is the fourth-largest global food commodity and is considered to be one of the most important to food security for 400 million people in producing countries<sup>[3]</sup>. Banana fruits are known for their high nutritional values, sugar and vitamins A, B and C, as well as minerals, particularly potassium, calcium, sodium and magnesium<sup>[4]</sup>.

In Ethiopia, Banana production is concentrated in the southern and southwest regions and the major produce comes from small-scale growers for home consumption and the national market as well as a source of income. Recently, 898,354.81 tone bananas were produced from 95,954.13 hectares of land in Ethiopia and about 118,536.81 tones of banana production are found from 15,358.74 hectares in the Southern Nations Nationalities and Peoples Regional State (SNNPRS)<sup>[5]</sup>. On the other hand, banana production in the South Omo Zone of SNNR is mainly produced in home gardens and used for home consumption rather not for commercial purposes. However, recently the promotion of different irrigation systems, which is linked with the production of fruits and vegetables all over the country, banana production in the South Omo Zone especially in lowland areas is coming into outlining and a recent year later it is expanded to Dasenech district of South Omo Zone<sup>[6]</sup>. Because of the high temperature and exclusive access to Omo River banks, it is blessed with favorable soils for the production of fruit crops. However, beyond to use of those resources properly for crop production, residents are suffering for food insecurity<sup>[7]</sup>. Towards that, Jinka Agricultural Research Center (JARC) has introduced and evaluated banana varieties in the pastoral area of the South Omo Zone to alleviate food insecurity and nutrient deficiency problem.

The report of Jinka Agricultural Research Center's unpublished data indicated that Dwarf Cavendish and William-1 banana varieties were identified as high-yielding and adapted varieties in lowland areas of the South Omo Zone. But those selected improved banana varieties are not well promoted and commercialized all over pastoral areas of the South Omo Zone. Making use of improved technologies, adaptable crops, high-yielding cash crops and linking to market access may help to cope with food insecurity and would enhance the income status of the pastoral and agro-pastoral households in the area. To this end, Jinka Agricultural Research Center in collaboration with different partners is one of the major efforts extended

to promote and commercialize improved banana variety in the pastoral and agro-pastoral area of South Omo Zone. Thus, the objective of this study was to demonstrate improve (William-1) banana variety production in the Nyanghtom district of the South Omo Zone and to establish orchards for sucker multiplication.

## 2. Material and Methods

### 2.1 The Description of the Study Area

The present study is conducted at Nyanghtom district of the South Omo Zone, SNNPR in the year 2022/2023 cropping season. The district has 20 kebele administration (1 urban and 19 rural) covering 2652 km<sup>2</sup> and located at 4.850-5.670 N and 35.750-36.230 E. The total human population of the districts is 22,562, of which 11,375 are male and 11,187 are female according to population projection by the central statistical agency<sup>[5]</sup>. The population density is estimated to be 8 persons per km<sup>2</sup>. The district is bounded to the north by Bench Maji zone and Salamago district, to the south by Dasenech district, to the east by Hamer district, and to the west by Kenya and South Sudan. The agroecology of the district is lowland, with an altitude that ranges between 300 and 450 m.a.s.l. The mean annual temperature of the district ranges between 33 and 420 °C. The rainfall in the district is erratic and the mean annual rainfall ranges from 350 to 500 mm. Livestock production is the dominant livelihood source whereas beekeeping and fishing are also important income sources in the district. The second most important source of livelihood is opportunistic crop production with an overflow of the Omo River. But recently, sorghum, maize, haricot bean, onion and banana are the major crops produced in the area. More importantly, the district does have huge potential for the production of bananas due to the availability of the Omo River for irrigation.

### 2.2 Pastoral Agro-Pastoral Research and Extension Group (PAPREG) Member Formation and Identification of Technology Demand

Before the demonstration of this improved banana variety production and commercialization in the study area there was community-level problem analysis with the PAPREGs and non-beneficiary's pastoral and agro-pastoral research group members. In this regard, 25 pastorals were grouped into one PAPREG which was composed of 12 males and 13 females based on interest in the topic, willingness and capability of managing trials and consensus among the members. Group discussion with trial PAPREGs and non-trial agro pastorals was done to analyze the problems in the production and demand of the

PAPREGs for the technology.

