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Pre-scaling up evaluation of banana technology under irrigation conditions in Abergelle District, Wag-himra Zone, Ethiopia

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Summary: The study was conducted to compare the improved banana technology against the local production technique to enhance demand-driven banana technology up-scaling and diffusion. Data were collected at the field and farmers' levels. Descriptive and inferential statistics, cost-benefit analysis and matrix ranking were employed for analysis. The result revealed that the average yield (38.40 ton ha^{-1}) of improved banana technology had a significant yield advantage (47.24%) over the local practice ($p<0.05$). Despite the higher cost of production, its net return was by far higher than the local practice. The benefit-cost ratio also displays that 9.49 Ethiopian Birr (ETB) profit per 1.00 ETB investment in an improved technology package. The overall farmers' perceptions were laid under strongly agree and agree categories, and 95% of them believed that the improved banana technology was appropriate for their area and hence accepted with full confidence. The respective organizations working on rural livelihood improvement are therefore advised to up-scale the improved technology for the wider community based on the irrigation potential.

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Key words: 'Butazu' banana variety, irrigation potential, improved technology, pre-scale up

Introduction

Banana *(Musa acuminata colla)*, a fruit plant of the genus *Musa* belonging to the family *Musaceae* is a perennial herbaceous plant native to Southeast Asia but grows in the warmer areas of the world. (Menkir & Bekele, 2007). Banana ranked as the major top ten crops in the world next to maize, rice, wheat, cassava, and potato. It is also considered a major export fruit, widely consumed and a source of employment opportunity for millions of people (Arnarson, 2019). Banana has crop cycles of 3-5 months and it is a semi-perennial crop under optimum conditions and even longer with lower temperatures or more erratic water supply. Banana production globally increased from 69 to 116 million tons on average from 2000-2002 to 2017-2019 (German et al., 2015). Ethiopia has diversified agro-ecologies suitable for the production of different banana varieties. The most important banana varieties grown in Ethiopia are 'Dwarf and Giant Cavendish, Robusta and Butuzua cavendish, Poyo, Williams and Grand naine' (Woldu et al., 2015).

Banana-producing farmers use furrow irrigation in dry seasons for supplementation and maintain their fields until the yield starts declining and then they start a new plantation in another plot (Zinabu, 2019). The fruit contains a good source of nutrients and minerals and has great health benefits of digestion, heart health, and weight loss, and highly convenient snack food (Chandrashekhar, 2019). It contains soft and digestible flesh having humble sugar, i.e., fructose and sucrose important to replace energy and revitalize the human body instantly. Because of this wonderful benefit, athletes have been consuming bananas to get immediate energy and using them as supplemental food for underweight children (Koeppel, 2008).

Even though Ethiopia has suitable agroecology for the production of bananas, the sub-sector has been challenged by a lack of improved cultivars, lack of skilled manpower in horticulture, and post-harvest losses (Gebre-Mariam, 2003). On the other hand, the government of Ethiopia has given attention to the commercialization of horticulture and training of young people in horticulture, higher local, as well as international market demand, government attention to modern irrigation construction, are good opportunities for banana production (CSA, 2020). The coverage and productivity of banana in the Wag-himra zone are by far lower than the national and regional average ***(Table 1)***, and it does not satisfy the market demand of the zone thus banana is imported from the southern part of Ethiopia (CSA, 2020).

Because of the above factors, Sekota Dry-land Agricultural Research Center has conducted an adaptation trial of different banana varieties in the last few years and recommended the 'Butazu' variety with its production packages (improved banana technology, hereafter) to the lowlands of the Wag-himera zone. Therefore, this study was conducted for five consecutive years to compare the improved banana production technology against the local method of production, thereby enhancing demand-driven banana technology up-scaling and dissemination in the study area.

Table 1. Disaggregated area coverage of fruit crops and banana cultivars in Ethiopia.

