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Response of Rice to Nitrogen and Phosphorus Applied on Typical Soils of Dakawa Irrigation Scheme, Morogoro, Tanzania

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***Abstract**: A screen-house pot experiment was conducted at Sokoine University of Agriculture, Morogoro, Tanzania to assess response of rice variety TXD 306 growth parameters to nitrogen and phosphorus applied to the dominant soil type at Dakawa Irrigation Scheme (DIS) Morogoro, Tanzania. The study was prompted by low rice yields and the need to find out the soil constraints to high rice production at the scheme. Based on physical, chemical and biological properties of composite soil sample, the soil had low total N, OC, exchangeable Ca and Mg, hence rated as marginally to moderately suitable for rice production. N and P rates adopted were 0, 50,100, 150, 200 kg N ha*$^{-1}$ *and 0, 40, 80, 120, 160 kg P ha*$^{-1}$*, respectively. Sources of N and P were* $(NH_4)_2SO_4$ *and* $Ca(H_2PO_4)_2$*, respectively applied in a* 5^2 *factorial in CRBD. Number of tillers increased significantly (p < 0.05) with N and P levels from* P_0N_0 *kg ha*$^{-1}$ *to* $P_{80}N_{200}$ *kg ha*$^{-1}$*. Biomass weight (g) increased significantly (p<0.05) from 10.99 g pot*$^{-1}$ *to 93.04 g pot*$^{-1}$ *at* P_0N_0 *kg ha*$^{-1}$ *and* $P_{160}N_{200}$ *kg ha*$^{-1}$*, respectively. Grain yield (g) increased significantly (p<0.05) from 2.24 g pot*$^{-1}$ *to 33.06 g pot*$^{-1}$ *for the absolute control and* $P_{160}N_{200}$ *kg ha*$^{-1}$*, respectively. Thus, for optimum grain yield of TXD 306 on Cambisols at DIS, 80 kg P ha*$^{-1}$ *should be applied as basal and N in two splits i.e. 100 kg N ha*$^{-1}$ *close to tillering and 100 kg N ha*$^{-1}$ *at panicle initiation. For appropriate N and P recommendations, field studies should be conducted to take onboard integrated soil fertility management strategies, principles and practices in rice cultivation based on soil types to allow extrapolation of the results to other similar soils and areas.*

Key Words: *Soil fertility evaluation, Cambisols, rice variety TXD 306, Nitrogen, Phosphorus, Dakawa, Tanzania*

1. Introduction

Rice is a multipurpose crop as it is used both as food and cash crop and is the third most important cereal crop in Tanzania after maize and sorghum [19]. In terms of food value, rice ranks second after maize. Rice can be grown in a wide range of soil conditions from flooded to dry land fields, on hilly terraced to non-terraced landscapes [20]. In Tanzania, rice is extensively grown in the lowlands of Southern Highland Zone, Mwanza, Shinyanga, Manyara, Kilimanjaro, Morogoro and Coast regions. Majority of farmers who grow rice in Morogoro Region, prefer traditional cultivars such as *Shingo ya mwali, Kabangala, Tule na bwana, Mbawa mbili, Kalimata, Kaniki, Afaa, Kahogo, Sindano and Kilombero* (*Super India*). These varieties are aromatic and have good milling and cooking qualities [10], but are genetically low yielding compared to improved varieties such as TXD 306 [10]. Yields of the aforementioned traditional or local varieties range between 2.5- 4 ton ha^{-1} compared to 8-10 ton ha^{-1} for TXD 306 (SARO 5) variety [4].

