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Research Article

Effect of Cassava (*Manihot esculenta Crantz*) as Influenced by Nitrogen and Phosphorus Fertilizers in Southwest Ethiopia

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ABSTRACT

A field experiment was conducted at Jimma Agricultural Research Center to investigate the effect of different rates of inorganic nitrogen and phosphorus fertilizers on the yield and yield related traits of cassava in Southwest Ethiopia, during 2016/2017 cropping season. Variety Qulle was planted at the field density of 6667 plants/ha and the rate of fertilizer application consisted of four levels of nitrogen (0, 40, 80 and 120 kg N ha) and five levels of phosphorus (0, 23, 46, 69 and 92 kg P_2O_5/ha). The experiment was laid as a randomized complete block design (RCBD) with three replications in a factorial arrangement. Data on 11 yield and yield related traits were collected and subjected to various data analyses. Results of the present study indicated, the highest storage tuber yield was obtained by the application of 120kg N /ha and 92 kgP_2O_5/ha. The, application of nitrogen increased at rates of 120 kg N/ha significantly increased the storage tuber yield of cassava by 21.89%, than the control. Similarly, the application of phosphorus at the rate of 92 kg P_2O_5/ha increased significantly tuber yield by 34.83%. The economic analysis also showed that the highest net benefit of 14,415.0 Ethiopian Birr (ETB/ha) with marginal rate of return of 2402.5% was obtained by the application of 40 kg N/ha. Likewise, the net benefit of 36276.0 ETB/ha with marginal rate of return of 8762.3% was obtained by the application of 92 kg P_2O_5/ha. Based on the above results, a combined application of 40 kg N/ha and 92 kg P_2O_5/ha are optimum and economically better for cassava production at Jimma and similar areas.

INTRODUCTION

Cassava is a tropical woody shrub dicotyledonous plant belonging to the family Euphorbiaceous [1]. It originated from North East Brazil with additional center of origin in Central America [2]. Though the domestication of cassava started in these regions, today the crop is cultivated all over the tropical world [3]. Of all the tropical root and tuber crops, cassava is the most widely distributed and cultivated in different parts of the tropics [4]. It is being cultivated as the main source of energy and as the most important staple food crop for over 900 million people of the world [5]. From all crops, cassava is the second most important staple crop in Africa after maize and the 6th most consumed crops in the world [6]. The Abuja Declaration (2006) also identified cassava as one of the crops with the greatest potential to combat poverty and food and nutrition insecurity in Africa. The crop has particularly potential for fertile and waste land when other crops are not survived, where it could help overcome food shortage [7]. It is primarily grown for its starchy tuberous root; its flour can be produced for soup, biscuits, bread and beverage. The leaves used as vegetable, as it contains a high carbohydrate that is useful for people in the developing countries of Africa.

In tropical Africa, cassava is mainly a subsistence crop grown for food by small-scale farmers who sell the surplus. It grows well in poor soils with limited labor requirements [8]. It provides food security and fills seasonal food gaps during other crops absent in the field. Apart from food, cassava is very versatile and its derivatives and starch are applicable in many types of products such as foods, confectionery, glues, plywood, textiles, paper, biodegradable products, glutamate, and drugs. It is rich in carbohydrates, calcium, vitamins B and C, and essential minerals [9]. However, nutrient composition differs according to variety and age of the harvested crop, and soil conditions, climate, and other environmental factors during cultivation. Cassava chips and pellets are used in animal feed and alcohol production (IITA, 2009).

Cassava was first introduced to Ethiopia by the British and then distributed mainly in moisture stress areas of the country. It is well known by its principal ability to produce economic yields under relatively marginal rainfall and soil conditions. Besides, cassava has well adapted to soils of low fertility. Due to this reason, most farmers in many growing areas do not apply fertilize for cassava, as they are satisfied by the minimal yield obtained from using limited inputs from their poor soils [10]. Currently, cassava used as an industrial crop in Ethiopia and produced starch from cassava for

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export and domestic purposes. It is now being grown on large scale, repeatedly season after season on the same piece of land. Under this condition, the fertility of the soil and yields declined overtime [11]. Decline in soil fertility is especially serious problem in tropical regions, where the soil lacks adequate plant nutrients and organic matter, due to leaching and erosion of top soil by intense rainfall [12]. As the result, the yield became low. To enhance production and productivity, good understanding on the importance of cassava in association with its appropriate fertilizer requirement and types are essential to boost cassava production, which minimize the poverty and improve the livelihood of rural households. Therefore, this study was designed to determine the effect of NP fertilization on the yield and yield related traits of cassava in Southwest Ethiopia.