### 2.3 Site Selection

The study site was selected in discussion with district experts of Livestock and Fishery Resources, Agriculture and Natural Resources, Pastoral and Agro-pastoral affair, Lowland Resilient Project and researchers of the Jinka Agricultural Research Center. One kebele was identified namely Narogoy for initial demonstration purposes and used for further teaching and learning of other kebeles which was taken into consideration the possibility of clustering of agro-pastoralist, land and irrigation access.

### 2.4 Design and Varieties

One selected banana variety (Wiliam-1) was planted with a single large plot that contain 100 \* 100 m. The land was divided into 25 equal parts with 12 \* 44 m for each PAPREG member. Row planting method was employed and spacing of 3 m \* 3 m between inter and intra-spacing. Full recommended management packages for banana production (improved variety, row planting, weed management, irrigation scheduling and, etc.) were conducted.

### 2.5 Training and Promotion Technique

The training on agronomic practices and irrigation water use was given to selected trial PAPREGs and non-trial agro-pastoralists, development agents and administrators of the kebele to enhance awareness and skills on field management and all other banana agronomic practices and postharvest handling before starting planting. The field visit was conducted just the crop is coming to the maturity stage. Trial PAPREGs members, non-trial agro-pastoralists, experts and other relevant stakeholders were invited to acquire experience and learn about improved banana cultivation.

### 2.6 Implementation Process, Field Management, and Follow up

First, the selected site was cleaned by human power and prepared for plantation using a tractor. A total of one hectare was ready for 25 PAPREGs, each having a share of 0.04 ha of land to plant. After land preparation was well done, holes of 60 cm in width, depth and length were manually prepared using a spacing of 3 m \* 3 m for square planting. Healthy 1111 suckers were planted at the prepared hole. Since the area is arid, irrigation was applied using furrow irrigation. Water was applied at 3-day intervals at the initial stage and once within a week after the canopy was covered uniformly. Re-shaping of holes

and earthing up around the crop was done to prevent the outbreaking of irrigated water and conserve water near the plant. Weeding was performed when weeds occurred. After planting the sucker, researchers from Jinka Researcher Center, and experts from the zone and district of Low Land Resilient project office conducted frequent follow-ups and evaluated the progress. Feedback regarding the weakness and strengths of each PAPREG were given to further improve the management and irrigation water access. This feedback gave the lesson to strengthen those with weak management of their plot and share good experiences with those with good management of their plot. Moreover, at different stages of production, regional coordinators of the Low Land Resilient Project and Southern Agricultural Research Institute conducted follow-up, and evaluation and gave feedback. All these coordinated efforts resulted in the successful demonstration and production of improved banana variety production in the study area.

### 2.7 Data Datasets and Recording

Important data sets collected include PAPREGs variety preference of improved banana, frequency of harvest, number of bunches per harvest, the total number of bunches per hectare, the weight of bunch per kilogram and the selling price of a one-kilogram banana. Data was collected by measuring each parameter with a data collection sheet and face-to-face interviews with PAPREGs using structured questionnaires. Moreover, lessons learned and feedback on important attributes of improved banana production technology were collected through group discussions with PAPREGs. The organization of groups was based on the interest of PAPREGs to participate in the discussion regarding improved banana production technology and the group constituted ten different social members such as elders, women and youth pastorals.

### 2.8 Data Reporting System

This study used both quantitative and qualitative data sets. Quantitative data includes frequency of harvest, number of bunches per harvest, the total number of bunches per hectare, the weight of bunch per kilogram and the selling price of a one-kilogram banana, and analyzed using simple descriptive statistics (percentage, mean and maximum and minimum). Qualitative data sets include PAPREGs' variety preference of improved bananas and constraints of banana production were analyzed using the Likert scale and ranking. The benefit-cost ratio was used to analyze the profit from the production of bananas in the

study area.

