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Effect of Farmyard Manure and Inorganic Nitrogen Fertilizers Rates on the Yield and Yield Traits of Sweet Potato (*Ipomoea batatas* L.) at Assosa District

Desta Bekele*, Merga Boru

Assosa Agricultural Research Center, Ethiopian Institute of Agricultural Research, Addis Ababa, Ethiopia

Email address:
destabek.48@gmail.com (D. Bekele)
*Corresponding author

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Abstract: Sweet potato is high yield potential and adaptability to a wide range of environmental conditions. However, due to low soil fertility the yield was become low in some part of country. The objective of this study was to evaluate the combined effects of organic farmyard manure and inorganic nitrogen on yield and yield components of sweet potato. Four farmyard manure rates (0, 4.5, 9 and 13.5 ton ha^{-1}) and four nitrogen rates (0, 45, 90 and 135N kg ha^{-1}) fertilizers were evaluated in RCBD with three replications at Assosa district. The interaction effects of farmyard manure with nitrogen fertilizers rates were not significantly ($P > 0.05$) influenced total root yield of sweet potato. The highest yield was recorded by the combination 13.5 ton farmyard manure per ha with that of 45 kg of nitrogen per ha. The combination of 13.5 ton ha^{-1} farmyard manure with 45kg nitrogen ha^{-1} fertilizers recorded more than minimum acceptable of marginal rate of return (393.39%). So, we conclude that applying 13.5 ton ha^{-1} farmyard manure with 45kg nitrogen ha^{-1} fertilizers benefits farmers or beneficiaries at Assosa district. In future the researchers would have to investigate the combination of farmyard manure with nitrogen rates for more than two years at Assosa area.

Keywords: Farmyard, Manure, Nitrogen, Rates, Sweet Potato

1. Introduction

Sweet potato (*Ipomoea batatas* L.) belonging to the family Convolvulaceae is believed to have originated in the northern parts of South America and Central America [1-3]. Sweet potato is one of the world's most important food crops, especially in developing countries, due to its high yield potential and adaptability to a wide range of environmental conditions [2, 4].

Sweet potato is a tuber root- bearing vegetable species grown in tropical areas for either domestic or industrial uses. Root of sweet potato is rich in vitamin A, B6, C, riboflavin, copper, pantothenic and folic acid [5]. It is an important food and vegetable crop that grows throughout the world for its edible tubers, which can be eaten boiled and fried or baked. In sub Saharan Africa, sweet potato is the third most important root crop after cassava and yam. In this region of Africa, over 7 million tons (5% of global production) of sweet potato is produced annually [6]. China is the highest producer of sweet potato (82,474,410 tonnes) and making Asia the leading producer of sweet potato in the world [7]. In Ethiopia, sweet potato has been cultivated for many years and is important in diet where population growth is highest, land holding is least and threat of large scale starvation is ever present [8]. Over 95% of the crop is produced in the south west, Eastern and southern parts of Ethiopia where it has remained for centuries as one of the major subsistence crops especially in the periods of drought.

According to Tamirie [9], one of the causes of low yield of the crop in the country is low soil fertility which may be attributed to removal of surface soil by erosion, nutrient removal by crops from the soil, complete removal of plant residues from farm land, etc. In general, the low soil fertility status of the country is one of the factors limiting the productivity of different crops including sweet potato.

In every 100 grams of sweet potato contains high enough calories and nutritious and a complete composition such as protein, fat, calcium, carbohydrates, phosphorus, iron, vitamins, and water (Directorate of Nutrition and Health, 2005 [10].

Nitrogen fertilizer was essential to increase crop yields, crop quality and production efficiency as N was the nutrient absorbed in the greatest amounts by plants in terms of equivalents [11]. Low soil fertility is one of the problems to sustain agricultural production and productivity in Ethiopia. To decrease the challenges, integrated nutrient management is an option as it utilizes available organic and inorganic nutrients to build ecologically sound and economically viable farming. Inorganic fertilizers are usually expensive and not available in required quantities to the subsistence farmers who produce the bulk of the production. Organic inputs proposed as alternatives cannot meet crop nutrients demand for large scale production because of their relatively lower nutrient composition, high application rates, high labor requirements and limited availability [12].