It has been reported that, in spite of efforts on the part of researchers and Government of Tanzania to increase rice yields, average yield of rice like SARO 5 is still lower than its genetic potential of 10 ton ha^{-1} [4]). There are a number of factors contributing to low rice yields; namely deficiencies of nutrients especially N and P, improper nutrient management, pests and disease control, growing of poor quality seeds, poor soil water management, transplanting of old seedlings (≥ 27 days old) as well as inappropriate traditional transplanting methods [4]. Inherent factors such as rainfall, temperature and soil conditions such as soil moisture, redox potential, pH and salt content affect the rate of nutrient uptake and use efficiency of N and P by rice plants [1]. For optimum rice production, it is mandatory to establish optimum doses of N and P as well as other essential plant nutrients, their uptake efficiencies and their influence on components of yields [13], other rice growth requirements being optimal.

The soils of DIS are Cambisols which are predominantly clayey in texture. The heavy texture coupled with good quality irrigation water favour rice production and the majority of farmers capitalize on these qualities. Yet, yields obtained by farmers are still very low due to low fertility status of the soils, hence supplementation of nutrients like N and P is highly recommended.

Paddy crop requires more water compared to other cereals [23] like maize, hence adequate soil water throughout the active growing period is essential. In addition, the Principles of System of Rice Production Intensification (PSRPI) that integrate aspects of water management, use of good quality rice seeds, transplanting young rice seedlings (8-12 days old), mechanical weed control, appropriate spacing (25 cm x 25 cm) and single seedling per hill [25] have to be given due consideration. In the adoption of PSRPI aimed at attaining high yields, appropriate rice varieties to be grown have to be taken onboard.

Efforts by Government of Tanzania to establish irrigation and intensive system of TXD 306 rice variety production have increased yields from an average of 3.25 to 6 ton ha^{-1} [31], which is still below its yield potential under optimum growing conditions. The main constraints to achieve optimum potential yield are attributed to low fertility status of soils and application rates of the deficient plant nutrient elements like N and P that are below the requirements for optimal yields [13]. Proper dosage of N and P can be achieved by conducting on site experiments. To improve rice productivity, adoption of high yielding varieties is crucial. Yields of rice for varieties like TXD 306 are very low in most areas of Morogoro and N and P have been reported as the most limiting plant nutrients [27]. Currently, there are no established N and P rates for the rice variety SARO 5 (TXD 306) at DIS, that have critically addressed their use efficiencies and cost-value ratios of the N and P applied [13]. Therefore, this study serves as a guide for establishing N and P rates for SARO 5 in the Cambisols of DIS.

2. Materials and Methods

2.1. Description of the study area

A screen-house study was conducted at Sokoine University of Agriculture, Morogoro Tanzania using composite soil sample taken from Dakawa Irrigation Scheme (DIS) which covers an area of 2000 ha located in Mvomero District, Morogoro Region, Tanzania. Some pertinent features of DIS are given in Table 1.

Table 1. Important Features of Dakawa Irrigation Scheme (DIS), Morogoro, Tanzania

Characteristics	Description
Coordinates of the Centre of DIS	Latitude 6^0 24'S and Longitude 37^0 33'E
Altitude (m asl)	361
Landform	Alluvial plain, Almost flat, slope < 1%,
Lithology	Aluvium derived from Neogene parent material originating from Mnguu Mountains [21]
Mean Annual Rainfall (mm)	985
Ranfall Distribution Pattern	Bimodal with short rains lasting from October – January, long rains from March - May
Land use	Paddy rice cultivation under basin irrigation system
Soil Temperature Regime (STR)	Isohyperthermic
Soil Moisture Regime (SMR)	Ustic
Soil Classification	*Haplic Vertic Cambisols (WRB for Soil Resources)*
	Vertic Calciustepts (USDA Soil Taxonomy)

Agricultural activities in the study area are mainly irrigated rice cultivation which is grown both as food and cash crop. Water is usually pumped from Wami Dakawa River for irrigation to supplement inadequate rainfalls for rice production. Based on local and technical indicators of soil fertility, the soils have been previously categorized as of low to medium fertility status [13] hence moderately and marginally suitable for rice production. The major soil fertility limitations include high soil pH and deficient levels of N and P [27].