MATERIALS AND METHODS

Description of the study area

The experiment was conducted at Jimma Agricultural Research Center (JARC). The center is located at latitude 7° 40.00' N and longitude 36° 47'.00' E with an altitude of 1753 meters above sea level. The area receives mean annual rainfall of 124.6 mm with mean maximum and minimum temperatures of 26.2°C and 12.0°C, respectively. The soil of the study site is Eutric Nitosol (reddish brown) with pH of 5.3 (Table 1).

Experimental materials

For this study, one improved variety (Qulle) was planted at JARC main station during 2016/17 cropping season. Treatment consisted on N applied at (0, 40, 80 and 120 kg ha^{-1} as urea (46% N) and P applied at (0, 23, 46, 69 and 92 kg ha^{-1}) as DAP (46% P_2O_5 and 18% N). Both fertilizers were applied near the rows. All DAP and 50% of urea was applied at planting. The remaining 50% of urea was applied as side banded after 60 days of planting (Table 2).

Experimental design and management

The experiment was laid out in RCBD with three replications. Plants were field established using inter-row spacing of 1.5m and intra-rows spacing of 1m. Cuttings of the same size and age were used as planting material. Both fertilizers were applied near the rows. All DAP and 50% of urea was applied at planting. The remaining 50% of urea was applied as side banded after 40 days after planting. One month after planting, seedlings were earthed up followed by frequent weeding. All other agronomic practices were followed according to the recommendations.

Data collection and analysis

Data were collected from six plants from each plot and the average values were used for data analysis. The characters that are used for data collection were: stand count at harvest, maximum horizontal distance (m), number of branch/plant, plant height (m), stem girth (cm), above ground biomass (kg/plant), number of tuber/hill, tuber length (cm), tuber diameter (cm), tuber fresh weight (kg/plot) and tuber dry weight (kg/plot). Analysis of variance and differences between the mean values were established with Least Significant Difference (LSD) at 1% and 5% of probability level by using Statistical Analysis System (SAS) computer package (version 9.0 of SAS Institute Inc, 2000). Besides, adjusted mean storage tuber yield, total variable cost and net benefit analysis was adopted to determine the partial budget and sensitivity analysis to establish the profitability of cassava to the nitrogen and phosphorus fertilizers.

RESULTS AND DISCUSSION

The results of the ANOVA of variance indicated that, maximum horizontal distance, plant height, number of branches /plant, tuber fresh weight (kg/plot) and tuber dry weight were significantly increased across N and P rates (Tables 3). The widest plants were obtained at 120 N/ha and 92 kg P/ha rates. Tuber fresh weight, tuber dry weight per plot, and number of plants/plant followed similar trends.

Except stand count at harvest, tuber length and diameter, the control plots (0kg N and P) showed the lowest performance that was observed in this study. The superior yield and yield related traits obtained from high rates of N and P in this study has been

Table 1: Climate data on the research site during the growth period 2016/17.

	Total rain fall (mm)		Mean temperature (°C)				Mean Relative humidity (%)		Mean Soil temperature (0-30 cm) (°C)		Mean Sunshine (hours)	
			Minimum		Maximum							
	Mean (1968-2015)	2016/17	Mean (1968-2016)	2016/17	Mean (1968-2016)	2016/17	Mean (1968-2015)	2016/17	Mean (1968-2016)	2016/17	Mean (1968-2016)	2016/17
Jan	44.9	56.2	12.1	10.4	27.6	25.61	58	69.4	21.8	23.9	7.4	7.8
Feb	41.8	61.6	12.8	12.5	28.4	29	57	53	22.5	24.1	7	7.4
Mar	98.9	97.8	13.6	12.5	28.2	25.61	59	61.4	23.2	24.1	6.5	8.2
Apr	136.7	96.5	14.7	11.3	27.6	25.97	63	59.3	23.4	23.8	6.4	8
May	191.3	192.4	14.8	11.9	26.4	27	68	67	23.1	23.8	6.5	6.7
Jun	218.1	185.9	14.5	10.6	24.7	26.9	74	66	22.3	23.4	5.1	5.4
Jul	229.5	205.6	14.5	12	23.2	23.9	79	62.7	21.2	20.8	3.4	4.9
Aug	235.3	210.4	14.3	13.6	23.5	24.6	79	68	21.3	23.1	3.8	3.9
Sep	210.6	250.2	14.2	15.6	24.7	24.8	75	76	22.1	23.8	5.1	5.6
Oct	122.7	63.3	11.9	12.8	25.9	27	69	65	22.6	23.8	7.2	7.2
Nov	63.8	22.1	10.4	11.8	26.5	28.5	67	58	22.3	23.9	8	6.4
Dec	58.4	53.2	8.7	8.9	27.1	28.8	61	53	21.8	23.6	7.9	6.7
Total	1652	1495	165.5	143.9	313.8	317.7	809	758	267.6	282.1	74.3	78.2
Mean	137.7	124.6	13	12	26.2	26.5	67.4	63.2	22.3	23.5	6.2	6.52