### 3. Results and Discussion

#### 3.1 Household Characteristics of PAPREGs

An effort was made to assess the household characteristics of the sample respondents as shown in Table 1. Consequently, about 46.9% and 53.1% of the PAPREGs of banana production technology were males and females respectively. This indicates that women were more participated than men in pastoral and agro-pastoral research and extension groups. Furthermore, the Low Land Resilient Project encourages women's participation in every activity they implement to improve their income-earning capacities. Different studies reported that women participate more than men in horticultural crop cultivation <sup>[8-10]</sup>. Moreover, the study by Hidosa et al. <sup>[11]</sup> reported that agro-pastoral women participate in panicum grass production more than men as they are nearer to providing live-stock feed. The mean age of the respondent was 36 years indicated the PAPREGs involved in banana production technology are productive. Regarding the education level of the PAPREGs, the mean grade achieved was grade one. This implies that the beneficiary's education achievement is very low and there is a dominance of illiteracy in the area as the study area is pastoral and agro-pastoral area. The minimum and maximum family size of PAPREGs was two and nine. The mean family size of the respondent was 6. This implies that family size in the household has some role in the labor force to engage in different income-generating activities like banana production in addition to livestock production activities. A similar finding was reported by Tadesse et al. <sup>[12]</sup> that the average family size of the households is 6 persons in the Nyangtom district.

It is clear that the district has huge potential for water and land resources for banana production using the Omo River, but yet they have not been involved in improved banana production. Recently Jinka agriculture research

center in collaboration with Low Land Resilient Project introduced improved bananas and demonstrated them to the agro-pastoral. Thus, the PAPREGs have one-to-two-year experiences in improved banana production. This implies that they are new to the improved banana production technology and enough training and strong support was provided to them to successfully produce and get benefits. The minimum, maximum and mean numbers of family members who engaged in banana production technology were 1, 7 and 3 persons. This implies that the banana production technology in the study area created more jobs for household members. Thus, household members who engaged in banana production technology generate income and reduce the number of family members who have no job thereby improving their livelihood.

#### 3.2 Banana Production Status and Its Importance on Livelihood Improvement

The production status of improved bananas is juvenile that previously they do not have a practice of improved banana production technology. However, they do have a small practice of local banana production using the Omo River for irrigation. As to key informant discussion with district experts planted bananas had also spread in the area and were incorporated into development plans by Pastoral and Agro-pastoral Affairs, agricultural office, Jinka Agricultural Research Center, Lowland Livelihood Resilient Project and other development projects. More importantly, the production area that banana early planted area was increased from one to three hectares. This implies that the demand for improved banana production technology is increasing and has some contribution to livelihood improvement for pastoral and agro-pastoral households. The PAPREGs who are expanding their land indicated that they are solving the sucker shortage problem in their area and selling and sharing the sucker with other neighboring agro-pastoral. As indicated in Table 2, all PAPREGs (100%) agreed that they don't have banana sucker access

**Table 1.** Household characteristics of sample respondents.

Attributes of respondents		Frequency		Percent	
Sex of household	Male	15		46.9	
	Female	17		53.1	
	Min	Max		Mean	Std. Dev.
Age of respondent (Year)	25	55		36	8.53
Family size (Number)	2	9		6.4	2.19
Education status (Grade)	0	11		1.27	2.98
Banana production experience (Year)	1	2		1.21	2.84
Household member engaged in banana production (Number)	1	7		2.53	1.43

Source: Own survey, 2023.



previously but now there is no sucker access problem in their area to produce and distribute. Inclusively, this indicates banana sucker shortage problem is not a problem now for both the PAPREGs and non-PAPREGs in the area. The reason for not cultivating previously was a lack of knowledge regarding improved banana production technology. As reported by PAPREGs, about 78.1, 15.6 and 6.3% were due to lack of sucker, awareness and support from different stakeholders respectively. Moreover, they indicated there are different benefits of cultivating improved bananas such as household income source, food and livestock feed. About 84.4 percent of PAPREGs reported that the importance of cultivating improved bananas was highly improving whereas 15.6 percent reported slowly improving. This implies that the majority of PAPREGs realized the importance of cultivating improved bananas as their livelihood improvement activity. This finding is identical to the findings of Adhikari et al. <sup>[13]</sup> who reported cultivation of bananas enhanced household income and improved the livelihoods of producers.