2.2. Soil fertility evaluation

The purpose of characterizing the soil was to establish fertility status of the soil at the study site before conducting a screen-house pot experiment. By using an auger, 30 randomly selected soil sampling points from the area covering 8 ha were established. Sampling depth was 0 - 30 cm. The sampled soil was gathered and thoroughly mixed to constitute a composite sample for evaluation of fertility status of the soil. The composite sample was air dried, ground to break soil aggregates and sieved through 2 mm sieve for comprehensive laboratory analysis. The sample was analyzed using procedures compiled by [22].

2.3. Soil sampling for pot experiment

About 6 kg soil sample portions were gathered from each of the 30 identified soil sampling points for the screen-house pot experiment making a total of 180 kg soil. Sampling depth was 0 - 30 cm. The 180 kg soil was thoroughly mixed to constitute the bulk composite soil sample used for pot experiment. The bulk composite soil sample was air dried, slightly ground and sieved through 8 mm sieve. Three and half kg soil sample portions were weighed into 4 litres capacity plastic pots for screen-house pot experiment.

2.4. Screen-house pot experiment

N and P fertilizers were used as treatments and SARO 5 (TXD 306) was used as test crop. The rates of N and P adopted in the screen-house pot experiment were 0, 50, 100, 150 and 200 kg N ha^{-1} as $(NH_4)_2SO_4$ while the P rates were 0, 40, 80, 120 and 160 kg P ha^{-1} as $Ca(H_2PO_4)_2$ designated as N_0, N_{50}, N_{100}, N_{150} and N_{200} and P_0, P_{40}, P_{80}, P_{120} and P_{160}, respectively. The design of the experiment was 5^2 factorial in CRBD replicated twice. $Ca(H_2PO_4)_2$ fertilizer was applied once during sowing whereas $(NH_4)_2SO_4$ fertilizer was applied in two splits, 1st at tillering and 2nd split at panicle initiation growth stage. Data collected during the experiment were: number of tillers per plant, plant height, biomass yields and grain yields. Except for biomass and grain yields which were collected during harvesting, number of tillers and plant height were counted during panicle initiation stage. Biomass samples were chopped, dried, ground and sieved to pass through 0.5 mm sieve which were digested and analyzed for N and P contents following procedures described by [22]. The gathered data were statistically analyzed using Gen stat software and Duncan's New Multiple Range Test was used to separate means at ($p<0.05$). Optimum rates of N and P in TXD 306 were then derived from the response data.

3. Results and Discussion

3.1. Soil fertility evaluation of DIS

Some of the chemical and physical properties of composite soil sample from the study area gathered for the purpose of evaluating fertility status of the soil are presented in Table 2. The fertility constraints based on soil analytical results include low percent total N, percent OC, exchangeable Ca, Mg and high pH. Low level of N in the soil would interfere with vegetative growth of the plants hence contributing to low rice yields. Very low organic carbon is an indication of low organic matter content in the soil. The low OM content of the Cambisol would negatively affect moisture and nutrient retention capacity, soil structure and biological activities in soil, hence poor plant growth performance. The low levels of exchangeable Ca and Mg could be attributed to losses through leaching, runoff and mining through continuous plant uptake. Furthermore, the DIS soils have high pH due to dissolved salts.

Table 2: Chemical properties of composite soil sample from DIS

Soil parameters	**Value**	**Rating** (Landon, 1991)
pH (H_2O)	7.93	H
OC (%)	0.81	L
OM (%)	1.39	L
TN (%)	0.07	VL
CEC (cmol(+) kg^{-1})	28.2	H
Exch. Na (cmol (+) kg^{-1})	0.43	M
Exch. K (cmol (+) kg^{-1})	0.84	M
Exch. Ca (cmol (+) kg^{-1})	1.52	L
Exch. Mg (cmol (+) kg^{-1})	0.25	L
Sand (%)	72	SCL
Silt (%)	2	
Clay (%)	26	
DTPA extractable micronutrients (mg kg^{-1})		
Fe	13.7	VH
Cu	1.4	H
Zn	6.4	VH
Mn	42.7	VH

