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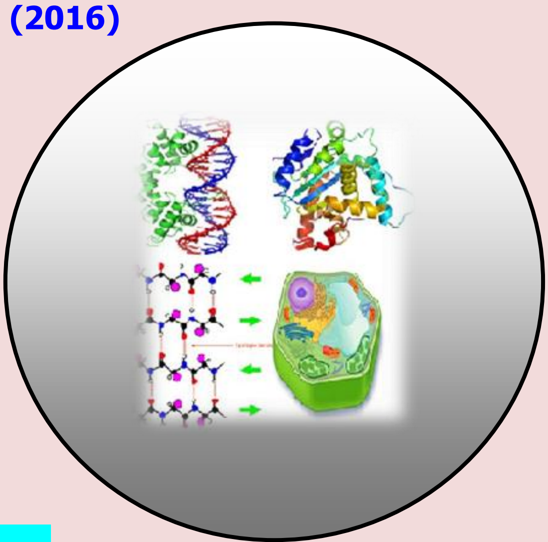

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RESEARCH PAPER

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Effect of Mineral N and P Fertilizers on Storage Tuber Yield and Yield Components of Taro [*Colocasia esculenta* (L.) Schott] in Southwest Ethiopia

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ABSTRACT

The experiment was conducted at Jimma Agricultural Research Center of Ethiopia, for two cropping seasons (2015 and 2016) with the objective of determine the effect of different rates of inorganic N and P fertilizers on taro (variety Denu) for storage tuber yield. Four levels of N (0, 55.5, 111.1 and 166.5 kg N/ ha) and four levels of P (0, 20, 40 and 60 kg P_2O_5 /ha) were arranged in RCBD with three replications. Data on 14 yield and yield related traits were collected and subjected to various data analyses. Results of the study revealed that, the highest storage tuber yield was obtained at the rate of application of 55.5 kg N /ha and 40 kgP_2O_5/ha. Application of nitrogen at a rate of 55.5 kg/ha significantly increased storage tuber yield of taro up to 19.94% than the control. Similarly, phosphorus application at a rate of 40 kg P_2O_5/ha increased significantly tuber yield by 20.56%. The economic analysis also revealed that the highest net benefit of 49,455.0 Ethiopian Birr/ha (ETB/ha) with marginal rate of return of 5940.5% was obtained by the application of 55.5 kg N/ha. Likewise, the net benefit of 30,667.5 ETB/ha with marginal rate of return of 8518.7% was obtained by the application of 40 kgP_2O_5/ha. Based on the above results, a combined application of 55.5 kg N/ha and 40 kgP_2O_5/ha are optimum and economically better for taro production at Jimma and its vicinity.
Keywords: Nitrogen, Phosphorus, Fertilizer Rate and Taro.