### 3.3 Household Income Analysis of Banana Production

As far as access to irrigation water is not a problem for agro-pastoral, it is easy to cultivate bananas using irrigation. Once they planted the banana sucker, they frequently water as per plant water requirement and effectively manage weeds, then they do have a continuous harvest of the fruit or duplicate the banana sucker to the surrounding. Once banana planting was established in the area, it has taken 9 months to cut the first banana fruit and later the average harvesting frequency was nearly 1.8 times in a year in the area if properly managed and access irrigation water. However, after first harvesting, later harvesting frequency depends on irrigation water access and weed management, and the minimum, maximum, and average harvesting frequency of improved banana per year in the study area is 1, 2 and 1.8 times respectively. The mean bunch produced per ha/year was 710 bananas bunch and

on average each weighs 22.2 kg. This means that the mean amount of bananas produced was 28,371.6 kg per hectare in the area under agro-pastoral management (Table 3). This indicates that the mean yield of bananas was 284 quintals or 28.4 tons per hectare which is a far better yield than in the study by Dawit and Asmare <sup>[14]</sup> who reported the mean productivity of bananas is in the range of 10 to 20 tons per hectare under farmer management. This might be due to the virgin land which is not previously cultivated, the favorable environment, improved variety, and irrigation water access.

The minimum and maximum price of bananas was 8 and 10 Ethiopian Birr (ETB) per kilogram respectively with a mean price of 9.73 ETB per kilogram. The mean sucker sold by an individual household in a year was 307 and the minimum and the maximum sucker were 125 and 550 respectively. Each sucker cost the mean of 14.5 ETB and the minimum and the maximum price per sucker were 10 and 20 ETB respectively in the production season 2022. The mean income from the sale of the banana fruit per hectare and the sucker was 276,055.7 and 4,551 ETB respectively in the production season 2022. The mean total income from the sale of the banana fruit per hectare and the sucker was 280,606.7 ETB in the production season of 2022. The minimum and maximum total income per individual household generated from the sale of the banana fruit per hectare and sucker were 61,250 and 571,000 ETB (Table 4). This implies that agro-pastoralists who were able to manage improved banana production effectively may generate a maximum income of more than half a million in a single production year per hectare and could harvest continuously as banana is a perennial fruit crop.

### 3.4 Cost of Improved Banana Cultivation

All costs of improved banana cultivation were recorded by researchers and experts at the implementation site. The main cost items recorded were planting material (sucker), site cleaning and land preparation, planting sucker, ir-

**Table 2.** Status of banana production in the area.

Attributes		Freq	Percent
Access to improved banana sucker	Yes, now	32	100
	No, so far	32	100
Reason for not cultivating banana	Lack of sucker	25	78.1
	Lack of awareness	5	15.6
	Lack of support	2	6.3
Importance of cultivating improved banana	Highly improving	27	84.4
	Slowly improving	5	15.6

Source: Own survey, 2023.

**Table 3.** Mean fruit yield and yield-related parameters of the improved banana variety.

Parameters	Min	Max	Mean
Day to 50 % of 1st cycle harvesting	268	290	279
Harvesting frequency per year	1	2	1.8
Bunch produced/ha/year (number)	500	875	710
Weight of bunch (kg)	15	32	22.2
Fruit yield per hectare (tone)	7.5	56	28.4

Source: Own survey, 2023.

**Table 4.** Income from improved banana cultivation/ha/year.

Attributes	Min	Max	Mean
Total fruit yield/ha/ year (tone)	7.5	56	28.4
Price of banana per kg (ETB)	8	10	9.73
Sucker sold per household/ha/year (number)	125	550	307.5
Price per sucker (ETB)	10	20	14.8
Income from the sale of a fruit per hectare (ETB)	60,000	560,000	276,055.7
Income from the sale of sucker per hectare (ETB)	1,250	11,000	4,551
Total income (ETB)	61,250	571,000	280,606.7

Source: Own survey, 2023.

rigation, weeding management and harvesting. Thus, the average cost of improved banana production per hectare was 70,959 ETB. All the cost items purchased and labor per day prevailed by the current market price at the time of production season. The cost of the sucker was 16,665 ETB per hectare and also others all well described in Table 5.