NB: MA=Moderately Alkaline, L= Low, VL= Very Low, H= High, VH= Very High, M=Medium, GQ= Good quality, SCL= Sand Clay Loam

3.2. Response of rice (TXD 306/SARO 5) variety to N and P

The response of rice to N and P as $(NH_4)_2SO_4$ (sulphate of ammonia) and $Ca(H_2PO_4)_2$ (triple super phosphate), respectively applied to the Cambisol of DIS in terms of plant height, number of tillers, biomass yield and grain yield are as presented in Table 3. Plant height increased with increasing rates of N from 60.5 cm for the absolute control to 80.00 cm for the highest rate (N_{200} kg N ha^{-1}) (Table 3), but decreased with increasing rates of P. The increase in plant height was statistically significant ($p< 0.05$). The increase in plant height with increased N application might be due to enhanced vegetative growth with adequate nitrogen supply to the plants. This observation concurs with the study conducted by [2] and [17]. Furthermore, rice plants that received no N and low N rates (N_0 and N_{50}) showed some N deficiency symptoms such as chlorosis, few numbers of tillers and delayed maturity. The positive increase in height was due to the effect of N as the native N content in the soil was very low (Table 2). Similar findings were reported by [13].

Table 3: Response of TXD 306 Rice Variety to N and P applied to Cambisols of DIS

Treat-ments	Plant Height (cm)	Tillers pot^{-1}	*Biomass yield g pot^{-1}	Grain yield g pot^{-1}	%N	%P
$_0N_0$	60.50 de	4.00 abc	10.99 a	2.24 a	1.58 a	0.16 a
P_0N_{50}	65.50 g	6.00 cde	15.18 b	2.55 a	1.83 abcd	0.20 bc
P_0N_{100}	70.00 hi	7.00 def	19.70 c	4.64 b	2.10 dfgh	0.23 fg
P_0N_{150}	73.50 ij	8.50 fgh	42.10 f	11.89 e	2.20 ghi	0.23 fg
P_0N_{200}	80.00 k	10.00 hi	48.97 h	17.65 g	2.31 hij	0.24 ghi
P_0N_0	60.50 de	4.00 abc	10.99 a	2.24 a	1.58 a	0.16 a
$P_{40}N_0$	61.50 ef	5.00abcd	11.89 a	2.41 a	1.71 ab	0.19 b
$P_{80}N_0$	55.00 bc	4.00 abc	16.04 b	3.94 ab	1.80 abc	0.21 de
$P_{120}N_0$	53.00 b	4.00 abc	18.41 c	4.46 b	1.83 abcde	0.22 def
$P_{160}N_0$	46.00 a	3.00 a	20.12 c	5.03 b	2.01 cdefg	0.24 ghi
$P_{40}N_{50}$	67.50 gh	7.50 efg	29.54 d	8.10 c	1.70 ab	0.21 cd
$P_{40}N_{100}$	70.50 hi	9.00 fgh	42.75 f	12.94 e	2.22 ghi	0.23 fgh
$P_{40}N_{150}$	75.50 j	10.50 hi	48.46 h	15.00 f	2.40 ijk	0.24 gi
$P_{40}N_{200}$	80.00 k	9.50 ghi	65.65 k	20.66 h	2.51 jkl	0.27 kl
$P_{80}N_{50}$	68.00 gh	7.50 efg	32.91 e	9.66 cd	1.93 bcdef	0.23 efgh
$P_{80}N_{100}$	60.00 de	8.00 j	46.10 g	16.54 fg	2.25 ghij	0.25 ij
$P_{80}N_{150}$	64.50 fg	10.50 hi	65.86 k	21.98 hi	2.42 ijk	0.27 kl
$P_{80}N_{200}$	68.50 gh	11.50 i	76.16 l	29.78 k	2.64 klm	0.28 lm
$P_{120}N_{50}$	55.00 bc	4.50 abc	34.93 e	9.95 d	2.07cdefgh	0.26 jk
$P_{120}N_{100}$	57.00 cd	5.00 abcd	55.04 i	17.04 g	2.42 ijk	0.28 mn
$P_{120}N_{150}$	61.50 ef	9.00 fgh	67.90 k	22.90 ij	2.51 jkl	0.29 no
$P_{120}N_{200}$	65.00 fg	9.50 ghi	84.07 m	31.82 l	2.74 lm	0.29 no
$P_{160}N_{50}$	54.50 bc	3.50 ab	41.86 f	12.97 e	2.23 ghij	0.26 k
$P_{160}N_{100}$	52.00 b	5.50 bcde	60.26 j	20.94 h	2.51 jkl	0.30 op
$P_{160}N_{150}$	67.50 gh	7.50 efg	75.39 l	24.11 j	2.70 lm	0.31 p
$P_{160}N_{200}$	68.00 gh	10.50 hi	93.04 n	33.06 l	2.89 m	0.32 q
Cv%	2.2	13	1.8	2.9	5.4	2.7

