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RESEARCH ARTICLE

Yield and Profitability Analysis of Orange Flesh Sweet Potato (*Ipomoea batatas* (L.) Lam.) Varieties at Different Rates of Blended NPSB Fertilizers at Central Ethiopia

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ABSTRACT

Sweet potato (*Ipomoea batatas* (L.) Lam) is one of the economically important and food securing root crop in Ethiopia. Fertilizer has a greater effect on the yield of sweet potato crop. A field experiment was conducted at Qebena Woreda, Rekaboka kebele to evaluate the effect of four different rates of NPSB fertilizers (0, 75, 150, and 225) kg/ha on the yield of the three orange fleshed Sweet potatoes varieties (OFSP) (Kebode, Alamora and Dilla). The experiment was arranged in 3 x 4 factorial randomized complete block design with three replications. The analysis of variance revealed that the interaction effect of the varieties and NPSB rates were highly significantly influenced the vine number, internode length, shoot fresh and dry weight, and total tuber number per plant. However, a number of leaf per plant, shoot fresh weight, shoot dry weight, total tuber number per plant, root fresh weight, and root dry weight were resulted significantly the highest difference due to the main both effect of both variety and fertilizer ($P < 0.01$). Statistically, the highest number of leaf per plant was obtained from Dilla combined with 225 and 150 kg/ha (659.72 and 632.22), respectively. The Dilla variety with 225 kg/ha resulted significantly highest difference in both shot fresh and shoot dry weight (1526.10 and 6466.67 kg). Kebode with 150 kg/ha resulted significantly highest difference in root fresh and dry weight (22762 kg) and (20524.7 kg), respectively. The Kebode, which received 150 kg/ha of NPSB scored the highest marketable tuber number (5.00) and the least unmarketable tuber number (1.22). Significantly, highest different total tuber number was scored in the Dilla with no NPSB fertilizers application (8.22). Root fresh weight was significantly the highest different in Kebode, which received 150 kg/ha (22762 kg), and followed by the kebode variety with 225 kg/ha. The Root dry weight was significantly the highest in the Kebode × 150 kg/ha (20524.7 kg), 225 kg/ha NPSB (17978.4 kg), respectively. The Total tuber yield was significantly the highest in the Kebode with 150 kg/ha (20.52 tonha). The analyzed partial budget for the average of the whole treatments was resulted in the highest MRR at the Kebode, Dilla, and Alamora, which received 150 kg/ha with 238.57%, 125.29%, and 144.49%, respectively. The highest marginal rate of return 238.57% was obtained in Kebode with150 kg/ha. The Overall 150 kg/ha NPSB was recommended with the Kebode in terms of yield per hectare for the highest significant yield. However, further studies should be needed for the remaining OFSP varieties for yield improvement with respect to the different rates of NPSB fertilizer.

Key words: Biomass, economic analysis, NPSB fertilizer rates, sweet potato varieties

INTRODUCTION

Sweet potato (*Ipomoea batatas* (L.) Lam) is an herbaceous dicotyledonous plant with creeping,

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perennial vines and adventitious roots, and belongs to the Convolvulaceae family.[1] It is originated in Central America of Mexico which is a center of diversity.[2,3]. It is widely grown throughout the tropics and warm temperate areas of the world.[4] Globally Sweet potato is the seventh most important food crop after wheat, rice, maize, potato, barley, and cassava.[5] While in Africa, it is the second most important root crop after cassava.[6,7] The orange fleshed sweet potato (OFSP) varieties have high β-Carotene and potentially reduces the effects of Vitamin A deficiency. OFSP is currently at high demand in all developing countries. They have been popularized in Ethiopia through different approaches, hence, resulted in high demand for more OFSP cuttings.[8] In Ethiopia, sweet potato is also economically important food crop, and it is the second most important root crop after Ensete.