INTRODUCTION

Taro [*Colocasia esculenta* (L.) Schott] is an herbaceous, monocotyledonous, perennial tuber crops that widely cultivated in tropical and sub tropical areas of the world (Jianchu *et al*., 2001; TPI, 2000-2004). Globally, it is important crop, ranking fourth in area and production after, potato, sweet potato and yam (FAO, 2010). In sub-Saharan Africa, taro mainly cultivated as subsistence crop for food and income source by small-scale farmers who sell the surplus. It grows well in poor soils with limited labor requirements (Tewodros and Getachew, 2013). Besides, it provides food security during the off season, when other crops absent in the field (Amsalu, 2003; Yared, 2007). Apart from food, taro is very versatile, its derivatives and starch are applicable in many types of products such as glues, plywood, cosmetics, paper, biodegradable products, glutamate, and drugs (Susan *et al*., 2013). It has rich in carbohydrates, calcium, vitamins B and C (Niacin, riboflavin and Thiamin), and essential minerals (Abu, 2015). Fresh corms are a good source of phosphorus and calcium (Kochhar, 1998). The protein content of taro corm is slightly higher than that of yam, cassava or sweet potato (Asfaw, 2006). The nutrient composition differs between varieties, age of the harvested produce, soil conditions, climate, and other environmental factors during cultivation. Like as cassava, taro chips and pellets are used to feed animal and alcohol production (IITA, 2009). Despite its importance both in food security and income source, taro in Ethiopia cultivated by resource poor farmers' in small areas of land (Norman *et al.,* 1995; Yared, 2007). Moreover, in many growing areas, taro is usually intercropped with vegetables, coffee, maize, enset and other legumes with limited fertilizer application (Simon, 1992; Schott *et al*., 2000; Admasu, 2002). This might be due to the fact that taro has been little attention given by research and development programs in the country and leads the taro genetic resources are being eroded by physical and bio-physical factors (Edossa, 1996). Besides, in Southwest Ethiopia, the land scarcity, soil erosion and infertility are the most important constraints and high contribution for reduced taro productivity (Tewodros, 2012). Furthermore, study on optimum nutrient requirement of taro in Ethiopia is rare, even the newly released varieties (Boloso-I, Denu and Keyaqe) have not been subjected to fertilizer studies for optimum nutrient requirements. In the traditional farming system, taro is usually planted at April-May and the average crop yield is low about 18 tons/ha (Fisseha and Tewodros, 2014) as compared to global average tuber yield of 32.2 t/ha (TPI, 2000-2004). This low yield is in part attributable to low fertility status of the soil, resulting from depletion by proceeding crops (Hermann *et al*., 2013). To increase the productivity, better understanding on the importance of taro in association with its appropriate fertilizer requirement and types are needed to boost taro production, which minimize poverty and improve the livelihood of rural households. Therefore, this study was designed to determine the effect of nitrogen and phosphorus fertilization on the yield and yield related traits of taro 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^o 40.00' N and longitude 36^o 47'.00' E with an altitude of 1753 meters above sea level (m.a.s.l.). The area receives mean annual rainfall of 124.6 mm with mean maximum and minimum temperatures of 26.2^{0}C and 12.0^{0}C, respectively. The soil of the study site is Eutric Nitosol (reddish brown) with p^H of 5.3.

Soil sampling and analysis

Fiften core soil samples randomly collected from 0-30cm top soil bulk to form a composite. Samples were air dried, crushed and allowed to pass through a 2mm sieve. Particle size distribution was carried out by the Hydrometer method, while soil p^H in soil solution ratio 1;2 in 0.01M C_aCl_2 . Soil organic carbon was determined by the Walkey and Black method and total N by the micro-kjeldahl digestion method (Bremer and Mulraney, 1982). Available P was determined by Bray and Kurtz (1955) extraction method. Exchabgeble bases were extracted with neutral 1M NH_4OAC at soil solution ratio of 1:10 and measured by flame photometry. Exchabgeble acidity was determined by titration of 1M KCL extract against 0.05M NaOH to a pink end point using phenolphthalein as indicator (Maclean, 1982).

Experimental materials

For this study, the improved variety (Denu) was planted at JARC main station. Treatment consisted on N applied at (0, 55.5, 111.1 and 166.5 kg/ ha) as urea (46%N) and P applied at (0, 20, 40 and 60 kg /ha) as DAP (46% P_2O_5 and 18% N).

Experimental design and management

The experiment was laid out in RCBD with three replications. The gross plot size for each treatment was 4mx 3m. Plants were field established using 0.70cm inter-row spacing and intra-rows spacing of 0.50cm. Tubers of the same size which started sprouting were used as planting material. Both fertilizers were applied near to the rows. All DAP and 50% of urea was applied at planting. The remaining 50% of urea was applied as side banded after 45 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.

Table 1. Climate data on the research site during the growing period.

