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The Productivity of Orange Fleshed Sweet Potato as Influenced by Organic Manure and Inorganic Amendments in Dodoma Municipal

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Abstract: *A new variety of orange-fleshed sweet potato (Carrot-C) has been introduced in Dodoma Municipal but appropriate soil nutrient management for this cultivar is lacking and the yield is below its potential. Smallholder farmers are not aware of when Farm Yard Manures and inorganic fertilizers are incorporated together into the production of this crop. The present study identified the best combination of farm yard manure at four levels (0 tha^{-1}, 5 tha^{-1}, 10 tha^{-1}, and 15 tha^{-1}) and phosphorus at four levels (0 t of $P_2O_5ha^{-1}$, 23 t of $P_2O_5ha^{-1}$, 46 t of $P_2O_5ha^{-1}$, and 69 t of $P_2O_5ha^{-1}$) for orange-fleshed sweet potato production. In the on-farm experimentation, a factorial arrangement was used. The Randomized Complete Block Design was adopted with three replications. Partial budgeting and marginal analysis involving dominance analyses were used as analytical tools. The results of Partial budgeting analysis at 15t Farm Yard Manure/ha in a combination of 69t of P_2O_5/ha gave a positive and greatest net benefit of 25,814.5 TZS/ha and its Marginal Rate of Return was highest at 6,666.5%. In conclusion, the use of 15t Farm Yard Manure/ha plus 69t of P_2O_5/ha is viable and is recommended for farmers to use in their plots to earn the highest income.*

Keywords: Income, *Ipomea batatas*, Nutrient management, Partial budget, Soil fertility

JEL classification: C35, D63, I34

1.0 Introduction

The Orange Fleshed Sweet Potato (OFSP) is one of the improved varieties of sweet potato promoted by the research institutes in the country. It provides β-carotene which is the precursor of Vitamin A which is lacking in the diets of farming communities (Jaarsveld et al., 2019). This crop was introduced to mitigate Vitamin A deficiency as it affects 70% of children under five, and 11% of women living in rural areas (Aguayo et al., 2004; MISAU, 2018). Also, this crop improves the immune system of individuals living with HIV-AIDS (Du Guerny, 2002; Low et al., 2007). According to Adebisi et al. (2018), the OFSP is grown for food and income source for rural people in both tropical and sub-tropical regions. This crop is easy to cultivate, it matures in a short period and little labour is required (Afuape, 2014). These benefits prompted different stakeholders to promote OFSP.

Despite these benefits, this crop is facing challenges that limit productivity. These include low soil fertility caused by the removal of surface soil by erosion, complete removal of plant residue, and lack of crop rotation system (Chung et al., 2000). The potential yield was estimated at 20 tonnes/ha, but the average yield at the farm level was 5.6 tonnes/ha which had a 15 tonnes/ha yield gap (CSA, 2016). According to Ohaeri (2019), crop producers assume that the use of inorganic fertilizers such as phosphorus is not cost-effective because the response of various cultivars has not been established. The farmers use organic fertilizer occasionally. Yeng et al. (2012) pointed out that using organic fertilizer such as Farm Yard Manure in combination with inorganic fertilizers such as phosphorus is effective in raising yields of orange-fleshed sweet potatoes. This study intends to examine the economics benefits of using Farm Yard Manure (FYM) in combination with Phosphorus fertilizer.

2.0 Theoretical Review

This study is guided by two theories: The theory of production economics and the theory of resource allocation. According to Alimi et al. (2002), the theory of production economics is concerned with the optimization of the farmers' objectives or goals and optimization implies efficiency. Ohaeri (2019) defined the theory of resource allocation as the technical concept of efficiency which brings about great products to society from a given resource combination.

Therefore, soil fertility input is one of the major resource constraints facing the farmers resulting from continuous cropping activities on scarce land resources. Thus, there is a need to create a balance among the available soil maintenance alternatives (such as mineral fertilizer, composting, poultry manure, organic waste, etc.) to enable them to choose the most appropriate combination with the least cost. Efficient allocation of resources through an optimal input combination by these smallholder farmers among their usual multiple goals of providing food for the family and accumulating income to offset poverty should be the vital focus point in decision making. Orange-fleshed sweet potato production is such a lucrative enterprise that needs a research effort for improvement to create a balance between private and social costs.