The crop is mostly used for human consumption either alone or blended with other crops.[9] It is widely grown in Sidama, Southern Ethiopia, and Oromia Regions. Especially Wolayta and Gamo Gofa zones are well known for their production of sweet potatoes and they are heavily depend on this crop for food security.[8,10,11] Growth of sweet potato plants was significantly increased with increasing P rate from up to optimum[12,13] Nitrogen up to 45N kg/ha enhance vegetative growth to the optimum.[14,15] Applications of N and P to the optimum level significantly increase the tuber length and the diameter.[13,14] Application of P is very important on the growth and the productivity of sweet potatoes; as P fertilizer application positively enhanced sweet potato yield as compared with control[16,17] Plants supplied with adequate amounts of P were reported to form good root system, strong stem, matured early and gave high yield (Rending and Taylor, 1989). The total tuber yield (TTY) of sweet potato increased significantly with up to optimum application of boron.[18,19]

The potential yield of sweet potatoes reached up to 50 ton/ha on the research station with improved agronomic practices.[20] Sweet potatoes yield under the research field ranged from 30 to 35 ton/ha with improved cultivars.[13] Average yield of 37.1 ton/ha was obtained for the Bellala variety of sweet potato with the application of different fertilizers.[21] Abdissa *et al*.[22] reported that sweet potato yield was reach up to 64.4 ton/ha in the use of agronomic practices from the Bellala variety. Shoot dry matter weight of sweet potato was also highly responsive and greatly affected by the combined application of farmyard manure and phosphorus.[13] Total dry matter production and efficiency of dry matter allocation to storage roots are important factors determining storage root yield. A linear increase was observed in total yield and storage of root dry matter in phosphorus application.[23]

The productivity of the crop remained low (8 ton/ha) for a long time and it's production is declining due to many factors including recurrent drought, lack of planting materials, shortage of farmer-preferred varieties, poor extension system that does not encourage the production of root crops, market and post-harvest related problems.[24] Sweet potato viruses, sweet potato weevil, and sweet potato butterflies are the major sweet potato production constraints in Ethiopia. Low soil fertility is the other factor limiting the productivity of different crops including sweet potato. It may be caused due to removal of surface soil by erosion, nutrients removal by the crop from the soil, complete removal of plant residue from farmland, and lack of crop rotation system on the farm land.[25] Conventionally, farmers maintain or improve the fertility of the soil by practicing fallowing, adopting planting on ridge seedbed, use of farmyard manure, intercropping, and crop rotation.

Fertilizer application rates in Africa have been around 11 kg/ha, which is not even one tenth for the global average.[26] The result of low fertilizer use in Africa indicated that, cereal crop yields one-third of those in developing Asia and only one-tenth of those in the United States. It is estimated that enhancing crop yields in Africa by only 1% could save two million Africans from poverty. In Ethiopia, the fertilizers utilization trend has been focused mainly on the use and application of N and P fertilizers in the form of Di-ammonium phosphate (DAP) (18-46-0) and Urea (46-0-0) for the major food crops including sweet potatoes. Today, little information was exploited on the impacts of the rates of inorganic fertilizers such as NPSB fertilizers on the yield and quality of OFSP in the study area. Therefore, this study was initiated to evaluate the yield responses on different rates of NPSB fertilizers and to analyze the economically feasible rates of fertilizers for OFSP.

MATERIALS AND METHODS

Descriptions of the Study Area

The experiment was conducted at the Farmer's Training Center at Reka-boka Kebele, Qebena Special Woreda, Central Ethiopian Regional State, during the main rainy season. It was located 158 km from Addis Ababa, and 5 km from Wolkite South-west direction at the latitude of 8°0'N and longitude of 37°49'E with an elevation of 2000 m.a.s.l. The average annual rainfall ranges between 1500 and 1800 mm with the mean annual max and min temperatures of 20°C and 12.6°C, respectively.

Experimental Materials

Three nationally released potato varieties were brought from the southern research center/Hawasa: Kabode, Dilla, and Alamura were used. The varieties were selected based on their wider adaptability, yield potential, and the relative tolerance to the diseases compared to the local varieties. They have had more/less similar ecological requirements and growing periods, and the detailed description of the varieties is given in Table 1.