Locations	Land coverage		Productivity of banana (kg ha^{-1})
	Fruit crops (ha)	Share of banana (%)	
Ethiopia	161,470.82	59.43	8516
Amhara region	5,823.79	1.5	2271
Wag-himra zone	46.35	0.35	1028

Source: CSA, 2020

Materials and methods

Study area description

The study was conducted in Abergelle district of Wag-himra zone ***(Figure 1)***. The district is found in the Northeastern part of the Amhara region in Ethiopia and is located at 13°20′N and 38°58′E latitude and longitude, respectively within an altitudinal range of 1150-2500 m.a.s.l (Mihiretu et al., 2019a). Its annual temperature ranges between 23 ºC and 43 ºC, while the average annual rainfall varies between 250-750 mm. About 85% of the district's agroecology is characterized as lowland *(kola)* having low and erratic rainfall distribution annually (Mihiretu et al., 2021). The rainy season of the district is too short, hence determined as the late-onset (starts in early July) and early offset (ends in late August). The study district has about a 17.29% share of the total (16 240 ha) irrigable land in the Wag-himra zone (Mihiretu et al., 2019b).

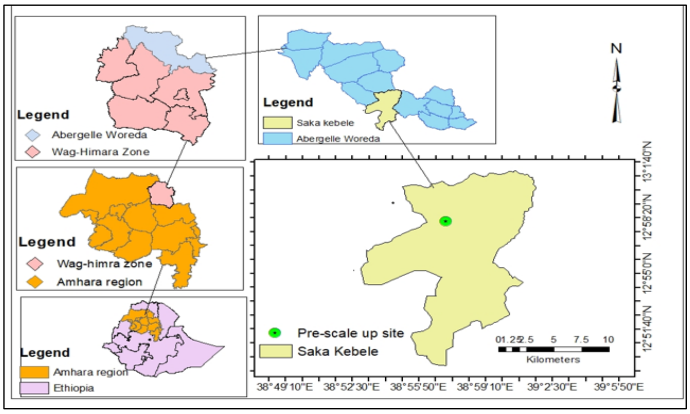

Figure 1. Map of the study area.

Farmer selection and responsibility-sharing

Two-stage sampling method was employed to select the study units. In the first stage, Abergelle district was purposively selected based on banana production potential in moisture-scarce areas. In the second stage, the irrigated farmlands and host farmers were selected jointly with horticultural experts and researchers considering the irrigation potential and interest to implement the experiment based on the recommendation (Mihiretu et al., 2020). In combination, 82 (14.6% female) farmers were selected to host the evaluation. A familiarization workshop was done with stakeholders to create awareness before the implementation of the study. The farmers and experts are hence trained about the agronomic practices of bananas and the general extension approach. Main stakeholders (farmers and Development Agents (DAs)) were identified and signed a memorandum of understanding (MoU) to take responsibility for the evaluation process (***Table 2***).

Table 2. Duties and responsibilities of stakeholders involved in banana technology evaluation.

Researchers	**Farmers**	**DAs**
Provide training	Prepare planting pits	Identify farmers and plots
Confirm selected plots and irrigation sites	Planting, weeding and harvesting on time	Provide technical support
Deliver inputs on time	Maintain sucker quality	Follow-up and monitoring
Provide technical support	Transfer suckers for interested farmers	Contact with researchers
Organize field days	Evaluate the technology	Follow-up disease outbreaks
	Provide plant information	Facilitate sucker exchange

Experimental materials and implementation

One introduced banana cultivar against the local genotype was evaluated in Abergelle district for five (2014-2018) years. Banana production under improved management technology (Banana production method using introduced new 'Butazo' variety applying di-ammonium phosphate and urea at the rate of 300 g per mat per year in three equal splits, while weeds were controlled by hand hoeing.) and farmers' existing practice (Production technique using local 'Dinke-1' banana cultivar without commercial fertilizer and weed management rather use of animal manure for fertilization.) were thus compared in the participatory approach. The experiment was laid out in a simple block design considering farmers as replications (Mihiretu, 2019). Averagely, 15 plants of each cultivar were planted on each plot per farmer. The plants were spaced at 2.5 m x 2.5 m (Alemu & Dagnew, 2008), providing a population of 1600 plants ha^{-1} in the first year, and three different aged plants (parent, first ratoon (sucker) and second ratoon (sucker)) per mat in the remaining two years. Irrigation (watering) was applied through furrow within 3 days interval (Dagnew & Belew, 2013).