Month	Total rain fall (mm)		Mean temperature (°C)				Mean Relative humidity (%)		Mean Soil temperature (0-30cm) (°C)		Mean Sunshine (hours)	
			Minimum		Maximum							
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
Jan	44.9	56.2	12.1	10.4	27.6	25.61	58.2	69.4	21.8	23.9	7.4	7.8
Feb	41.8	61.6	12.8	12.5	28.4	29.00	57.6	53.0	22.5	24.1	7.0	7.4
Mar	98.9	97.8	13.6	12.5	28.2	25.61	59.0	61.4	23.2	24.1	6.5	8.2
Apr	136.7	96.5	14.7	11.3	27.6	25.97	63.1	59.3	23.4	23.8	6.4	8.0
May	191.3	192.4	14.8	11.9	26.4	27.00	68.4	67.0	23.1	23.8	6.5	6.7
Jun	218.1	185.9	14.5	10.6	24.7	26.90	74.7	66.0	22.3	23.4	5.1	5.4
Jul	229.5	205.6	14.5	12.0	23.2	23.90	79.1	62.7	21.2	20.8	3.4	4.9
Aug	235.3	210.4	14.3	13.6	23.5	24.60	79,3	68.0	21.3	23.1	3.8	3.9
Sep	210.6	250.2	14.2	15.6	24.7	24.80	75.6	76.0	22.1	23.8	5.1	5.6
Oct	122.7	63.3	11.9	12.8	25.9	27.00	69.4	65.0	22.6	23.8	7.2	7.2
Nov	63.8	22.1	10.4	11.8	26.5	28.50	67.2	58.0	22.3	23.9	8.0	6.4
Dec	58.4	53.2	8.7	8.9	27.1	28.80	61.3	53.0	21.8	23.6	7.9	6.7
Total	1652.0	1495	156.5	143.9	313.8	317.7	273.5	758.8	267.60	282.1	74.30	78.20
Mean	137.7	124.6	13.0	12.0	26.2	26.5	66.7	63.2	22.30	23.5	6.20	6.50

Source, Jimma Agricultural Research Center

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 manifested for data collection were: stand count at harvest, maximum horizontal distance (m), plant height (m), number of active leaves/plant, number of sucker/plant, petiole length (cm), leaf length (cm), leaf width (cm), basal ring length(cm), tuber fresh weight (kg/plot), number of tuber/hill, tuber diameter(cm) and tuber dry weight (kg). 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) package (version 9.0 of SAS Institute Inc, 2000). Besides, economic analysis, partial budget, marginal rate of return and sensitivity analysis were adopted by using the manual developed by CIMMYT (1998). The two years mean value of storage tuber yield was used for economic analysis. Taro storage tuber yield was valued at an average local market price of 9.00 Ethiopian Birr (ETB)/kg. Urea and DAP were purchased at price of 1500 and 1800 ETB /100 kg, respectively. The average storage tuber yield of the trial was adjusted downwards by 10 % to reflect the actual production environment (CIMMYT, 1998).

RESULTS AND DISCUSSION

Data on the soil physico-chemical properties of top soil (0-30cm) of experimental fields at Jimma is presented in Table 2. The data Jimma soil indicated that the soil is a sandy clay and low N and available P, its characterization indicated soil p^H 5.65 in water, 0.539 g kg^{-1} N, 3.27 g kg-1 organic C. 0.691 ppm available P, 1.969 meq/100g K, 5.636 % organic matter, 0.120 meq/100g exchangeable acidity and 22.76 meq/100g CEC. Particle size distributions were 52% sand, 36% clay and 12% silt.

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

No	Physical composition	
1	% Sand	52
2	% Silt	12
3	% Clay	36
4	Textural class	Sandy clay
	Chemical characteristics	
6	p^H (H_2O)(1:2:5)	5.65
7	Organic carbon	3.269
8	Available P (ppm)	0.691
9	Total N (g/kg)	0.539
10	Available K (meq/100g)	1.969
11	%Organic matter	5.636
12	Exchangeable acidity (meq/100g)	0.120
13	CEC (meq/100g)	22.76
14	Exchangeable AL^{+++} (meq/100g)	Trace