3.0 Methodology

3.1 Study Location

The on-farm experiment was carried out under rain-fed conditions between January and March 2019 at Hombolo Ward in Dodoma Municipal at 05°45′ S Latitudes and 35°57′ E Longitudes. The choice of this study area was because this Ward is among the areas which produce Orange-Fleshed Sweet Potato. Agriculture is the main economic activity in this area. The distribution of rainfall is variable at mean rainfall of 589 mm annually. The annual temperature is recorded at an average of 22.7°C annually. Sandy and loamy are the types of soil in the study area which are not fertile.

3.2 The Design

A 4x4 factorial combination was used. It consisted of Phosphorus treatments at four levels (0, 23, 46, and 69 kg Phosphorus Pentoxide (P_2O_5) per ha) and Farm Yard Manure (FYM) at four levels (0, 5, 10, 15 t/ha). The alternatives were arranged in a Randomized Complete Block Design (RCBD) replicated 3 times. A variety studied was Carrot-C) which is highly adaptable, high-yielding, and resistant to disease. The inorganic fertilizer used in this study was the TSP fertilizer which contains 46% of P_2O_5.

3.3 The Experiment

Hand hoe was used to plough, harrow, and prepare ridges. The sizes of the plots were 9 m^2. Vine cuttings of 30 cm in length were planted. There were 10 plants per row and 50 plants per plot. The burying of two-thirds of their lengths was done in the soil at 45^0 angles at a spacing of 30 cm between plants and 60 cm between rows. The N-fertilizer was used at the vegetative growth stage according to recommendations by Tanzania Agricultural Research Institute (TARI). The application of Triple Superphosphate (TSP) fertilizer was done before vines planting. The FYM was applied in the plots two weeks before planting. Weeding was done using a hand hoe to keep the plots free from weeds.

3.4 The Collection of Data

The following are the data collected for each treatment such as total marketable tuber yield per hectare, the price for tuber per kilogram, quantity of TPS in kg/ha, prices of TPS per 50kg bag, the quantity of manure in t/ha, prices of manure in t/ha, number of workers for TPS application and its wage rate per day, and the number of workers for manure application and its wage rate per day.

3.5 Data Analysis

3.5.1 The partial budgeting

The partial budgeting method was used to analyse the net returns of the alternatives used in this study. The following data were collected and used during the computation of net return. The price of orange-fleshed sweet potato tuber used in this was 2,000TZSkg^{-1}. The price of TSP was 75,000 TZS per 50kg bag while the price of manure was 25,000 TZS per ton. About 20 people were used for FYM application in the field plot and 16 people were used to apply the phosphorus. They were paid 2,000 TZS per day as their wage.

The Net Return for each alternative used in this study was computed using Equation 1:

$$NB = GR - TVC \quad (1)$$

Where:

The GR is the Gross Return which was computed using Equation 2.

$$GR = AJY * P \quad (2)$$

Where P is the price and AJY is the adjusted yield which was adjusted downward by 10% as presented in Equation 3.

$$AJY = Y - (GAY * 0.1) \quad (3)$$

According to Kay et al. (2018), alternatives with high net return will be recommended for farmers to use.

3.5.2 The Marginal Rate of Return (MRR)

The MRR for each cost un-dominated alternative was computed using Equation 4.

$$MRR = (MB/MC) * 100 \quad (4)$$

According to CIMMYT (1988), accept an alternative with MRR 100% and above.

4.0 Results and Discussion

4.1 Total tuber yields

The application of 15t FYM/ha in combination with 69tof $P_2O_5ha^{-1}$ gave the greatest yield (23650 $kgha^{-1}$). The lowest yields at 3,600 $kgha^{-1}$ were recorded from unfertilized plots (0tha^{-1} of FYM plus0t/ha of P_2O_5 as presented in Table 1. The yield gap might be caused by the low fertility of the soil, but when the FYM and Phosphorus were used together the soil became fertile and gave better yields of the crop. The poor nutrient status of the experimental plots has negative implications for crop growth, development and yield.