Data collection and analysis

Both quantitative and qualitative data types were collected. Quantitative data such as plant growth and yield attribute records and qualitative data like fruit quality characteristics and perception were collected for two crop cycles and averaged (Mihiretu & Assefa, 2019). The measured growth parameters were days to flowering and days to fruit filling. Yield and yield components were bunch weight (kg), number of hands per bunch, number of fruits per bunch, fruit length (cm) and fruit girth (cm) and total fruit yields (ton ha^{-1}). Bunch and finger weights were measured using balances. Fruit length was measured using a measuring tape while fruit diameter was measured by a digital caliper at the middle of each fruit perpendicular to its large axis (Zinabu, 2019). The collected data analyzed using mean, percentages, and frequency. Paired sample t-test was used to note the significant difference between improved and local banana production practices. The yield advantage was assessed using Eq. 1. Technological and extension gaps and technological index were estimated using Eq. 2, 3 and 4 in the order provided (Mihiretu et al., 2019).

$$\Delta Y = \frac{Ys - Yb}{Yb} \times 100 \quad (1)$$

$$TG = Ys - Yb \quad (2)$$

$$\mathrm{EG} = \mathrm{PY} - \mathrm{Ys} \quad (3)$$

$$\mathrm{TI} = \frac{\mathrm{TG}}{\mathrm{PY}} \times 100 \quad (4)$$

Where, ΔY = change of yield, Ys = yield of improved technology, Yb = local practice yield, PY = potential yield, TG = technological gap, EG = extension gap and TI = technology index.

To assess the profitability of improved technology over the local practice, economic variables were calculated using Eq. 5 and 6. Variable cost is the cost that varies with changes in output while total revenue is total income obtained by multiplying the quantity sold by unit price. Technologies that have more than one benefit-cost ratio are profitable (Mihiretu & Assefa, 2019).

$$\mathrm{GM} = \mathrm{TR} - \mathrm{TVC} \quad (5)$$

$$\mathrm{BCR} = \frac{\mathrm{TR}}{\mathrm{TVC}} \quad (6)$$

Where, GM=gross margin, TR=total revenue, TVC=total variable cost, BCR=benefit-cost ratio.

To draw the farmers' perception of technology preference, sensory attributes and consumer acceptability of fruits from treatments, color, texture, taste, earliness, disease reaction and general acceptability were scored by panelists using a five-point Likert scale (1-1.8 = strongly disagree, 1.8-2.6 = Disagree, 2.6-3.4 = Neutral, 3.4-4.2 = Agree, 4.2-5 = strongly agree). The scale scores of each attribute were computed in a simple ranking matrix (De Boef & Thijssen, 2007).

$$\sum \frac{N}{n} \quad (7)$$

Where, N is a value given by the group of farmers for each treatment based on the selection criteria**,** and n is the number of selection criteria used by farmers.

Secondary data was also collected from different research documents, websites, zonal and district agricultural office reports for triangulation with the findings.

Results and discussion

Plant growth and performance

There were highly significant differences ($p \leq 0.05$) among treatments in survival rate, days to flowering, days to fruit filling, bunch weight, number of fruits per bunch and fruit length. On the other hand, treatments did not show significant variations in the number of fruits per bunch and fruit girth (***Table 3***). The yearly survival rate of planted suckers was 94.84%, which shows improved technology's better survival trend. The better survival rate of improved technology may be directly associated with the application of recommended production package components. The improved technology was the earliest to flower, and had a short duration for harvest; shorter time to flower, it was also early maturing. This result is consistent with the finding of Goncalves et al. (2018) who reported that the improved method of banana production reduces the days to maturity and shortens the time from flowering to harvest. The improved technology gave an average bunch weight of 24 kg, which brings a yield difference of 11.34 kg per bunch from the locally available banana production technique. The variance in time taken to shooting, shooting to bunch maturity and from planting to harvest could be explained predominantly by innate genetic variability attributes of improved and local cultivars. The maturity period and acceptable eating quality attainment at the early stage of development are vital agronomic attributes of bananas (Njuguna et al., 2008).

