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Phosphorus Dynamics and Rice Yield Response to Different Fertilization in Acid Soils

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Abstract: Proper fertilizer management is needed to overcome the problem of phosphorus deficiency in acid soils which is a major constraint in rice production. Knowledge on phosphorus (P) fractions is vital in understanding the P bioavailability. The objective of this study was to compare the effect of organic manures and compost, cattle manure, poultry manure and sheep manure and Triple Super Phosphate (TSP), on phosphorus availability and rice yield. The treatment with TSP + recommended chemical fertilizer (200 kg ha^{-1} NPK 15:15:15, 50 kg ha^{-1} Urea (tillering stage) + 50 kg ha^{-1} MOP (panicle initiation)) recorded highest yield but showed no significant difference with TSP+ cattle manure treatment. The lowest yield, available P, total P and highest Al-P and Ca-P recorded in control (no fertilizer). This indicates that application of P is necessary to maintain the soil phosphorus level at optimum to achieve targeted yield in acid soil. Maximum level of available and total phosphorus was recorded by application of TSP +cattle manure. Cattle manure with TSP increased yield and P availability which helps to reduce the mineral fertilizer usage and production cost. This could be a good practical technique that improves soil P content and increases the yield in acid soils.

Keywords: Acid Soil, Inorganic P Fractions, Rice Yield, Organic Manures

1. Introduction

Although in Brunei Darussalam the major staple is rice; about 95% of domestic rice consumption is imported. The self-sufficiency level is yet at 5% [18]. Realizing the necessity of self sufficiency from national food security perspectives, Government of Brunei launched national rice project in 2008. As majority of the soils of Brunei are acidic a suitable soil management strategy is crucial to achieve the targeted rice production. Low available phosphorus content due fixation by iron and aluminum are the primary constraints in rice cultivation of Brunei Darussalam [20]. A viable strategy to overcome the problem of low P availability will be through proper management practices such as the application of P-based fertilizer/manure to increase P use efficiency [32]. In agriculture system, soil P management is critical to get the optimum yield and reduces P losses by increasing soil P status in low P soils and by limiting soil P accumulation to target level of 20 to 40 mg/kg [21].

Low yield of rice is due to limitation of P level in most parts of the world [11]. P is essential for plant growth as it plays a vital role in the developmental processes such as plant metabolism; photosynthesis; biological membranes and supports root and shoots growth of crops [50]. However, in high rainfall areas with acid and clay soil conditions, P availability is low because soluble inorganic P is fixed by Al and Fe [49].

An inorganic and organic P sources is critical for maintaining the soil P in sustainable agricultural production [1]. Application of inorganic fertilizers can provide the P to crops but most of the P is transformed into insoluble P compounds by reacting with Fe and Al compounds especially in acidic conditions [2]. Over reliance on use of chemical fertilizers has been associated with declines in soil physical and chemical properties and crop yield [14] and significant land problems, such as soil degradation due to over exploitation of land and soil pollution caused by high application rates of fertilizers application [42]. Organic fertilization increases P availability by reducing of Fe and Al fixation in acid soil [12] and humic substances promote the bioavailability of P fertilizers at low pH of soil [16]. According to [31], organic materials provide not only the plant nutrients but also improve soil physical and chemical properties. But, the use of organic manure alone to replace inorganic fertilizer is not adequate to maintain the present levels of crop productivity of high yielding varieties [8]. Therefore, integrated plant nutrient management in which a combination of inorganic P fertilizer and organic fertilizer is used to maintain soil fertility and to sustain a balance in the nutrient supply in order to boost up the crop yield per unit area [36].

Knowledge of the nature and distribution of P fractions is important to understand the bioavailability of P in the environment. The available P fraction includes available inorganic P, low molecular weight organic P molecules, and inorganic P produced by organic P mineralization [4]. Plants obtain P mainly from inorganic P forms in soil [24], and water-soluble inorganic P is the common bio-available P [43]. No sufficient research information is available on the combined effects of inorganic P with organic input on soil P fractions, availability, plant growth and yield in rice growing soils in Brunei Darussalam. Thus pot study was conducted with the objectives were (i) to investigate the proportions of P fractions and P availability at different crop growth stages, (ii) to evaluate the impact of P fertilizer and organic manures on plant growth and yield, and (iii) to study the P uptake of rice plant in acid soils.

2. Method

2.1. Experimental Site and Design

The pot experiment was carried out in a net house located near the Faculty of Science of the University Brunei Darussalam. For the study, soil from Wasan agricultural development area in Brunei-Muara District was collected. There seven treatments tested were T1- control (no fertilizer),T2- TSP 100 kg ha^{-1}, T3- TSP 100 kg ha^{-1}+ recommended NPK (200 kg ha^{-1} NPK 15:15:15 (10 days after planting), 50 kg ha^{-1} Urea (tillering stage) + 50 kg ha^{-1} MOP (panicle initiation)), T4- TSP 100 kg ha^{-1} + compost 10 t ha^{-1}, T5- TSP 100 kg ha^{-1} + 10t ha^{-1} sheep manure, T6- TSP 100 kg ha^{-1} +10 t ha^{-1} cattle manure, T7- TSP 100 kg ha^{-1} + 10 t ha^{-1} poultry manure.