Based on the of averages data from the two growing seasons 2015 and 2016, maximum horizontal distance, plant height, number of active leaves/plant, petiole length, leaf length, leaf width, tuber fresh weight (kg/plot), number of tuber/hill, tuber diameter, and tuber dry weight were significantly increased across N and P rates (Tables 3). The tallest plants were obtained at 166.5 kg N/ha and 60 kg P_2O_5/ha rates. Tuber fresh weight, tuber dry weight per plot, leaf length, number of tuber per plant and tuber diameter followed a similar trend. The control plots (0 kg N and P_2O_5) showed the shortest plants with the lowest number of active leaves/plant, petiole length, basal ring length, tuber fresh and dry weight. The superior growth attributes was obtained at high rates of N and P_2O_5 in this study has been reported by other researchers (Taye and Gifole, 2016). The positive response of growth characters to the applied plant nutrients is attributable to their role in cell division, multiplication and photosynthesis which gave rise to increase in size and length of leaves and stems. The sympathetic response also confirmed the important of N and P_2O_5 in plant growth and development (Mengel and Kirkby, 2001). The results obtained from this study are also in agreement with the findings of Suminarti *et al.* (2016). The number of sucker and active leaves/plant followed similar trends as increased the NP rates from 0 kg N/ha to 55.5 kg N/ha and 0 kg P_2O_5/ha to 20 kg P_2O_5/ha, respectively. The incremental rate of N and P from 111 kg N/ha to 166.5 kg N/ha and 40 kg P_2O_5/ha to 60 kg P_2O_5/ha resulted in a corresponding reduction in petiole length, while the opposite result was observed on tuber dry weight when the advanced rates of N and P_2O_5 effects (Table 3). The longest petiole 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. This result is consistent with the results of Taye and Gifole, (2016) and Suminarti *et al.* (2016). Leaf width and tuber length had highest at 166.5 kg N/ha rates, but the tuber length obtained at 0 and 166.5 kg N/ha rates were statistically similar (Table 3).

Tuber length and diameter/plant were significantly increased by P_2O_5 application up to the 40 kg/ha rate and not beyond. On average, the application of 0, 55.5 and 111 kg N/ha, increased the number of tubers/plant by 7.21, 2.11and 1.2 %, whereas, the same rates for P_2O_5 gave corresponding values of 3.2, 2.66 and 1.41%, respectively over the control. Total fresh tuber yield obtained at 166.5 kg N/ha rates showed an increase of only 8.69% over that of 55.5 kg N/ha rate whereas, increasing P rates from 0 to 20 kg, increased yield by 20.56%; a further increase up to 60 kg/ha increased tuber yield by 24.45 percent. The positive response shown by yield parameters to N and P_2O_5 could be directly linked to the well developed photosynthetic surfaces and increased physiological activities leading to more assimilates being produced and subsequently translocation and utilized in fast tuber development. Both N and P_2O_5 have been shown to be necessary for tuber initiation; elongation, increase in tuber size and number (Ayoola and Makinde, 2007). Nitrogen increases the chlorophyll contents of the leaves, thereby promoting the photosynthetic capacity of the plant, plays a part in the manufacture of proteins and is also responsible for high tuber yield in plants. 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 (Abu, 2015). Adequate supply of P is important for energy synthesis and translocation, and it also increases yield and improves tuber quality (Mehdi *et al*., 2007). Hence, the positive response of tuber yield and yield components to increased rates of N and P_2O_5 could be adduced to high energy synthesis and translocation activities stimulated by N and P application. Moreover, the experimental soil was slightly low in nitrogen content, hence, the positive response observed. However, the p^H of the experimental soil was 5.65, and there is some fixation of P in the soil solution, as a result, difficulty to utilize available nitrogen and other essential mineral nutrients from the soil by plants. The result of Suminarti *et al.* (2016) indicated, optimum storage tuber yield of taro was obtained by applying 127.04 kg N/ha and 65 kg P_2O_5/ha with tuber yield of 16.72t/ha. Besides, Taye and Gifole, (2016), also reported significant differences on yield of taro due to N and P_2O_5 application, while the best yield and yield attributes was obtained at 80 kg N/ha (NRCRI, 2005) in cassava. Our results are in conformity with the findings of these different reports and consistent with the report of Yared, (2007) who suggested that the maintenance dressing of 100 kg N/ha and 60 kg P_2O_5/ha per cropping season may be adequate for continuous taro production.