*Mean values in a column having same letter(s) do not differ significantly using DNMRT at 5% level of probability. *Biomass = straw + grain

Plant height increased at the low P rates but decreased when P rates were further increased. The highest plant height recorded in this experiment was 61.5 cm when 40 kg P ha^{-1} were applied and the lowest height (46 cm) at 160 kg P ha^{-1}. Furthermore, plant height increased significantly (p<0.05) with increasing applied P rate up to 40 kg P ha^{-1} but further increase beyond 40 kg P ha^{-1} resulted to a negative effect on plant height (Table 3). The plants did not show any signs of P deficiency symptoms during growth indicating that the amount of native soil available P was sufficient for roots and plant development hence plant growth (Table 2). Similarly, [24] and [34] reported increases in rice plant height due to increasing P fertilizer application rates and decrease when P rates were increased beyond 40 kg P ha^{-1}. The response of rice to the N x P interactions did not follow a well-defined trend in plant height. The highest plant height recorded in this experiment was 80 cm at $P_{40}N_{200}$ kg ha^{-1} and the lowest plant height was 52.00 cm at $P_{160}N_{100}$ kg ha^{-1}.

The promotion of rice plant height in the present study due to applications of N and P is apparent as N is an essential nutrient for plant growth since it is a constituent of all proteins and nucleic acids, whereas P is essential for production and transfer of energy in plants. [5] and [2] have also observed that rice plant height was enhanced by combined N and P applications. The synergistic effect of the N x P interaction was evident in this study as well as the antagonistic effects, where N and P requirements were in appropriate and inappropriate balances, respectively.

The response of TXD 306 to N and P in terms of number of tillers is presented in Table 3. Number of tillers per plant increased with increasing rates of N. The increased number of tillers per plant was statistically significant (p<0.05). The highest number of tillers was 10 at 200 kg N ha^{-1} and the lowest number (4) was recorded in the absolute control. Increase in number of tillers with N application was attributed to increase in soil N as the soil from DIS was deficient in N (Table 2). N deficiency symptoms such as thin and weak tillers were also observed in pots where low rates of N were applied (0 and 50 kg N ha^{-1}). [16] reported that rice plants produced more productive tillers per hill (23.42) when 225 kg N ha^{-1} was applied. These results were in line with those reported by [18]. Enhanced tillering by increased nitrogen application might be attributed to more nitrogen supply during the active tillering stage. Similar findings were also reported by [6] that application of N at rates exceeding 50 kg N ha^{-1} facilitated high vegetative growth and tillering in most plants.