Thus, a combined use of farmyard manure and inorganic sources of fertilizers and use of quality manure on the farms land should be focused. Integrated nutrient management technologies should be developed to address the problem in a sustainable manner. Information on the integrated nutrient utilization is important for additional yield improvement of the given crop. So, the objective of this study is to evaluate of the combined effect of farmyard manure and nitrogen fertilizers rates on yield and yield traits of sweet potato and to identify economically feasible rates of farmyard manure and nitrogen for sweet potato production in the study area.

2. Materials and Methods

2.1. Description of Study Area

The experiment was implemented at Assosa Agricultural Research Center (AsARC) on station in 2019 main cropping season under rain fed condition, in Benishangul Gumuz Regional State of Ethiopia. Assosa Agricultural Research Center is found at 1553 meters above sea level, located at 4 km east of Assosa town and at 660 km west of Addis Ababa, the capital city of Ethiopia. Assosa has a unimodal rainfall pattern, which starts at the end of April and extends to mid-November, with maximum rainfall happened in June, July, August, September, and October. The total annual mean rainfall of Asossa is 1275 mm. The annual mean minimum and maximum temperatures are 14.33 and 28.43°C, respectively. The experimental site of soil was characterized as reddish brown (Nitosols and Fluvisols) with the soil pH ranging from 5.1 to 6.0 and texturally clay [13].

2.2. Experimental Design and Treatments

The experiment was laid out in factorial Randomized Completed Block Design with (4x4) with 3 replications. The treatments were combined four N rates, 0, 45, 90, 135 kg N ha^{-1} and four Farmyard manure rates, 0, 4.5, 9 and 13.5 ton/ha. Total numbers of experimental units were 48. Each plot had a size of $5.04m^2$ with four rows and 7 plants per row with a total population of 28 plants per plot at spacing of 0.6 m and 0.30 m between rows and plants, respectively. The improved sweet potato variety called Awassa-83, which was released nationally by Hawassa Agricultural Research Center, was used as a planting material [14]. The entire plots were applied P_2O_5 at planting in the form of Triple Superphosphate (TSP). Urea was applied with two split; 1/2 of the rate at the time of planting, the rest at active growing stage of the crop, in the form of urea (CO $(NH_2)_2$). Farmyard manure fertilizer rates were applied at planting time. All cultural practices were carried out as per the recommended packages.

2.3. Soil Sampling and Analysis

Twelve random surface soil samples (0-30cm) were collected following diagonal sampling technique from the entire experimental field before planting to get one representative composite sample. The composite sample was air dried ground and passed through 2mm sieve for analysis of selected physicochemical properties. Soil total nitrogen was determined by the Kjeldahl method using micro- Kjeldahl distillation unit and Kjeldahl digestion stand as described by Jackson [15]. The experimental site was low in total nitrogen 0.14% [16]. According to Olsen method [17] available phosphorus found in the soil was low (4.35 mg kg^{-1}) whereas the organic carbon was medium (1.75%) at the experimental site [18].

2.4. Data Collection

Vine length, root diameter, root length, number of root per plant, specific gravity, marketable root yield, unmarketable root yield and total root yield data were recorded.

2.5. Data Analysis

Data was analyzed by statistix 8 version 2.0 software and other related software. Whenever the treatment mean differences were tested using LSD at 5% level of significance and the results were interpreted by Gomez and Gomez [19].

2.6. Partial Budget Analysis

Partial budget analysis was done following CIMMYT [20] steps. For economic evaluation, dominance analysis, cost and marginal rate of return (MRR) were calculated according to the procedures of CIMMYT [20]. The procedures of calculating the marginal rates of return of alternative treatments, proceeding in steps from the low variable cost treatment to the high variable cost, and deciding if they are acceptable to farmers, is called marginal analysis [20]. The field price of root yield of sweet potato was 10 Birr kg^{-1} at the time of harvesting while the price of Urea and farmyard manure were 8.24 Birr kg^{-1} and 2 birr kg^{-1}, respectively.

3. Results and Discussion

3.1. Growth Performance and Yield Components

The analysis of variance revealed that no significance difference (P>0.05) among interaction effects of different level of farmyard manure and nitrogen fertilizers application on vine length, root diameter, root length, specific gravity and number of root per plant. However, increasing farmyard manure rates increases vine length linearly.