Table 3. Effect of Nitrogen and Phosphorus on yield and yield related traits of taro 2015 and 2016 grown at Jimma.

Treatment	St.co	MHD	PH	Nosk	Noacl	PetL	LL	LW	BRil	TFW	NoTu	TL	TDi	TDW
Nitrogen (Kg/ha)														
0	33.58^{a}	0.98^{b}	0.98^{b}	7.20^{a}	21.50^{b}	10.24^{b}	41.25^{b}	22.12^{b}	47.75^{ab}	59.99^{b}	49.45^{b}	8.94^{a}	7.04^{b}	28.20^{b}
55.5	34.16^{a}	1.01^{ab}	1.03^{ab}	7.54^{a}	24.70^{ab}	10.66^{b}	41.12^{b}	24.75^{ab}	48.00^{a}	67.44^{ab}	53.33^{ab}	9.86^{a}	7.12^{b}	31.69^{ab}
111	34.50^{a}	1.07^{a}	1.10^{ab}	7.70^{a}	26.29^{a}	13.83^{a}	42.75^{ab}	25.75^{a}	49.58^{a}	73.86^{a}	53.50^{ab}	9.90^{a}	7.30^{ab}	32.17^{ab}
166.5	34.42^{a}	1.06^{a}	1.18^{a}	6.54^{a}	26.53^{a}	12.89^{ab}	43.87^{a}	26.70^{a}	50.54^{a}	68.45^{ab}	53.83^{a}	10.2^{a}	7.41^{a}	34.71^{a}
Phosphorous (P_2O_5 Kg/ha)														
0	34.33^{a}	1.01^{b}	1.00^{b}	6.52^{ab}	23.17^{b}	12.67^{ab}	41.37^{b}	25.04^{ab}	48.62^{a}	53.28^{b}	51.79^{a}	9.65^{ab}	7.15^{b}	29.74^{b}
20	33.17^{a}	1.00^{b}	1.06^{b}	7.08^{ab}	24.29^{ab}	12.62^{ab}	42.20^{b}	24.54^{b}	50.33^{a}	67.07^{ab}	52.08^{a}	10.1^{ab}	7.24^{ab}	32.36^{ab}
40	34.75^{a}	1.05^{ab}	1.12^{ab}	7.58^{a}	24.25^{ab}	14.20^{a}	42.82^{ab}	26.33^{a}	48.16^{a}	68.85^{ab}	52.75^{a}	11.20^{a}	8.25^{a}	51.53^{a}
60	34.41^{a}	1.15^{a}	1.17^{a}	7.70^{a}	37.16^{a}	14.12^{a}	43.79^{a}	26.41^{a}	48.75^{a}	70.52^{a}	53.50^{a}	9.91^{ab}	7.31^{ab}	33.14^{ab}
SE$\pm$	2.37	0.08	0.11	1.99	6.21	3.13	3.10	2.40	5.73	14.73	9.67	1.31	0.77	6.92
Interaction N x P	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Mean	34.17	1.04	1.08	7.23	25.99	12.65	42.40	25.21	48.97	66.18	52.53	9.97	7.35	34.19
LSD (<0.05)	1.97	0.07	0.09	1.65	5.16	2.60	2.58	2.00	4.76	12.25	8.04	1.09	0.64	5.75
CV (%)	6.96	8.61	11.28	27.51	24.12	23.40	7.35	9.31	11.71	21.84	18.45	13.21	10.70	21.84

St.co= Stand count at harvest, MHD= Maximum horizontal distance(m) PH= Plant height (m), Nosk= Number of sucker/plant, Noacl= Number of active leaves/plant, PetL= Petiole length (cm), LL= Leaf length(cm), LW= Leaf width (cm), BRil= Basal ring length (cm), TFW=Tuber fresh weight (kg/12m^2), NoTu= Number of tuber/hill, TDi= Tuber diameter (cm), TDW= Tuber dry weight (kg/12m^2).