Experimental Design and Treatments

The experiment consisted of four levels of blended NPSB fertilizers rate: (0, 75, 150, and 225 kg/ha) and three orange-fleshed sweet potato varieties (Kabode, Dilla, and Alamura) in a complete factorial arrangement. A total of 12 (3 × 4) factorial treatment combinations were laid out in a randomized complete block design, with three replications. The distance between the blocks and the plots was 1 m and 50 cm, respectively. The gross plot size for each treatment was 1.8 m × 2.4m (4.32 m^2). The spacing between rows and plants was 60 cm and 30cm, respectively, and each plot accommodated a total of 24 plants.

There was a lack of baseline information about levels of NPSB fertilizer to be applied. Since the experiment was new to the study area. Hence, NPSB rates were determined based on previously recommended N_2 and P_2O_5 at the rate of 150 and 150 kg/ha Urea and DAP, respectively. To determine NPSB rates, 50% of P_2O_5 (DAP) available at blanket (150 kg/ha) were converted in terms of NPSB. NPSB fertilizer was used as a source of P_2O_5, S, and B while urea was used to compensate for N_2 which was not covered by NPSB in treatment.

Site Preparation and Soil Sampling

The land was prepared by following a standard practice. The experimental site was plowed using the tractor, then after using oxen 2 times. Before planting, soil samples were randomly collected using an auger in a zig-zag pattern at a depth of 30 cm. The soil samples from 10 spots across the site were collected, composited, and packed to determine the soil physicochemical properties such as texture, pH, Cation Exchange Capacity (CEC) (Cmol($^+$)kg^{-1}), Organic Carbon (%), total N_2 (%), the available phosphorus [mg/kg (ppm)] to Wolkite soil laboratory before planting.

Under the specification, the layout was prepared, and each treatment was assigned at random to experimental plots within each block independently. Uniform and recommended size of the sweet potato vine cuttings were planted in a well-prepared ridge at a recommended spacing of 0.3 m between plants and 0.60 m between rows.

Based on the treatments, NPSB fertilizers were applied 8 days after the time of planting. The total quantity of N_2 in NPSB was subtracted and the remaining N_2 from the blanket recommendation (100 kg/ha urea) was applied in splits, the first half after a week, and the rest was applied in two splits at 25 and 50 days after planting. All the recommended cultural practices including weeding, pest, and disease control were done uniformly for all experimental plots.

Data Collected

After the proper recording, all the data related to the crop growth attributes and yield due to blended

Table 1: The description of improved potato varieties used for the study

Varieties	year of release	rf (mm)	altitude	maturity time	yield th^{-1}	breeder/maintainer
Kabode	2005	750–1000	1200–2200	150	27.0	harc
Alamura	2006	750–1000	1600–2800	110–120	29.2	harc/eiar
Dilla	2006	750–1000	1600–2800	150	21.0	harc/eiar

fertilizers application and varieties were taken from three plants from a net plot at random. The parameters for different data collection are given below:

- Number of leaves/plant (NLPP)
- Vine length
- Shoot fresh weight (SFW)
- Shoot dry weight (SDW)
- Biomass (BM)
- Marketable tuber per plant
- Un-marketable tuber per plant
- Total tuber number per plant
- TTY
- Root fresh weight
- Root dry weight

Data Analysis

The collected data of all parameters were subjected to Analysis of Variance using the Statistical Analysis Software version 9.3.[27] Treatment mean comparisons were done using the least significance difference test at 5% and 1% significance levels. The correlation analysis among the selected parameters was done using Pearson's simple correlation coefficient.

RESULTS AND DISCUSSION

Soil Physiochemical Properties

Physiochemical properties of the soil before planting are shown below [Table 2]. Accordingly, the result showed that the soil textural class was clay. The pH was neutral. The CEC of the soil was (42 mg/100 g) which was a medium. The soil had a low total N_2 concentration (1.287%) and moderate (31.21 ppm) available phosphorus level. Since, the root of sweet potato root is short and small, which does not easily utilize less readily available phosphorus, an extensive amount of readily available phosphorus is required. Thus, the site was appropriate for sweet potatoes.