Root diameter, root length and number of root per plant were significantly (P<0.05) influenced by the main effect of farmyard manure whereas vine length and specific gravity were not influenced by the main effect of farmyard manure rates. This result is in line with the finding of Boru *et al*. [21] who reported that increasing the rates of farmyard manure increases vine length linearly. This is might be due to high nitrogen content in farmyard enhance vegetative growth or vine length of sweet potato. Root diameter, root length, vine length, specific gravity and number of root per plant were not significantly (P>0.05) influenced by main effect of nitrogen fertilizer rates.

Table 1. *Main effects of different levels of farm yard manure and inorganic nitrogen fertilizers rates on means of vine length, root diameter, root length, number of root per plant of sweet potato in 2019/2020 cropping Season.*

Source of variation	VL (cm)	RD (cm)	RL (cm)	NRP	SG
FYM (tha^{-1})					
0	152.88	3.15b	10.04b	1.53b	1.04
4.5	166.85	4.92a	14.34a	2.37ab	1.22
9	168.95	4.72a	14.87a	2.72a	1.25
13.5	201.8	5.63a	14.53a	2.88a	1.16
Sign level	Ns	*	*	*	Ns
LSD	36.49	1.08	3.21	0.88	0.31
N (kgha^{-1})					
0	157.87	4.62	13.03	2.28	1.14
45	191.8	4.91	14.01	2.53	1.25
90	170.27	4.53	13.31	2.27	1.17
135	170.55	4.35	13.12	2.42	1.12
Sign level	Ns	Ns	Ns	Ns	Ns
LSD	36.49	1.08	3.21	0.88	0.31
CV	25.36	28.19	28.65	44.77	31.94

Ns= Non significance, **= highly significant, LSD= Least of Significance Difference, CV= Coefficient Variation, VL=Vine Length, RD= Root Diameter, RL=Root Length, SG= Specific Gravity, NRP= Number of Root per plot.

3.2. Marketable and Total Root Yield of Sweet Potato

3.2.1. Marketable Root Yield

The interaction effect of different level of farmyard manure and nitrogen fertilizers not significantly influenced the marketable root yield. However, marketable root yield was high significantly influenced by farmyard manure rates whereas nitrogen main effect was not significantly influenced. The highest marketable root yield recorded by 13.5ton per ha of farmyard manure whereas the lowest marketable root yield scored by without fertilizer plot. The result is in line with the finding of Gezahegn *et al.* [22] who stated that application of 46 kg N ha^{-1} and 5 t ha^{-1} FYM increased marketable root yield on sweet potato by 48.55% as compared to non- fertilized treatment. This may be due to nutrient addition by applied FYM which enriched the soil for the uptake of macro and micro nutrients which are important for increasing root yield.

3.2.2. Unmarketable Root Yield

Unmarketable root yield was not significantly (P>0.05) influenced by interaction effect of different level of farmyard manure and nitrogen fertilizers (table 2). However, unmarketable root yield was significantly influenced by the main effect of farmyard manure whereas not significantly influenced by nitrogen. The highest unmarketable yield (0.42tha^{-1}) was recorded by 13.5tha^{-1} farmyard manure whereas the lowest unmarketable root yield was scored by plot without fertilizer application.

3.2.3. Total Root Yield

Total root yield was not significantly (P>0.05) influenced by interaction effect of different level of farmyard manure and nitrogen fertilizers. However, total root yield was highly significant (P<0.01) influenced by the main effect of farmyard manure fertilizer rates whereas the total root yield was not significantly influenced by main effect of nitrogen fertilizer rates. Increasing the rate of farmyard manure fertilizer linearly increased the total root yield of sweet potato.

Application of 13.5 t ha^{-1} of farm yard manure with 45 N kg ha^{-1} fertilizers increases total root yield of sweet potato by 91.17% as compared to treatment without application farmyard manure and nitrogen fertilizers. The highest total root yield was recorded by the application of combined farmyard manure with that of nitrogen fertilizers. This is result in line with the finding of Koroto [23] who reported that increasing farmyard manure rates increased marketable and total root yield of sweet potato linearly. The increase in total root yield was also correlated to FYM at increased rate which might have enhanced the available nitrogen and phosphorus to the soil which was immediately usable to the crop.