Table 2: Physico-chemical properties of top soil (0-30 cm) of experimental fields at Jimma.

No	Physical composition	Results
1	% Sand	71
2	% Silt	3
3	% Clay	26
4	Textural class	Sandy clay
	Chemical characteristics	
6	pH (H_2O) (1:2:5)	5.05
7	Organic carbon	2.36
8	Available P (ppm)	6.458
9	Total N (g/kg)	0.214
10	Available K (meq/100g)	3.235
11	%Organic matter	4.069
12	Exchangeable acidity (meq/100g)	0.064
13	CEC (meq/100g)	25.02
14	Exchangeable AL+++ (meq/100g)	Can't detected

Table 3: Effect of Nitrogen and Phosphorus on yield and yield related traits of cassava 2016-2017 at Jimma.

Treatment	St.co	MHD	NoBr	PH	StG	AGB	No Tu	TL	TDi	TFW	TDW
0kg/ha	16.06^{a}	1.78^{c}	9.19^{b}	2.28^{ab}	3.93^{a}	6.47^{c}	6.02^{a}	43.36^{a}	5.51^{a}	65.31^{c}	34.72^{c}
40kg/ha	15.26^{a}	1.82^{ab}	10.88^{a}	2.32^{a}	4.00^{a}	6.73^{b}	5.77^{a}	45.37^{a}	5.51^{a}	75.12^{ab}	40.99^{ab}
80kg/ha	16.06^{a}	1.82^{ab}	10..3^{ab}	2.24^{b}	3.93^{a}	6.99^{a}	5.82^{a}	49.88^{a}	5.73^{a}	80.27^{a}	44.06^{a}
120kg/ha	16.26^{a}	1.91^{a}	10.1^{ab}	2.34^{a}	3.97^{a}	7.00^{a}	5.83^{a}	40.39^{a}	5.76^{a}	80.95^{a}	44.53^{a}
SE	9.95	23.15	4.14	8.06	0.2	3.19	3.88	12.91	0.27	25.88	14.82
0kg/ha	15.16^{a}	1.84^{ab}	10.20^{a}	2.29^{ab}	4.05^{a}	6.46^{a}	6.00^{ab}	42.88^{c}	5.44^{b}	58.44^{c}	31.93^{c}
23kg/ha	15.67^{a}	1.77^{c}	10.44^{a}	2.26^{b}	3.86^{a}	6.77^{a}	5.95^{ab}	45.15^{a}	5.73^{a}	79.1^{abc}	43.79^{abc}
46kg/ha	15.50^{a}	1.81^{acb}	9.85^{a}	2.24^{b}	4.03^{a}	7.30^{a}	6.16^{a}	48.98^{a}	5.75^{a}	84.67^{ab}	45.49^{ab}
69kg/ha	15.58^{a}	1.81^{ab}	9.65^{b}	2.34^{a}	3.80^{a}	7.06^{a}	5.06^{c}	45.58^{ab}	5.65^{a}	65.21^{bc}	35.90^{bc}
92kg/ha	16.67^{a}	1.94^{a}	10.51^{a}	2.35^{a}	4.09^{a}	7.03^{a}	6.14^{a}	47.41^{a}	5.57^{ab}	89.67^{a}	48.86^{a}
SE	9.95	23.15	4.14	8.06	0.2	3.19	3.88	12.91	0.27	25.88	14.82
Interaction N x P	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