Table 2: Pre-planting soil physicochemical properties of the experimental site

Physiochemical properties	Result	Status	References
Clay (%)	46		
Silt (%)	28		
Sand (%)	26		
Textural class		Clay	USDA[28]
p^H (1:2.5H_2O)	7.1	Neutral	
OC (%)	14.93	Low	Tekalign[29]
OM (%)	2.48	Medium	
Total N_2 (%)	1.29	Low	Murphy[30]
CEC (mg/100 g)	42	Medium	
Available *P* (ppm)	31.21	Medium	Cottenie[31]

Number of Leaf per Plant and Shoot Fresh, and Dry Weights

The influence of varieties and NPSB fertilizer were highly significantly different on shoot fresh and dry-weights, and leaf/plant numbers ($P < 0.01$). The Dilla variety at 150 kg/ha NPSB resulted in the highest leaf number (659.72), while, it significantly not different from the Dilla (631.22) at 225 kg/ha and the Alamora at 150kg/ha fertilizers (608.94) [Table 3]. The finding was in line with,[32] the interaction effects of varieties with NPSB blended fertilizer have resulted in a highly significant difference in leaf number. Moreover,[33] reported that the highest number of leaves per plant Okumkom grown 30-45-45 kg/ha NPK was significantly different from other amended and control plots. Contrarily,[34] reported that the leaf number did not show any significant differences at the highest 60 P_2O_5 kg/ha or 26.4 P kg/ha. Significantly the highest shoot fresh weight (15.26 t/ha), was recorded from the Dilla variety with 225 kg/ha, followed by 150 kg/ha (14.34 t/ha), and 75 kg/ha (10.4 t/ha) NPSB fertilizers.

Table 3: Effect of NPSB on the number of leaf/plant, shoot fresh and dry weights of Orange fleshed sweet potato varieties

variety	npsb kg/ha	number of leaves per plant	shoot fresh weight	shoot dry weight
dilla	0	496.11^{d}	9427.80^{d}	3480.00^{f}
	75	571.22^{bc}	10394.40^{c}	4401.22^{c}
	150	631.22^{a}	14338.90^{b}	5472.22^{b}
	225	659.72^{a}	1526.10^{a}	6466.67^{a}
kebode	0	169.11^{g}	2972.20^{g}	1338.89^{j}
	75	229.83^{f}	3623.30^{g}	1402.78^{j}
	150	264.03^{f}	6920.00^{f}	2438.89^{h}
	225	271.63^{f}	7138.90^{f}	2938.89^{g}
alamora	0	377.52^{e}	7966.70^{e}	2161.11^{i}
	75	544.76^{d}	8061.10^{e}	2505.56^{h}
	150	567.50^{bc}	9594.40^{cd}	3911.11^{e}
	225	608.94^{ab}	9833.30^{cd}	4166.67^{d}
mean cv (%)		449.30	6794.35	3390.09
		6.92	5.48	2.37

a-j shows that a given parameter is significant differences per plant ($P < 0.05$) and highly significant differences per plant ($P < 0.01$)

The lowest shoot fresh weight was recorded on the Kebode at a nill rate, not significantly different from the Kebode at 75 kg/ha (57.24 t/ha) [Table 3]. This was in line with[32] stating that the effects of varieties and NPSB rates highly significantly influenced the above-ground biomass fresh weight.[15] reported that an increase from 0 to 25 kg/ha P increased biomass significantly. However, it increased from 50 to 75 kg/ha, there was a significant decreases and the highest biomass was recorded at 25 kg/ha on ridge and flat. The SDW was significantly highest and recorded by Dilla with NPSB 225 kg/ha (64.67 t/ha). However, the least was recorded by Kebode without NPSB, not significantly different from Kebode, which received 75 kg/ha. It was in agreement with the findings of,[16] who reported shoot dry weight was highly significantly affected by the variety and interaction of NPSB and variety.[15] reported the highest shoot dry weight(207g) at 90 kg/ha and 25 kg/ha of N_2 and P_2O_5 respectively.[13] also stated that shoot dry weight was increased as the proportion of FM: P decreased.[14] also stated that the application of 92 kg/ha N_2 and 23 kg/ha P increased above-ground dry biomass production in sweet potatoes.