Table 2. *Main effects of different levels of farmyard manure and inorganic nitrogen fertilizers on marketable root yield, unmarketable and total root yield of sweet potato in 2019/20 cropping season.*

Source of variation	MRY (tha^{-1})	UMRY (tha^{-1})	TRY (tha^{-1})
FYM (tha^{-1})			
0	2.16c	0.099b	2.26c
4.5	8.82b	0.29a	9.11b
9	9.37b	0.29a	9.66b
13.5	13.14a	0.42a	13.56a
Sign level	**	**	**
LSD	2.52	0.75	2.56
N ($kgha^{-1}$)			
0	8.13	0.29	8.42
45	8.57	0.25	8.82
90	9.37	0.29	9.66
135	7.42	0.27	7.69
Sign level	Ns	Ns	Ns
LSD	2.52	0.075	3.21
CV	25.36	28.19	25.61

** = highly significant, Ns= Non significance, LSD= Least significant Difference, CV= Coefficient Variation, MRY =Marketable Root Yield, UMRY= Unmarketable Root Yield, TRY= Total Root Yield, tha^{-1}= ton per hector.

3.3. Partial Budget Analysis

The enhanced production of the crop due to the application of inputs might or might not be beneficiary to farmers. Therefore, partial budget analysis [20] was calculated to estimate the net benefit and marginal rate of return that could be obtained from different alternative treatments.

There are a couple of things to notice about this conclusion. First the recommendation is not (necessarily) based on the highest marginal rate of return. For farmers who not used FYM with investing in 45 kg N/ha gave a very high rate of return, but if farmers stopped there, they would miss the opportunity for further earnings. Farmers will continue to invest as long as the returns to each extra unit invested (measured by the marginal rate of return) are higher than the cost of the extra unit invested (measured by the minimum acceptable rate of return). The second thing to notice is that the recommendation is not (necessarily) the treatment with highest net benefits. The recommendation for treatments subjected to marginal rate of return is not (necessarily) based on the highest marginal rate of return, rather based on the minimum acceptable marginal rate of return and the treatment with the highest net benefit together with an acceptable MRR becomes the tentative recommendation [20]. The farmers would have to use the combination of 13.5 ton ha^{-1} farmyard manure and 45N kg ha^{-1} fertilizers amount to obtain highest benefits with acceptable marginal rate of return.

Table 3. *Marginal rate of return of un-dominated treatments as influenced by combined effects of farmyard manure and nitrogen fertilizers rates on sweet potato yield at Assosa district.*

FYM tha^{-1}	N kg ha^{-1}	TVC	MC	NB	MB	MRR%
0	0	0		13167		
0	45	780	780	20955	7788	998.46
0	135	2340	1560	24795	3840	246.15
4.5	0	9650	7310	76840	52045	711.97
4.5	90	11210	1560	78997	2157	138.27
9	0	19300	8090	80456	1459	18.03
9	45	20860	1560	87626	7170	459.62
13.5	45	29730	8870	119859	32233	363.39

FYM= Farmyard Manure, N= Nitrogen, TVC= Total Variable Cost, MB= Marginal Benefit, NB= Net Benefit, MC= Marginal Cost, MRR= Marginal Rate of Return.

4. Conclusion

The low soil fertility status of the country is one of the factors limiting the productivity of different crops including sweet potato. The objective of this study is to evaluate the combined effects of organic farmyard manure and inorganic nitrogen fertilizer sources on the root yield and yield components of sweet potato. In study area nitrogen, phosphorus and potassium deficiency were observed. Actually the treatments with farmyard manure gave high yield as compared to treatments without farmyard manure with nitrogen. The treatments those have highest marginal rate of return will not (necessarily) recommended treatment. The treatments that have greater marginal rate of return than minimum acceptable rate has the probability to be recommend. We are tentatively recommend that the combination of 13.5 ton ha^{-1} and 45 kg Nha^{-1} gave highest total root yield and the marginal rate of return greater than that of minimum acceptable rate (100%). So, for the Assosa area in future farmyard manure and potassium rates should have to be done for more than two years to confidently conclude.

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