The average yield of improved banana technology was 38.40 ton ha^{-1} while the local technique had 20.26 ton ha^{-1}. The paired t-test value in ***Table 3-4*** shows that the improved technology has a 47.24% yield advantage over the local practice ($p<0.05$). The result confirmed that improved technology could enhance the productivity of bananas and the income of smallholder farmers. The technological gap of 18.14 ton ha^{-1}, revealed that the banana production problem could be overcome by adopting the improved varieties with their production package components. On the other hand, the extension gap of 7.2 ton ha^{-1}, exhibits that it was impossible to replicate the yield attained at the research site in a real farm context. So, a lower technological index (39.78%) depicts the feasibility of improved banana technology in the farmer's context. To bridge the gap between developed and transferred technology, there is a need to strengthen the extension network on top of providing attention to environment-specific technological recommendations (Mihiretu et al., 2019b).

Profitability and comparative advantage

According to CIMMYT (1988), yield in farmers' real context is lower than the yield at research sites despite the same technology. Therefore, the yield obtained from each treatment was adjusted by 10%, and the farm gate price was taken as the selling price (Abeje et al., 2016). Sucker production is also an additional income source for banana producers. The participant farmers were sold suckers from the improved banana technology and got 25-50 birr per sucker on average. Similar variable costs were assumed as constant and the benefit-cost ratio was computed on a hectare based. The result revealed that the total variable cost of farmers' practice was lower than the improved banana production technology. The improved technology provided 718 114.17 ETB ha^{-1}, while the farmers' practice gave 242,397.9 ETB ha^{-1} (***Table 5***). The benefit-cost ratio of 94.9%, hence suggests that for every 1.00 ETB investment in improved technology, farmers can get an additional income of 9.49 ETB after recovering the initial cost of 1.00 ETB. This finding agrees with Mihiretu & Wubet (2021) who conveys that using improved production technology is profitable as compared to the farmers' production technique.

Smallholder farmers' banana production is mostly for the market and small for consumption (Ostertag et al., 2005). The main market places were the district town *(*Niruak*)* and Zonal town *(*Sekota*)* which are 17 km and 50 km far from the production site, respectively. The main road linking Sekota with Mekele (city of Tigray regional state) is crossing a banana-producing site, and that creates a good market opportunity for producers.

Table 3. Comparison of growth performances of improved and local banana production practices across crop cycles.

Treatments	Plant growth performance							
	SR (%)	DF	DFF	BW (kg)	NHPB	NFB	FL(cm)	FG(cm)
Improved variety	94.84±1.02	379.5±1.22	405.5±71.65	24±2.75	9.0±1.43	187±12.98	22.8±1.22	3.95±0.39
Local variety	72.36±1.42	416.0±1.38	411.9±15.38	12.66±3.96	10.57±2.09	147.23±39.98	12.9±1.38	3.4±0.10
Std.	22.48	36.5	6.4	11.47	1.57	39.77	9.9	0.55
t-value	2.04	3.46	0.24	2.01	0.23	1.06	1.18	0.19
Sig.	0.042**	0.002***	0.034**	0.016**	0.135	0.001***	0.023**	0.167

Where, SR=Survival Rate, DF=Days to flowering, DFF=Days to fruit filling, BW=Bunch weight, NHP=Number of hands per bunch, NFB=Number of fruits per bunch, FL=Fruit Length and FG=Fruit girth.
Note: ***, ** are significant levels at 1% and 5%
Source: Field Survey, 2014/15-2017/18

Table 4. Yield performance and gap analysis of different banana production practices at Abergelle district.