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

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 (ETB/ha)	Net Benefit (ETB/ha)	Change gross cost	Change Net benefit	MRR (%)
N(Kg/ha)										
0	49992.7	44992.5	404933.5	0	0	0	404933.5	-	-	-
55.5	56200.0	50580.0	455220.0	832.5	0	832.5	454387.5	832.5	49455.0	5940.5
111	61550.0	55395.0	498555.0	1665.0	0	1665.0	496890.0	832.5	42502.5	5105.4
166.5	57041.7	51337.5	462038.5	2407.5	0	2407.5	459540.0	832.5	37350.0	4486.5
P(P_2O_5kg/ha)										
0	44400.0	39960.0	119880	0	0	0	119880	-	-	-
20	57375.0	51637.5	154912.5	0	360.0	360.0	154192.5	360	3645.0	1012.5
40	55891.7	50302.5	150907.5	0	720.0	720.0	150547.5	360	30667.5	8518.7
60	58766.7	52890.0	158670	0	1080.0	1080.0	157590.0	360	3397.5	943.7
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)										
0	49992.7	44992.5	404933.5	0	0	-	364440.1	-	-	-
55.5	56200.0	50580.0	455220.0	832.5	0	915.75	408948.7	915.75	44508.6	6075.0
111	61550.0	55395.0	498555.0	1665.0	0	1831.5	447201.0	915.75	38252.3	5212.0
166.5	57041.7	51337.5	462038.5	2407.5	0	2648.2	413586	915.75	33615.0	6065.72
P(P_2O_5 Kg/ha)										
0	44400.0	39960.0	119880	0	0	0	107892.0	-	-	-
20	57375.0	51637.5	154912.5	0	360.0	396.0	138773.2	396.0	30881.2	7798.3
40	55891.7	50302.5	150907.5	0	720.0	792.0	135492.7	396.0	3280.5	828.4
60	58766.7	52890.0	158670	0	1080.0	1188.0	141831.0	396.0	6338.3	1600.5

MRR=Marginal Rate of Return, field price of taro = 9ETB/kg, price of urea= 15ETB/kg, price of DAP= 18ETB/kg.

The results of economic analysis revealed that, the highest change net benefit of 49,455.0 ETB/ha with marginal rate of return (MRR) of 5940.5% and 30,667.5 ETB/ha with marginal rate of return of 8518.7% were obtained by growing taro with the application of 55.5 kg N/ha and 40 P_2O_5/ha, respectively. An increase in output will always raise profit as long as the marginal rate of return is higher than 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 55.5 kg N/ha was greater than 50% marginal rate of return showed an economically feasible. The net benefit decreased as the cost increased. Besides, the marginal rate of return due to phosphorus application is also more than 50%, application of phosphorus fertilizer is economically profitable up to the rate of 40 kg P_2O_5/ha. Sensitivity analysis of profitability of fertilizer use relative to 10% increase in fertilizer price remained feasible (Table 4). Similarly, it remained profitable up on 10% yield decrease due to moisture loss during transportation and storage. In both cases MRR were above the acceptable range. This depicts relative advantage and stability of economic benefits due to NP fertilizer use in the production of taro in Jimma and other areas of similar soil and climatic conditions of Southwest Ethiopia.

CONCLUSION AND RECOMMENDATION

Nitrogen and phosphorus had positive effects on growth; yield and yield related a trait of taro as they significantly improved it's the storage tuber yield. The application of 55.5 kg N and 40 kg P_2O_5 /ha had significantly improved tuber yield of taro. This also supported by the economic analysis.

The marginal rate of return economically feasible since the marginal rate of return of application is between 50 to 100% indicating that the application of the fertilizers is economical. The economic analysis reveals that further increase the levels of NP fertilizer are not economical. Thus, application of 55.5 kg N/ha and 40 kg P_2O_5/ha kg/ha is economical and recommended for taro production under Jimma condition.

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