Table 1: Tuber yields in organic manure and inorganic manure applied at different rates of combinations for orange fleshed sweet potato of Carrot-C variety in Homboro ward during 2018/2019 cropping season

Treatments		Marketable Yield $Kgha^{-1}$	Adjusted Yield $Kgha^{-1}$
Farm Yard Manure (t/ha)	**P_2O_5 (kg/ha)**		
0	0	3,600	3,240
0	23	5,020	5,020
0	46	5,885	5,300
0	69	5,420	4,880
5	0	9,125	8,200
5	23	4,850	4,400
5	46	5,880	5,300
5	69	4,600	4,140
10	0	6,850	6,200
10	23	8,780	7,900
10	46	9,550	8,600
10	69	11,980	1,080
15	0	10,760	9,700
15	23	11,100	9,990
15	46	13,730	12,350
15	69	23,650	21,300

Source: Experimental data, 2018/19 cropping season

The application of either farm yard, phosphorus pentoxide or in combination of both ensured a balanced nutrients supply, which is essential for orange fleshed sweet potato growth. The balanced nutrition promoted better plant health and higher yield potential. The combination of improved root growth, nutrient availability and plant health translated into more substantial tuber development and higher yields. Havlin et al (2005) observed that microbial activity and recycling of nutrients through soil organic matter substantially impacts on plant nutrient availability. The positive response of yield to nutrient applications is in line with the report of Tindall (193) and Murwira and Kirchman (2017).

4.2 The Partial Budget Analyses

The results in Table 2 shows that the greatest net benefit of 4,895,337 TZS/ha was recorded at 15t Farm Yard Manure/ha plus 69 kilograms of P2O5/ha. The lowest net benefit was obtained from unfertilized (without fertilizer) (0t/ha FYM + 0t/ha P_20_5). The low net benefit obtained might be due to low yield resulting from poor soil fertility. The profitability study showed that application of 15t Farm Yard Manure/ha in combination with 69 kilograms of Phosphorus which provided the greatest net benefit was the peak of fertilizers. This indicated that total costs increased until a certain level, and the net benefit obtained increased. These findings agree with the study by Evans (2015).

Table 2: Partial budgeting of different levels of options applied at different rates of combinations for orange fleshed sweet potato of Carrot-C variety in Homboro ward during 2018/2019 cropping season

Treatments		Gross Field Benefit (TZS/ha)	Total Variable Cost (TZS/ha)	Net Benefit (TZS/ha)
Farm Yard Manure (t/ha)	P_2O_5 (t/ha)			
0	0	806,890	0	806,890
0	23	1,125,661	16,406	1,109,254
0	46	1,319,912	25,008	1,294,904
0	69	1,215,315	33,609	1,181,706
5	0	2,042,128	131,706	1,910,422
5	23	1,095,776	148,112	947,664
5	46	1,319,912	157,072	1,162,840
5	69	1,031,026	165,673	865,353
10	0	1,544,048	253,656	1,290,392
10	23	1,967,416	270,062	1,697,354
10	46	2,141,744	278,664	1,863,080
10	69	2,689,632	312,631	2,377,001
15	0	2,415,688	375,606	2,040,082
15	23	2,487,910	392,012	2,095,897
15	46	3,075,644	400,614	2,675,030
15	69	5,304,552	409,215	4,895,337

Source: Experimental data, 2018/19 cropping season

3.3 The Dominance Analyses

The dominance analysis procedure as detailed in CIMMYT (1998) was used to select potentially profitable treatments (Table 3).