Treatments	Range yield index (ton ha^{-1})	Mean yield (ton ha^{-1})	Std.	t-value	Sig.	Technology gap (ton ha^{-1})	Extension gap (ton ha^{-1})	Technological index (%)
Improved	22.42 – 46.48	38.40	3.64	2. 98	0.001***	18.14	7.20	39.78
Local	14.60 – 28.58	20.26						

Note: *** is a significant level at 1%
Source: Field Survey, 2014/15-2017/18

Table 5. Profitability and comparative advantage of different banana production methods.

Cost-Benefit Items	Treatments	
	Improved	Local
Adjusted yield (ton ha^{-1})	345.6	182.30
Income from sucker (ETB ha^{-1})	375	-
Total return (ETB ha^{-1})	725,760	246,110.4
Cost of fertilizer (ETB ha^{-1})	3933.33	-
Labor cost for the package (ETB ha^{-1})	3,712.5	3,712.5
Total costs that vary (ETB ha^{-1})	7,645.83	3,712.5
Gross margin, GM = TR-TVC	718,114.17	242,397.9
Cost-Benefit Ratio, CBR = TR/TVC	94.9	66.3

Working hour per day = 8 hours
Time to package practices = 220 hours per year ha^{-1} (220/8=27.5 days)
Local banana selling price per kg = 13.5 ETB
Improved banana selling price per kg = 21 ETB
Average field wage rate of labor = 135 ETB/person
Price of fertilizer in ETB per kg =12.5
1 ETB (Ethiopian Birr) = USD 27.8

Source: Field data (2017/18)

Table 6. Farmer's preferences and perceptions of different banana production methods.

Preference parameters	5-point Likert score		Statistical test		
	Improved	Local	Std.	t-value	Sig.
Color	4.80	4.00	0.80	0.024	**
Texture	4.40	4.20	0.28	0.124	ns
Taste	4.40	3.80	0.60	0.032	**
Earliness	4.60	3.60	1.04	0.002	***
Disease reaction	3.20	3.28	0.02	0.102	ns
Marketability	4.60	4.22	0.24	0.140	***
Low perishability	3.80	3.60	0.02	0.042	**
Labor intensive	3.95	4.24	0.34	0.218	ns
Ease applicability	3.86	4.00	0.23	0.123	ns
General acceptability	4.60	3.86	0.84	0.034	**
Total score	41.81	38.8			
Mean	4.18	3.88			
Rank	1	2			

Source: Our survey, (2017-18)

Perception and technology preference

Mean scores and standard deviations were calculated for all five-point Likert Scale items to measure farmers' perceptions (Mihiretu, 2019). The overall farmers' perception laid under the categories of strongly agree and agree, which shows that the farmers have accepted the improved technology with full confidence (***Table 5-6***). Despite statistically significant difference ($p \leq 0.05$) in color, taste, earliness, marketability, low perishability and the general acceptability parameters, the simple ranking matrix result revealed that farmers had confidence in both improved and local banana production methods. The reason for the price difference and higher market demand for improved banana technology was due to the large fruit size and good taste. The applicability of new technology has played important role in adoption and intensity. As a result, 95% of farmers believed that the new banana technology is easily understandable and appropriate for their marginal lowland area. More than 80% of farmers prefer to use natural fertilizer over commercial due to easy availability and lower cost. This result is in line with Zinabu (2019) who indicated that due to the higher cost of artificial fertilizer, farmers instead apply animal dung and compost to their banana fields as organic fertilizers at planting. In the end, field days were organized involving different stakeholders to visit and evaluate the production methods. The participants preferred the improved technology for its earliness, color, marketability and low perishability. However, the improved banana technology was criticized for its poor disease tolerance across seasons.

Conclusions

The improved banana production technology provided a higher yield and net economic return than the local method of banana production. The improved technology was fully accepted by farmers with full confidence, thus demand for the improved technology was created for stakeholders during the field day to promote and disseminate in potential irrigation areas. The finding hence underscores further up-scaling of the improved technology to other areas having similar agro-ecology and irrigation potential. Detailed training also should be given to farmers and local experts on sucker management and improved banana technology to create sustainable sucker sources and technology multiplication for future users.

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