BM

The Biomass was highly significantly ($P < 0.01$) affected by the main effects and the interaction of blended NPSB fertilizers rates and Varieties. The highest days to biomass (43287 kg) was recorded on Kebode, which received 225 kg/ha NPSB fertilizers, while the least (19560 kg) was recorded on Dilla with no NPSB fertilizers [Table 4],[35] reported that, the dry weight partition of Sweet potato plants decline in the upper zone of soil (vegetative) and increase in the root zone and tubers, which resulted in high yield of tuber and inversely when plant production is dominated by vegetative growth, that makes leaves and stems growing excessively and lacking tuber formation due to a little carbohydrate left for tuber formation.[15] reported that phosphorus increased from 0 to 25 kg/ha, increased the biomass yield significantly. However, the increase from 50 to 75 kg/ha P, there was a significant decrease in the biomass yield and the highest biomass was recorded at 25 kg/ha P on ridge and flat.

table 4: Interaction effect of varieties and blended fertilizer on means of vine number, length and internode length

Variety	NPSB kg/ha	Biomass
Dilla	0	8.67^{cde}
	75	7.67^{ef}
	150	6.00^{g}
	225	6.33^{g}
Kebode	0	12^{a}
	75	10.67^{b}
	150	9.33^{c}
	225	9.00^{cd}
Alamora	0	8.67^{cde}
	75	8.00^{de}
	150	6.67^{fg}
	225	6.33^{g}
Mean CV (%)		8.28
		9.26

a-g shows that a given parameter is highly significant differences per plant (P < 0.01) and significant differences per plant (P < 0.05)

Marketable, Unmarketable, and Total Tuber Number

The interaction effects of varieties with NPSB blended fertilizer were resulted in highly significant differences on unmarketable and total tuber number per plant ($P < 0.01$) and significant differences on marketable tuber number per plant ($P < 0.05$) [Appendix Table 3]. Tuber number is one of the main components of yield in root and tuber crops; being they are the main edible organ of Sweet potato. Sweet potato variety Kebode, which received 150 kg/ha of NPSB, scored the highest marketable tuber number (5.00), which was significantly different from the other treatments [Table 5].

The least marketable tuber number was scored in the variety Alamura and Dilla with no NPSB

Table 5: Interaction effect of varieties and NPSB fertilizers on the means of marketable, unmarketable, and total tuber numbers per plant

Variety	NPSB kg/ha	MTNPH	UMTNPH	TTNPH
Dilla	0	2.89^{f}	5.22^{a}	8.22^{a}
	75	3.00^{ef}	4.00^{c}	7.44^{c}
	150	3,44^{d}	3.67^{d}	6.67^{e}
	225	3.22^{d}	3.00^{e}	6.00^{g}
Kebode	0	4.00^{c}	3.00^{e}	7.00^{d}
	75	4.00^{c}	1.66^{f}	6.34^{f}
	150	5.00^{a}	1.22^{g}	6.22^{fg}
	225	4,67^{b}	1.67^{f}	5.67^{h}
Alamora	0	2.89^{f}	5.00^{b}	8.11^{ab}
	75	3.11^{ef}	4.00^{c}	7.89^{b}
	150	4.00^{c}	3.00^{e}	7.33^{c}
	225	4.00^{c}	4.00^{c}	7.00^{d}
Mean CV (%)		3.68	3.28	6.99
		4.26	3.56	2.76

MTNPH: Marketable tuber number per hill, UMTNPH: Unmarketable tuber number per hill, TTNPH: Total tuber number per hill. a-g shows that a given parameter is highly significant differences per plant (P < 0.01) and significant differences per plant (P < 0.05) fertilize application (2.87).[15] reported that the highest marketable storage root numbers hill^{-1} were recorded at the levels of 45 N kg/ha and 25 P kg/ha fertilizer combinations. The Kebode variety which receives 150 kg/ha NPSB fertilizer resulted the least unmarketable tuber number (1.22) and followed by the same variety which receives 75 kg/ha and 225 kg/ha of NPSB fertilizer (1.66 and 1.67), respectively [Table 4],[15] who reported that the least unmarketable tuber number per hill was recorded at 90 kg/ha N and 50 kg/ha P. Therefore, a proper fertilizer application rate is important to improve the marketable storage root of sweet potatoes and reduce the unmarketable storage root number. Sweet potato variety Dilla with no NPSB fertilizer resulted in the highest total tuber number per plant (8.22), which was significantly different from the remaining treatments [Table 5].