The experimental design used was completely randomized design with four replications. Soils used in all the treatments were added with dolomite lime (2 t ha^{-1}) and organic manures 10 days prior to planting, and P in the form of TSP was added a day before transplanting. Locally developed rice variety BDR- 5 was used in this study. At the physiological maturity, the crop was harvested and the plant height and effective tiller numbers were recorded. The harvested plants were oven-dried at 70°C for 48 hrs and investigation were carried out on the dry matter weight and seed yield as recommended by [47].

The harvest index (HI) was calculated using the following formula [25]:

$$\text{Harvest Index (HI)\%} = \frac{\text{Economic yield (grain weight)}}{\text{Biological yield (total dry weight)}} \times 100 \quad (1)$$

Where, Economic yield = grain yield and
Biologicalyield = grain yield + straw yield.

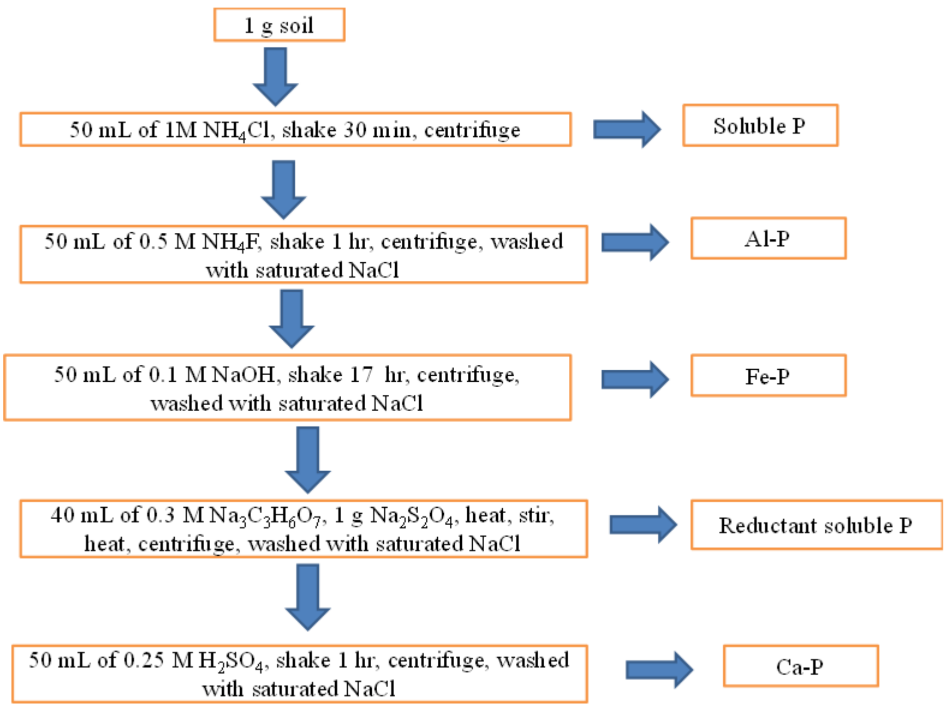


Figure 1 *Sequential extractions of P fractions.*

2.2. Soil and Plant Analyses

Soil sample was collected from each pot when the rice plants reached the vegetative stage (4 weeks after transplanting), reproductive stage (11 weeks after transplanting) and at harvest (17 weeks after transplanting). The soil samples were air-dried and processed for laboratory analysis. Total P was extracted by digesting 2 g of air-dried soil with 65% of nitric acid (30 mL) followed by filtration using filter paper. Available P (Bray- I) of soil samples was extracted by Bray's-1 extract. Kuo1996 fractionation method was used for measuring of the inorganic P fractions such as Saloid-P (soluble P), Al-P, Fe-P, reductant soluble-P and Ca-P. The sequential extractions of P fractions are given in a flow chart in Figure 1. Total P was determined with the metavanadate yellow method whereas inorganic P fractions including Bray's 1 P analyzed using ascorbic acid method [30] using UV-spectrophotometer. Straw and grain samples collected after harvest were dried in an oven and powdered using grinding machine. Subsequently, 1g of oven dried sample was digested by wet oxidation method (nitric acid: sulphuric acid- 2:1) [37]. Total P in grain, husk and straw was determined after digestion by metavanadate method using UV spectrophotometer.

The P uptake was calculated using the formula (Sharma and Dadhwal 1996):

$$\text{P uptake (kg ha}^{-1}) = \frac{\text{P content (\%)} \times \text{Dry matter (kg ha}^{-1})}{100} \quad (2)$$

Where, P contents (%) in plant part (dry matter) = P content in grain + husk + straw

Dry matter yield (grain + husk + straw)

2.3. Statistical Analysis

Data are presented as a mean value ± standard error. Data analysis was performed with SPSS version 20 statistical software [17]. Duncan's Multiple Range Test (DMRT) at 5% level of probability was used to estimate significance of the difference among the treatment means.