St.co= Stand count at harvest, MHD= Maximum horizontal distance (m), NoBr= Number of branch/plant, PH= Plant height (m), StG= Stem girth (cm), AGB= Above ground biomass (kg/plant), NoTu= Number of tuber/hill, TL= Tuber length (cm), TDi= Tuber diameter (cm), TFW=Tuber fresh weight (kg/plot) and TDW= Tuber dry weight (kg/plot).

reported by other researchers [13]. The result of the effect of nitrogen fertilizer on tuber yield and yield related traits showed that N fertilization significantly enhanced tuber yield and plots not treated with N fertilizer performed poorly. This result is consistent with the result of who showed that nitrogen fertilizer increased the photosynthetic apparatus of the leaves and thereby, enhanced storage tuber yield [14]. The sensitive response also confirmed the important of N and P in plant growth and development [15]. This result is in agreement with the findings of [16]. The number of tuber and active leaves/plant follows similar trends as increased the NP rates. In many cases, there was a gradual increase in tuber yield as N fertilizer application increased. However, according to [17] who reported the negative response of cassava to high N application as the plant produced excessive foliage and little tuber.

In this study, the incremental rate of N from 40 kgN/ha to 80 kg N/ha resulted in a corresponding reduction in number of branch/plant and plant height, whereas the application of P from 23 kg/ha to 46 kg/ha there is no significant differences were observed. However, the opposite result was observed on above ground biomass yield, tuber fresh and tuber dry weight when the advanced rates of N and P effects. The maximum canopy diameter as a result of N application is indicative of the role of N in promoting vigorous foliage growth, increasing meristematic and more intense physiological activities in the plant which favored the synthesis of more assimilates and tuber development [18]. This result is consistent with those of [19].

Maximum horizontal distance and number of branch's/plant had highest at 120 kg N/ha rates, However, the canopy distance and number of branch's/plant obtained at 40 and 80 kg N/ha rates were however, statistically similar. Tuber length and diameter/plant were significantly increased by P application up to the 46 kg N/ha rate and beyond that reduced significantly. On the application of 0 to 120 kg N/ha, increased the tuber yield by 21.89%, whereas, the application of P rates from 0 to 92 kg P/ha gave corresponding values of 34.83% over the control. Total dry weight obtained at 120 kg N/ha rates showed an increase of only 22-03% over that of the control, whereas increasing P rates from 0 to 92 kg, increased yield by 34.68%; and from 23 to 46 kgN/ha increased the dry matter yield by 4.36% a further increase from 46 to 92 kg/ha increased tuber yield by 6.89 percent (Table 3).

The positive response shown by yield parameters to N and P could be directly linked to the well-developed photosynthetic surfaces and increased physiological activities leading to more assimilates being produced and subsequently translocated and utilized in rapid tuber development and production. Both N and P have been shown to be necessary for tuber initiation; elongation, increase in tuber size and number [20]. Nitrogen increases the chlorophyll of leaves thereby promoting the photosynthetic capacity of the plant, plays a part in the manufacture of proteins and is also responsible for high yield in plants [21]. Phosphorous on the other hand, promotes CO_2 assimilation and energy for the translocation of carbohydrates from leaves to the tubers and tuberous roots of crops where carbohydrates are the main storage material [22].

Adequate supply of P is important for energy synthesis and translocation, and it also increases yield and improves tuber quality [23]. Hence, the positive response of tuber yield and yield components to increased rates of N and P could be adduced to high energy synthesis and translocation activities stimulated by N and P application. Moreover, the experimental soils were slightly low in nitrogen nutrient, hence the positive response observed. However, the pH of the experimental soil is 5.05, and there is some fixation of P in the soil solution, as a result, a little difficulty to utilize available nitrogen and other essential mineral nutrients from the soil by plants. Besides, high application of N fertilizer inhibits tuber yield in cassava [24] (Table 4).

Optimum storage tuber yield of cassava was obtained by applying 120 kg N/ha and 92 kg P/ha with tuber yield of 30.3t/ha. This result is similar to the report of [25,26] also reported significant differences in yield of taro due to N and P application while the best yield and yield attributes was obtained with 80 kg N/ha (NRCRI, 2005) in taro. Our results are in conformity with the findings of these various workers and consistent with those of [27] who suggested that a maintenance dressing of 120 kg N/ha and 80 kg K/ha per cropping season may be adequate for continuous cassava production.