Table 3: The Dominance Analysis of FYM and Phosphorus Pentoxide fertilizers applied at different rates of combinations for orange fleshed sweet potato of Carrot-C variety in Homboro ward during 2018/2019 cropping season

Treatments		Total Variable Cost (TZS/ha)	Net Benefit (TZS/ha)
Farm Yard Manure (t/ha)	P_2O_5 (kg/ha)		
0	0	0	806,890
0	23	16,406	1,109,254
0	46	25,008	1,294,904
0	69	33,609	1,181,706 D
5	0	131,706	1,910,422 D
5	23	148,112	947,664 D
5	46	157,072	1,162,840 D
5	69	165,673	865,353 D
10	0	253,656	1,290,392
10	23	270,062	1,697,354 D
10	46	278,664	1,863,080 D
10	69	312,631	2,377,001
15	0	375,606	2,040,082 D
15	23	392,012	2,095,897 D
15	46	400,614	2,675,030
15	69	409,215	4,895,337

D = Dominated treatment

Source: Experimental data, 2018/19 cropping season

The dominant analysis showed that the net benefit of treatment that were dominated are: 0t Farm Yard Manure/ha plus 69 t of P_2O_5/ha, 5t Farm Yard Manure/ha plus 23t of P_2O_5/ha, 5t Farm Yard Manure/ha plus 69 t of P2O5/ha, and 15t Farm Yard Manure/ha plus zero tonne of P_2O_5/ha. Further dominance analysis revealed that 5t/ha FYM plus 46t/haP_2O_5, 15t/ha FYM plus 23t/haP_2O_5, 10t/ha FYM plus 0t/haP_2O_5, 10t/ha FYM plus 23t/haP_2O_5, 10t/ha FYM plus 46t/haP_2O_5, were dominated treatments (Table 3). The results indicated that net benefit decreased as the total cost that varies increased beyond un-dominated fertilizer treatments application. Therefore, no farmer may choose other dominated treatments in comparison with the un-dominated treatments for further estimation of Marginal Rate of Return (MRR).

4.4 Marginal analysis

For each pair of ranked un-dominated treatments, a percentage Marginal Rate of Return (% MRR) was calculated. The %MRR between any pair of treatments denotes the return per unit of investment in fertilizer as expressed in percentage. This analysis was conducted and presented in Table 4.

Table 4: Marginal rate of return of FYM and Phosphorus Pentoxide fertilizers applied at different rates of combination for orange fleshed sweet potato of Carrot-C variety in Homboro ward during 2018/2019 cropping season

Treatments		Total Variable Cost (TZS/ha)	Marginal Cost (TZS/ha)	Net Benefit (TZS/ha)	Marginal Benefit (TZS/ha)	MRR (%)
Farm Yard Manure (t/ha)	P_2O_5 (t/ha)					
0	0	0		806,890		-
0	23	16,406	16,406	1,109,254	302,364	1843.0
0	46	25,008	8,602	1,294,904	185,650	2158.2
5	0	131,706	106,698	1,910,422	615,518	576.8
10	69	312,631	180,925	2,377,001	466,579	257.9
15	46	400,614	87,983	2,675,030	298,029	338.7
15	69	409,215	8,601	4,895,337	2,220,307	25,814.5

Source: Experimental data, 2018/19 cropping season

The results of analysis of un-dominated treatments indicated that for each one Tanzanian Shillings invested in purchase of fertilizer it was possible to recover one Tanzanian Shillings plus an extra of 18.43, 21.582, 5.768, 2.579, 3.387 and 258.145 as the fertilizer application changed from unfertilized plot (0t/ha FYM plus 0t/haP_2O_5) until supplementation of 15t/ha FYM plus 69t/ha P_2O_5 was applied.

5.0 Conclusion

The objective of this study was to analyse the best combination of farm yard manure at four levels and phosphorus at four levels on Carrot-C variety for orange-fleshed sweet potato production. The greatest total yield was obtained from plots that received 15t/ha FYM plus 69t/haP_2O_5. Partial budget analysis was also employed by considering total variable costs, net benefit, dominated and dominant treatments using dominance analysis and marginal rate of return. The results indicated that the combined application of 15t/ha FYM and 69t/haP_2O_5 was economically acceptable as compared to other dominant treatments, although the marginal rate of return obtained from all dominant treatment was above the minimum acceptable marginal rate of return. Hence to obtain optimum economic production in the study area, it is recommended that 15t Farm Yard Manure/ha plus 69 t of P_2O_5/ha be applied. This recommendation is made based on varying total costs and marginal rate of return from alternative treatments.

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