Increasing P rates significantly reduced number of tillers to 3 when 160 kg P ha^{-1} was applied (Table 3). There was significant response (p < 0.05) to P with increased P application rates. Lack of response to P application for the Cambisol was attributed to relatively high contents of initial P in the soil (69.06 mg P kg^{-1}) observed at the start of the experiment (Table 2). Similar observations were also reported by [26] in Kilangali, Mkindo, Mgomba and Majengo soils.

The interaction between the two nutrients (N and P) in tillering is as presented in Table 3. The highest number of tillers (11.5) was recorded at 80 kg P ha^{-1} and 200 kg N ha^{-1} and the lowest number (3) was recorded at $P_{160}N_0$ kg ha^{-1}. These findings imply that increase in number of tillers relates to the role of N in growth and development of a crop and ability of N to synergistically enhance availability of in-situ P from the soil exchange sites, which is a primary nutrient for tillering in rice.

The response of N, P and the interaction between N and P on biomass yields (straw and grain) are presented in Table 3. The biomass yield increased significantly (p <0.05) with increased N rates in the soil. The highest biomass yield (43.97 g) was obtained at 200 kg ha^{-1} and the lowest (10.99 g) recorded for the absolute control. The increase in biomass with N application was attributed to the N as the soils at the trial site were deficient in N (Table 2). This is the fact that N is one of the important nutrients for vegetative development of plants. Similar findings were also reported by [8] that N application increased biomass yield over the absolute control.

Similarly, biomass yield increased significantly ($p<0.05$) with increasing levels of applied P (Table 3). The highest biomass yield (20.12 g pot^{-1}) was recorded when 160 P kg ha^{-1} applied. The lowest biomass yield (10.99 g pot^{-1}) was recorded where no P fertilizer was applied. This also concurs with the study conducted by [8] and [13]. The interaction between the two nutrients (N and P) in rice significantly increased biomass yield ($p<0.05$). The highest biomass weight (93.04 g pot^{-1}) was recorded at $P_{160}N_{200}$ kg ha^{-1} and the lowest biomass yield was 10.99 g pot^{-1} observed in absolute control. These findings are in line with those reported by [6] and [32].

The weights of dry grain per pot were as presented in Table 3. The weight of grain increased significantly ($p<0.05$) with increasing N, P and N x P combination rates. Increased rate of N application significantly increased grain yields of rice. The highest grain yield was 17.65 g obtained when N was applied at the rate of 200 kg ha^{-1} while the lowest grain yield (2.24 g) was recorded in absolute control. Similar findings were reported by [32] that the highest grain yield was obtained when 80 kg N ha^{-1} was applied and the lowest in the absolute control. In addition, [32] reported that the increase in grain yield for application of N is mainly due to improvement in yield components such as number of effective tillers.

According to [29], N deficiency in rice results in stunted growth and chlorotic leaves caused by poor assimilate formation that leads to premature flowering and shortening of the growth cycle, which in turn reduce grain yield. In contrast, presence of N in excess promotes development of the above ground organs with abundant dark green (high chlorophyll) tissues of soft consistency and relatively poor root growth and poor grain yield. [12] and [28] also reported highest paddy grain yields as a result of nitrogen application at 150 kg ha^{-1} and 250 kg ha^{-1}. The higher paddy grain yield at higher nitrogen rates was due to high number of grains per panicle and 1000 grain weight [18].

Increased P rates also increased grain yields (Table 3). The highest grain yield (5.03 g pot^{-1}) was recorded at 160 kg P ha^{-1} and the lowest (2.24 g pot^{-1}) at the absolute control. The response of rice in terms of grain yield above 0 kg P ha^{-1} was possibly affected by the higher amount of inherent extractable (available) P in DIS Cambisol. The availabilities of both native and applied P have also been reported to increase grain yields on soils under flooded rice production in Pakistan [35]. [33] revealed that grain number per panicle was significantly influenced by phosphorus fertilizer. However, the highest grain yield (33.06 g pot^{-1}) was obtained at the highest combination rate of N and P ($P_{160}N_{200}$ kg ha^{-1}). This result was statistically at par with that obtained at $P_{120}N_{200}$ kg ha^{-1} (Table 3). [13] reported that basal application of P during sowing and top dressing with half dose of N fertilizer (50 kg ha^{-1}) at the beginning of tillering and the remaining half (50 kg ha^{-1}) at about panicle initiation was practically a viable option to increased rice grain yields.