From this experiment, we can justify that marketable grades are improved by agronomic practice like use of NPSB blended fertilizer. Due to this, the size and weights of tubers were improved in the use of phosphorus-containing fertilizers due to more carbohydrate storage,[36] which resulted in higher yield,[12] reported that P doses increase from 0 to 45 kg/ha found to be an increase in the total tuber and commercial tuber of sweet potato by 8% and 20% when 15 and 45 P_2O_5 kg/ha were applied, respectively, compared to that obtained without Phosphorus (P),[14] also found that the application of 23 P kg/ha resulted highest total tuber number in sweet potato. Busha (2006) also reported that as N level was increased beyond 45N kg/ha and P level was increased from 50 to 75 P kg/ha; there was a significant decrease in total tuber number which was an agreement with that of[13] who stated that, as the level of P increased from 0 to 180 P_2O_5 kg/ha average storage root number per plant decreased by 20.3% on sweet potato and the highest storage root number vary between 4 and 5 in number.

Root Fresh, Root Dry Weights, and Total Tuber Yield

The interaction effects of varieties with NPSB blended fertilizer were resulted in highly significant differences on root fresh weight, root dry weight, and total tuber yield ($P < 0.01$) [appendix Table 1]. Significantly highest fresh root yield in ton per hectare was recorded by variety Kebode, which received 150 kg/ha NPSB fertilizer (22.76 ton/ha) followed by the same variety which receives 225 kg/ha NPSB fertilizer (20.05 ton/ha) [Table 6]. Following these, variety Alamora that received 150 and 225 kg/ha NPSB fertilizer, scored 15.88 and 15.50 ton/ha yield, respectively; however, they did not differ significantly from each other [Table 4]. The least root fresh weight was recorded by variety Dilla with no fertilizer application. Significantly highest total tuber yield in ton per hectare was recorded by variety Kebode, which received 150 kg/ha NPSB fertilizer (20.52 ton/ha) followed by the same variety which receives 225kg ha^{-1} NPSB fertilizer (17.98 ton/ha) [Table 6].

Widaryanto and Saitama[35] reported that the dry weight partition of Sweet potatoes decline in the upper zone of soil (vegetative) and increase in the root zone and tubers, which resulted in a high yield of tuber and inversely when plant production is dominated by vegetative growth, that makes leaves and stems growing excessively and lacking tuber formation due to a little carbohydrate left for tuber formation.[15] reported that an increase from 0 to 25 kg/ha P increased biomass yield significantly. However, increases from 50 to 75 kg/ha P, there was a significant decreased in biomass yield and the highest biomass was recorded at 25 kg/ha P on ridge and flat.[13] stated that even though the shoot fresh weight of Sweet potato (Bellala) was benefited at the highest level of Farm yard manure, shoot dry weight was increased as the proportion of

Table 6: Interaction effect of orange-fleshed sweet potatoes varieties and NPSB blended fertilizer on means of root fresh weight, total tuber number per plant, and root dry weight

Variety	NPSB kgha^{-1}	RFW (kg)	RDW (kg)	TTY (t/ha)
Dilla	0	10146.6^{g}	9413.6^{f}	94.14^{f}
	75	12924.4^{f}	11728.4^{e}	11.73^{e}
	150	14606.5^{ed}	13657.4^{cd}	13.66^{cd}
	225	13657.4^{ef}	12307.1^{de}	12.31^{de}
Kebode	0	14660.5^{ed}	13271.6^{cd}	13.27^{cd}
	75	18402.8^{c}	17052.5^{b}	17.05^{b}
	150	22762^{a}	20524.7^{a}	20.52^{a}
	225	20054.0^{b}	17978.4^{b}	17.98^{b}
Alamora	0	13433.6^{ef}	12422.8^{de}	12.42^{de}
	75	14729.9^{ed}	13387.3^{cd}	13.39^{cd}
	150	15879.6^{d}	14429.0^{c}	14.43^{c}
	225	15501.5^{d}	14197.5^{c}	14.19^{c}
Mean CV (%)		15563.27 5.45	14197.53 5.93	14.195.93