### 3.5 Net Income from Improved Banana Cultivation

Table 6 describes the net income of banana cultivation in the study area. The average net income obtained from banana production in one production season was 209,647 ETB per hectare in the study area. This income is the income obtained after the first harvest that has taken nine months after planting and later continuous harvest. This

indicates that any agro-pastoral who participated in improved banana production would have a mean net income of 209,647 ETB per hectare. Besides, the ratio of benefit to cost (2.95:1) indicated that agro-pastoral households may get benefit from improved banana production nearly three times higher than the cost of production. This finding suggests that agro-pastoral households who invest in improved banana production would get better income in a single production season and further expand the production of bananas using suckers around the mother plant. And also, this is the most profitable business in the area that would encourage new agro-pastoralists to start with improved banana production to absorb the benefits of this profitable initiative. This finding is in line with others that banana cultivation is an economically profitable investment because of the higher positive returns earned<sup>[15-17]</sup>.

**Table 5.** Cost of improved banana production per ha.

Expense items	Measurement	Quantity	Unit cost (ETB)	Total cost (ETB)
Sucker	Number	1111	15	1111*15 = 16,665
Land preparation	Fuel by liter	150	69.36	150*69.36 = 10,404
Planting	Person per day	25	100	25*100 = 2,500
Irrigation	Round	50*4	100	50*4*100 = 20,000
Weeding management	Round	10*15	100	10*15*100 = 15,000
Harvesting	Frequency	1.8*710*5	100	1.8*710*5 = 6,390
Total cost				70,959

Source: Own survey, 2023.

**Table 6.** Net income from banana production.

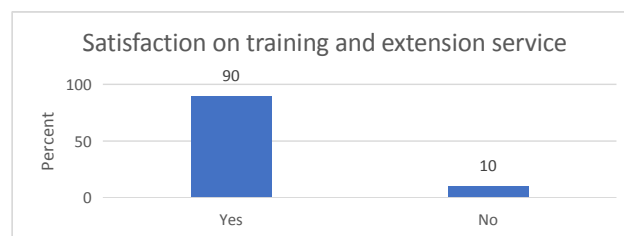
Income and cost of production	Mean (ETB)
Gross income	280,606.7
Cost of production	70,959
Net income	209,647.70
Benefit: cost ratio	2.95:1

Source: Own survey, 2023.

### 3.6 Extension Services and Training on Improved Banana Production Technology

Access to extension services has been improved over time due to a result-oriented extension approach in which agro-pastoral could see the yield difference of introduced banana production technology compared to the local one. Implementation of any new agricultural technology needs an effective approach and PAPREGs need to be conscious and responsive to effectively use the given technology and also has got information through extension agents<sup>[18]</sup>. Information sources about improved agricultural technologies are development agents, agro-pastoral-to-agro-pastoral and experience sharing in the district. As shown in Figure 1, they indicated that the training and extension service on improved banana production technology by the Jinka Agricultural Research Center, lowland Livelihood Resilient Project and District Office of Agriculture was very important. Thus, the training helped them to cultivate improved banana and realized benefit through income generation and household food sufficiency. In addition, about 90% of the PAPREGs reported they are satisfied with the training and extension services provided by different stakeholders whereas 10% did not satisfied. As