The economic analysis also revealed that the highest change net benefit of 14,415.0 ETB/ha with marginal rate of return (MMR) of 2402.5% and 36276.0ETB/ha with marginal rate of return of 8762.3% were obtained by growing cassava with the application of 40N and 92 P_2O_5/ha, respectively. An increase in output will always raise profit as long as the marginal rate of return is below the minimum rate of return i.e. 50 to 100%. Data in Table 4 showed that, the marginal rate of return at the nitrogen application rate of 40 kg N/ha was lower than 50% marginal rate of return showed an economically somehow feasible. The net benefit decreased as the cost decreased. Besides, the marginal rate of return due to phosphorus application is also more than 50 to 100%, application of phosphorus fertilizer is economically profitable up to the rate of 92 kg P_2O_5/ha economically feasible. Rate of phosphorus fertilizers at 92 kg P_2O_5/ha was dominated.

Table 4: Marginal rate of return and sensitivity analysis for NP fertilizer on cassava.

Fertilizer level	Mean Yield (Kg/ha)	Mean Yield (Kg/ha)	Mean Yield (Kg/ha)	Mean Yield (Kg/ha)	Mean Yield (Kg/ha)	Mean Yield (Kg/ha)	Mean Yield (Kg/ha)	Mean Yield (Kg/ha)	Mean Yield (Kg/ha)	Mean Yield (Kg/ha)
N(kg/ha)										
0kg/ha	27212.5	24491.25	97665	0	0	0	97665	-	-	-
40kg/ha	31302	28170	112680	600	0	600	112080	600	14415	2402.5
80kg/ha	33445.8	30101.25	120405	1200	0	1200	119205	600	7125	1187.5
120kg/ha	33729.1	30365.25	121425	1800	0	1800	119625	600	420	70
P(P_2O_5kg/ha)										
0kg/ha	24350	21915	87660	0	0	0	87660	-	-	-
23kg/ha	32958.3	29662.5	118650	0	414	414	118236	414	30576	7385.5
46kg/ha	32279.1	31751.25	127005	0	828	828	126177	414	7941	1918.11
69kg/ha	37170.8	33453.8	133815	0	1242	1242	133815	414	7638	1844
92kg/ha	37362.5	33626.25	134505	0	1656	1656	132849	414	36276	8762.3
Sensitivity analysis										
Fertilizer level	**Mean Yield (Kg/ha)**	**Adjusted Yield (Kg/ha)**	**Gross Benefit (ETB/ha)**	**Cost of Urea (ETB/ha)**	**Cost Of DAP (ETB/ha)**	**Gross Cost (+10%)**	**Net Benefit (-10%)**	**Change gross cost**	**Change Net benefit**	**MRR (%)**
N(kg/ha)										
0kg/ha	27212.5	24491.25	97665	0	0	-	87898.5	-	-	-
40kg/ha	31302	28170	112680	600	0	660	101412	660	13513.5	20475
80 kg/ha	33445.8	30101.25	120405	1200	0	1320	108364.5	660	6934.5	1050.6
120kg/ha	33729.1	30365.25	121425	1800	0	1980	109282.5	660	918	139
P(P_2O_5kg/ha)										
0kg/ha	24350	21915	87660	0	0	0	78894	-	-	-
23kg/ha	32958.3	29662.5	118650	0	414	455	106785	455	27891	6129.9
46kg/ha	32279.1	31751.25	127005	0	828	910.8	114304.5	455	7519.5	1652.6
69kg/ha	37170.8	33453.8	133815	0	1242	1366.2	120433.5	455	6129	1347
92kg/ha	37362.5	33626.25	134505	0	1656	1821.6	121054	455	620.5	136.3

MRR=Marginal Rate of Return, field price of taro = 4ETB/kg, price of urea= 15ETB/kg, price of DAP= 18ETB/kg.

CONCLUSION

The findings of the study showed that nitrogen and phosphorus had positive effects on growth and yield of cassava as they significantly enhanced its production. The application of 40 kg N and 92 kg P_2O_5/ha has significantly improved tuber yield of cassava. The economic analysis reveals that further increase the levels of NP fertilizer are not economical. Thus, application of 40 kg N/ha and 92 kg P_2O_5 kg/ha is economical and recommended for taro production under Jimma and its vicinity

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