3.3. N and P contents in biomass straw

The contents of N and P in biomass (straw) are presented in Table 3. The % N in biomass straw increased with increasing N application rates. The highest N (2.31 %) was recorded when 200 kg N ha^{-1} was applied and the lowest (1.58 %) in the absolute control. This increase was statistically significant ($p<0.05$). [30] categorized these biomass straw N as deficient (< 2 %) and optimum when it is ranging between 2.25 - 3.30 %. Therefore, based on [30], % N observed was deficient in absolute control but sufficient when 200 kg N ha^{-1} was applied.

Furthermore % P increased with increasing P rate. The highest P content in biomass straw was 0.24 % recorded in 160 kg P ha^{-1} and the lowest (0.16 %) in absolute control. Similar to N, this increase was statistically significant ($p<0.05$). According to [30], these values are rated as sufficient (> 0.15 %) but optimum when the values range between 0.18 - 0.32 %. [7] reported P deficiency to occur when a recently matured leaf (third leaf of a plant), contains < 0.15 % but adequately supplied with P when > 0.17%.

For the N x P combination, treatments receiving adequate supply of nitrogen had a positive impact in improving availability of P for plant uptake. Results of the combination showed that the highest P rate without N (P_{160} N_0 kg ha^{-1}) and zero P with higher level of N (P_0 N_{200} kg ha^{-1}) statistically gave similar P content in biomass straw ($p < 0.05$). These results are also supported by the findings by [9] that N supply increased P uptake due to its effect on root growth.

3.4. Optimum rates of N and P by rice (TXD 306) at DIS

The performance of different combined rates of N and P fertilizers applied to rice in Cambisol from DIS are also tabulated in Table 3. Increased rate of N and P significantly increased grain yield from 2.24 g to 33.06 g pot^{-1}. The lowest grain yield was recorded in absolute control (P_0N_0) and the highest mean grain yield per pot (33.06 g) was recorded when the highest combination rate ($P_{160}N_{200}$ kg ha^{-1}) was applied. Based on observations made, the optimum rates of N and P for rice in the Cambisol from DIS was $P_{160}N_{200}$ kg ha^{-1}. However, the economic analysis of rice production calls for field experiments and trials.

4. Conclusions and recommendation

The soil of the study area was moderately fertile and marginally suitable for rice production. The optimum grain yield and yield components were obtained with a combined application of N and P fertilizers. The results of the study indicated that the optimum rate of N and P to improve grain yield and yield components of rice grown on soils at DIS was $P_{160}N_{200}$ kg ha^{-1}. In this study, plant height, number of tillers per plant and straw biomass were the most important yield forming attributes causing significant variation in grain yield of rice (TXD 306). Based on the results of study it may be concluded that treatment $P_{80}N_{200}$ kg ha^{-1} is also suitable for rice cultivation in Cambisols at DIS. Therefore, marginal farmers who are unable to invest more might go for $P_{80}N_{200}$ kg ha^{-1} and large scale farmers may be advised to adopt $P_{160}N_{200}$ kg ha^{-1} which supplies balanced fertilization as the most suitable one provided that costs of input and market price of rice justify profit pending verification by field experiment or trial. Further studies are also required in the light of significant fertilizer recommendations for both N and P fertilizers, aimed at promoting integrated soil fertility management in rice cultivation based on other soil types so as to extrapolate the results to other places with similar type of the soil.

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