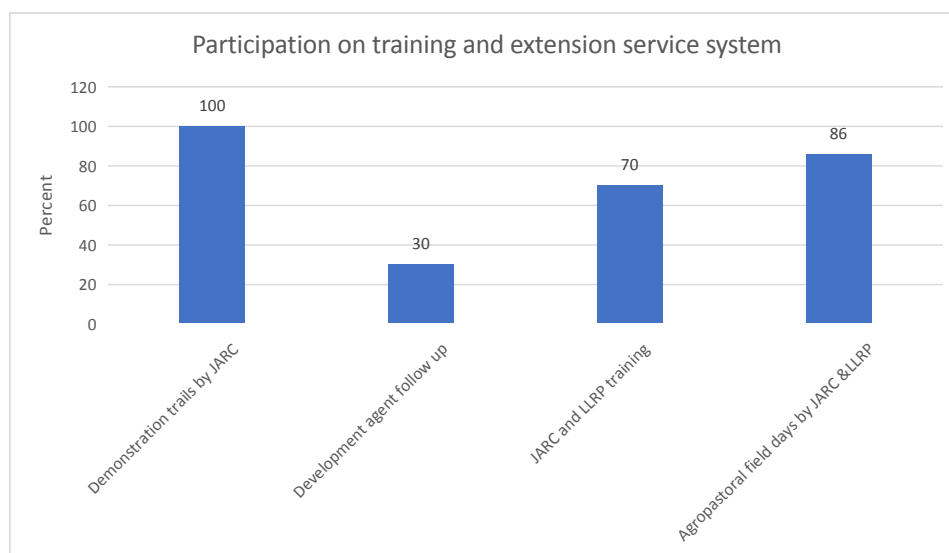
presented in Figure 2, all PAPREGs (100%) participated in the banana demonstration trail by Jinka Agricultural Research Center whereas about 30% of the respondents get extension services from development agents. This indicated that the extension provision regarding banana production by the development agent is weak. Moreover, about 70% of both trial PAPREG and non-trial agro-pastoral were involved in the collaborative training by the Jinka Agricultural Research Center and Lowland Resilient Project whereas 86% of the respondents participated in final pastoral and agro-pastoral field days. This shows that pastorals and agro-pastoral in the area are participating in different pieces of training from different stakeholders.



**Figure 1.** Satisfaction with training and extension services.

### 3.7 Agro Pastoralists' Trait Preference for Improved Banana Production

The objective of the demonstration is not only to maximize yield but to improve PAPREGs' involvement in selecting technologies that fulfill their preference for sustainable technology diffusion<sup>[19]</sup>. Thus, agro-pastorals identified six common preference parameters to compare improved bananas (William-1 variety) with local variety. The parameters were weighted according to their impor-



**Figure 2.** Method of training & extension delivery system.



tance to be used as a comparison, then technology with a greater percentage of the total was selected as the primary choice. The overall weighted ranking matrix result shows that improved banana (William-1) was the first choice of agro pastorals in all parameters except drought resistance whereas their local variety is the first choice only in drought resistance (Table 7). This implies that their local variety is not productive as the improved one but they still appreciate the local variety in drought resistance as compared to the improved variety. However, as the study area is agro-ecologically classified as dry land and described by recurrent rainfall shortage and their production practice of banana is with irrigation from Omo river by motor pump. Agro-pastoral given high score for early maturation, disease resistance and marketability of improved banana as compared to the locally available banana variety.

### 3.8 Constraints of Banana Production

The frequent breakdown of water pumps is the main constraint that hinders the production of bananas in the area. As the production is based on irrigation water access and lack of water due to pump breakdown order the plant to dry. Thus, the pump and generator breakdown are ranked as the first serious problem and operation and maintenance skills in irrigation systems are a basic necessity for sustainable use of the water lifting device and accessing water for production. The high cost of fuel to operate generators and tractors is another constraint that hinders the production of bananas and is ranked as the second most serious problem. As they are agro-pastoral, they are not capable enough to purchase fuel and the supporting organization in the district are getting on a budget shortage as the recent price of fuel is so high. The study by Asmera et al. <sup>[18]</sup> and Hidosa et al. <sup>[11]</sup> reported that the high cost of fuel is the changing factor of

panicum production in the Dasenech district. On the other hand, the lack of skills in the maintenance of generators and water pumps is the third important constraint that hinders banana production in the area. Thus, a lack of operation and maintenance skills in irrigation systems for water lifting devices may cause the failures of sustainable production using irrigation and may be associated with food insecurity problems in irrigation-based production-dependent areas. Extensive drought is the key factor that causes the banana to dry and hinders sustainable production. The PAPREGs reported that the recurrent drought is the fourth serious problem that hinders banana production and lets them to food insecurity. Market linkage is another important constraint of banana production as output markets are the main driving force for the products to be sold <sup>[20-22]</sup> and ensure the economic feasibility of irrigation projects and ensure sustainable production and economic returns. Failure of the market for irrigation-based agricultural products like bananas may cause the failures of irrigation projects and challenges the sustainable use of irrigation. Lastly, they reported that the lack of enough training and support on the production and irrigation of water by districts and stakeholders hinders banana production in the study area (Table 8).