RFW: Root fresh weight, RDW: Root dry weight, TTY: Total tuber yield. a-g shows that a given parameter is highly significant differences per plant (P < 0.01) and significant differences per plant (P < 0.05)

Table 7: Variable Coast of labors and seedling/cuttings used for partial budget analysis

Varieties	NPSB	TY Kg/ha	adjusted yield 90%	gross income	tvc	net benefit	mrr%
Alamora	0	12422.8	11180.52	83853.9	28600	55253.9	193.19
	75	13387.3	12048.57	90364.275	36960	53404.28	144.49
	150	14429.0	12986.1	97395.75	40920	56475.75	138.015
	225	14197.5	12777.75	95833.125	44880	50953.13	113.53
Dilla	0	9413.6	8472.24	63541.8	28600	34941.8	122.17
	75	11728.4	10555.56	79166.7	36960	42206.7	114.19
	150	13657.4	12291.66	92187.45	40920	51267.45	125.29
	225	12307.1	11076.39	83072.925	44880	38192.93	85.10
Kebode	0	13271.6	11944.44	89583.3	28600	60983.3	213.28
	75	17052.5	15347.25	115104.375	36960	78144.38	211.43
	150	20524.7	18472.23	138541.725	40920	97621.73	238.57
	225	17978.4	16180.56	121354.2	44880	76474.2	170.39

FM: P decreased. In general, P is responsible for the dry matter production of every part of sweet potatoes.

Partial Budget Analysis

The partial budget analysis revealed that the maximum net benefit of 97621.73 ha^{-1} ohthe Ethiopian Birr with the marginal rate of returns (MRR) of 238.57% [Table 7] was obtained from the Kebode variety that received NPSB fertilizers rate of 150kg/ha [appendix Table 2]. The application of NPSB fertilizer rate for the production of Marketable yield from all three varieties had the MRR above 100% but the maximum MRR (%) was obtained from the Kebode with the application of 150 kg/ha then followed by the same variety with 225 kg/ha NPSB fertilizers rate.

Based on the result, 150 kg/ha NPSB with the Kebode variety resulted in the highest adjustable marketable yield 2.05 was profitable to the farmers. The identification of a recommendation is based on a change from one treatment to another if the MRR of that change is greater than the minimum rate of return. Therefore, the Kebode variety at different rates of blended fertilizer with meets the acceptable minimum rate of return to the farmers' recommendation through the recommendation to maximize the net benefit to the farmer; thus the highest net benefit was recorded on the Kebode variety at 150 kg NPSB ha^{-1}

SUMMARY AND CONCLUSION

Sweet potatoes (*I. batatas* (L.) Lam) are economically important food security crop in Ethiopia. The OFSPs are nutritious and widely cultivated root crops known for their high β-carotenes contents, which is a proven cost-effective strategy for providing Vitamin A. The average national yield of sweet potato is about 8 ton/ha, which is very low as compared to the world's average production 14.8 ton/ha. The major cause of the low yield is the use of the poor agronomic practices, scarcity of information on the appropriate type and rates of fertilizers recommendations, and shortage of improved varieties having high nutritional and dry matter value.

The result of this experiment revealed that the means of SFW, SDW, and total tuber numbers per plants/TTNPP were highly significant ($P < 0.01$) in the interaction of the OFSP varieties with NPSB fertilizer. The Number leaf per plant/NLPP was resulted in a significantly highest different in the Dilla variety, which received 225 kg/ha (659.72) and 150 kg/ha (631.22) NPSB fertilizers rate. The SFW resulted in a significantly highest different in the Dilla, which received 225 kg/ha (1526.10 kg/ha) NPSB fertilizers. The potato variety, the Kebode, which received 150 kg/ha of NPSB scored the highest marketable tuber number (5.00) and the least unmarketable tuber number (1.22). Significantly the highest different total tuber number was scored in the Dilla with no NPSB fertilizers application (8.22). Root fresh weight was significantly the highest different in the Kebode, which received 150 kg/ha (22762 kg), followed by the kebode variety with 225 kg/ha. The Root dry weight was significantly the highest in the Kebode × 150 kgha^{-1} (20524.7 kg), 225 kgha^{-1} NPSB (17978.4 kg), respectively. The Total tuber yield was significantly the highest in the Kebode with 150 kg/ha (20.52 tonha). The analyzed partial budget for the average of the whole treatments (12) was resulted in the highest MRR at the Kebode, Dilla, and Alamora, received 150 kg/ha with 238.57%, 125.29%, and 144.49%, respectively. Over all 150 kg/ha NPSB was recommended with the Kebode in terms of the yield per hectare that was the cost-effective.