### Important lesson

Promotion of new technology to pastoral and agro as-tral through the PAPREG approach was very important for easiness of communication and contact with any number of PAPREGs at once to demonstrate improved technology. Moreover, it was effective for common problem identification, practical and participatory way of working on the ground, creating awareness and ownership of that technology, sustainable use of demonstrated technology and strengthening the team spirit between PAPREG, extension workers and researchers for the common objective.

**Table 7.** Preference of agro-pastoral on improved banana (William-1) and local variety.

Parameters	Improved (William-1)			Local		
	score	weight	score*weight	score	weight	score*weight
Early maturity	3	1	3	1	1	1
Disease/pest/resistance	3	2	6	1	2	2
Taste	3	3	9	2	3	6
Fruit size	3	5	15	1	5	5
Drought resistance	2	6	12	3	6	18
Marketability	3	4	12	2	4	8
Sum of Score*weight			57			40
Rank			1			2

Score = (1 = Fair, 2 = Good, 3 = V. Good) & Weight = (1 = Early maturity, 2 = Disease resistance, 3 = Taste, 4 = Marketability, 5 = Fruit size, 6 = Drought resistant).

**Table 8.** Constraints of banana production in the area.

Constraints of banana production	The level of constraints					
	Very serious	Medium	Serious	Score	Index	Rank
The generator and water pump break down	22	8	0	87	0.196	1
High cost of fuel to operator generator and tractor	16	14	0	81	0.182	2
Market linkage problem	6	20	4	67	0.151	5
Lack of skills in maintenance of generator & pump	12	18	0	77	0.173	3
Lack of training and support	12	6	12	65	0.146	6
Extensive drought	7	19	4	68	0.153	4

Note: The value is given for the level of constraints: Very serious = 3, Medium = 2, Serious = 1.

#### 4. Conclusions and Recommendation

The finding of this study indicated that the demonstration of improved banana production and commercialization in the areas has improved the economic status of the PAPREG and non-trial agro-pastoral and contributed to reduce the food security issues through the sale of banana fruit, sucker and feed biomass of bananas after harvesting. Moreover, the PAPREG approach to the demonstration was effective as it is an easy way of identifying practical problems on the ground, creating awareness, ownership of that technology, sustainable use of demonstrated technology and strengthening the team spirit among PAPREG members. The mean banana fruit produced was 28.4 tons per hectare in the area under agro-pastoral management. The average net income obtained from banana production in one production season was 209647 ETB per hectare in the study area. Besides, the ratio of benefit to cost (2.95:1) indicated that agro-pastoral households would get benefit from improved banana production nearly three times higher than the cost of production. Moreover, the agro-pastoral preferred improved banana (William-1) over the local in all parameters except drought resistance whereas their local variety is the first choice only in drought resistance. However, agro-pastoral raised the frequent breakdown of water pumps, lack of operation and maintenance skills, and the high cost of fuel to operate generators and tractors are major problems to sustain production. Therefore, strong efforts of respective stakeholders are needed to resolve irrigation system problems mainly the supply of easy water lifting devices for sustainable banana production and commercialization to ensure food security and improve the livelihoods of women and poor agro-pastoral in the area. Additionally, it could be concluded that PAPREGs should be involved in further expansion and linked with different market outlets like ETFRUIT and other national or regional markets to enhance their income.

#### Author Contributions

Mr. Atlaw Eshbel developed a proposal and defended, secured the budget, conducted the field experiment, trained beneficiaries and arranged field days, collected all field data, analyzed, and interpreted the result, and wrote the manuscript. Mr. Asmera Adicha prepared data collection sheets, collected data, analyzed, and interpreted the result, and wrote the manuscript. Mr. Anteneh Tadesse secured land, conducted the field demonstration, and arranged the field day and field data collection budgets. Mr. Awoke Tadesse was involved in planting, monitoring and evaluation, arranged field day and collected all field data. Yibrah Geberemeskel was involved in monitoring and evaluation, field day events and arranged field data collection budgets.

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#### Data Availability

Data used for this study are available in the text and can be accessed from the corresponding author upon request.

## Conflict of Interest

There is no conflict of interest among authors.

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