RECOMMENDATIONS

Based on the finding, rates of 150 kg/ha NPSB fertilizers application were economical and recommended for the orange flesh sweet potatoes production. However, further research should be needed on the remaining OFSP varieties with respect to the different rates of NPSB fertilizer application.

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APPENDIX TABLES

Appendix Table 1: Mean squares for analysis of variance for total tuber number per plant, root fresh weight, and root dry weight, at Kebena district in during 2022

Source of variation	DF	RFW	RDW
Rep	2	234.3[NS]	804871.5*
Fertilizer (NPSB)	3	38301685.4***	31998385.4***
Variety (VAR)	2	120005692***	91575619.1**
NPSB×VAR	6	681613.8*	3997451.2*
Error	22	98408.4	709476.3
CV (%) Mean		2.05 15271.60	5.93 14197.53

*Significant at the $P<0.05$ probability level; **Significant at $P<0.01$ probability level; ***Significant at the $P<0.001$ probability level. Ns- Non-significant; TTNPP: Total Tuber Number per plant, RFW: Root fresh weight, RDW: Root dry weight

Appendix Table 2: Variable coast of labors used for partial budget analysis

activities	unit	manpower required	unit/daily payment	no of days	total	10%	total sum
Site clearing	No.	10	50	2	1000	100	1100
Tractor rent	Ha	1	3000	1	3000	300	3300
Oxen force	Ox no.	2	100	2	400	40	440
Plowing	No.	1	50	2	100	10	110
Cutting preparation	No.	10	50	1	500	50	550
Ridge preparation	No.	15	50	2	1500	150	1650
Planting	No.	10	50	2	1000	100	1100
Fertilizer application	No.	10	50	2	1000	100	1100
Hoeing and weeding	No.	15	50	2	1500	150	1650
Earthing up	No.	15	50	2	1500	150	1650
Harvesting	No.	15	50	4	3000	300	3300
Transporting	No.	20	50	4	4000	400	4400
Guard	No.	1	50	150	7500	750	8250
Total					26000	2600	28600

Appendix Table 3: Coast of fertilizer used for partial budget analysis

fertilizer treatment	unit	npsb fertilizer rate	price/kg	total price	+10% sensitivity	urea	price/kg	total price	+10% sensitivity	total sum
NPSB 0	Kg	0	48	0	0	0	40	0	0	0
NPSB 1	Kg	75	48	3600	3960	100	40	4000	4400	8360
NPSB 2	Kg	150	48	7200	7920	100	40	4000	4400	12320
NPSB 3	Kg	225	48	10800	11880	100	40	4000	4400	16280

Appendix Table 4: Analysis of variance for the number of leaf per plant, shoot fresh, and dry weight

Source of variation	DF	Number of leaf per plant	Shoot fresh weight	Shoot dry weight
Rep	2	615.53*	729465.9*	3973.09
Fertilizer (NPSB)	3	47777.99***	36310641.9***	9314107.07
Variety (VAR)	2	431173.53***	155215725.2***	26045172.09
NPSB x VAR	6	2744.30*	2783660.8***	293027.92
Error	22	966.14	232686.6	6469.40
CV (%)		6.92	5.48	2.37
Mean		449.30	8797.35	3390.09

*Significant at the $P<0.05$ probability level; **Significant at $P<0.01$ probability level; ***Significant at the $P<0.001$ probability level. Ns- Non-significant; NLPP: Number leaf per plant, SFW: Shoot fresh weight, SDW: Shoot dry weight