3. Results and Discussion

3.1. PFractions and Availability

The initial chemical properties of the soil used for the study is presented in Table 1 and nutrient composition of organic manures used in Table 2. The available P, total P and inorganic P fractions (Saloid-P, Al-P, Fe-P, Reductant soluble-P and Ca-P) status of the soil at different growth stages of rice plants are presented in Tables 3, 4and 5 respectively.

Table 1. *Initial physico-chemical properties of the soil used in the study.*

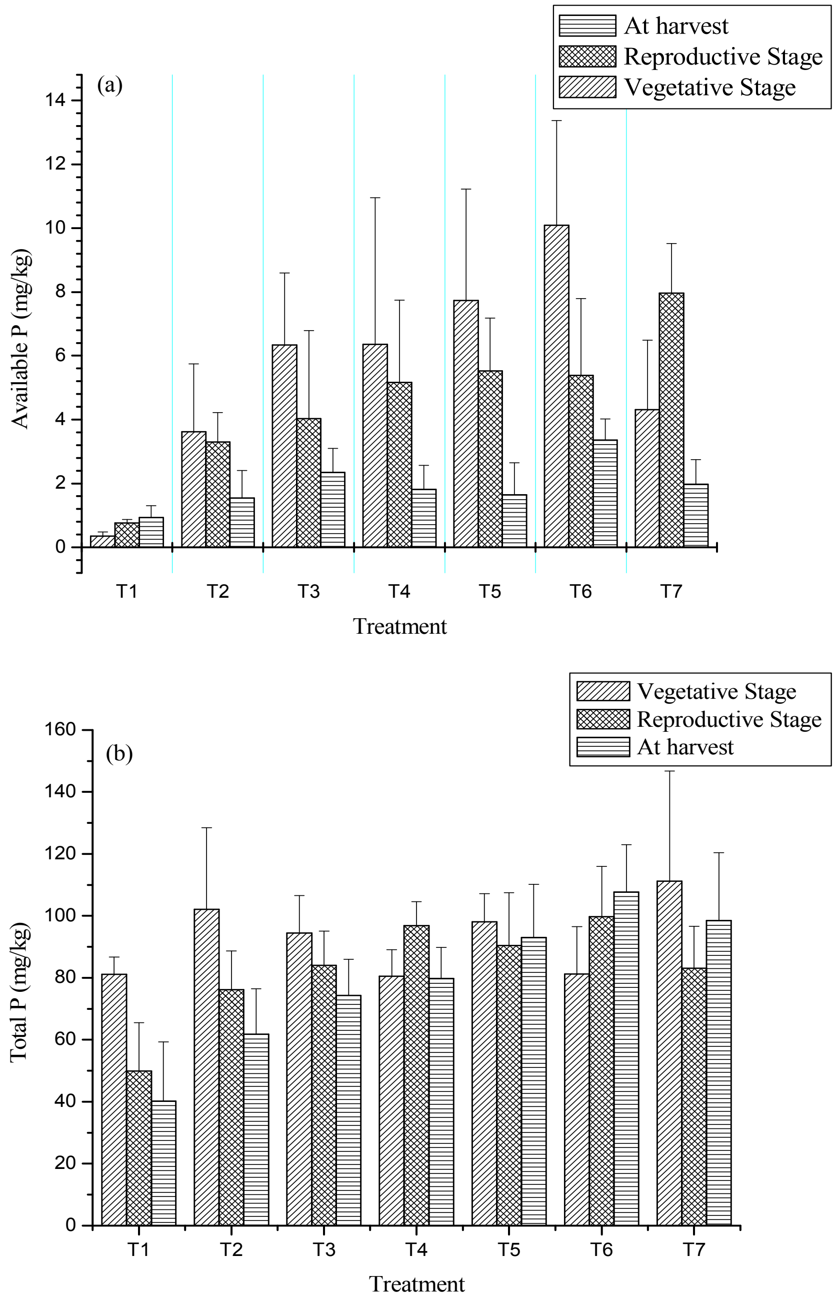
Parameters	Content
pH (1:2.5 soil: water)	4.1
EC (dS/m)	0.08
Organic matter (%)	2.54
Bray I-P (mg/kg)	1.3
Total P- (mg/kg)	82.8
Exchangeable calcium (cmol(c)/kg)	6.3
Exchangeable magnesium (cmol(c)/kg)	10
Exchangeable sodium (cmol(c)/kg)	10
Exchangeable potassium (cmol(c)/kg)	0.2
Exchangeable aluminum (cmol(c)/kg)	4
Cation exchangeable capacity (cmol(c)/kg)	18.5
DTPA extractable Fe(mg/kg)	22.7
DTPA extractable Cu(mg/kg)	3.2
DTPA extractable Mn(mg/kg)	26.7
DTPA extractable Zn (mg/kg)	3

Table 2. *Composition of the organic manures used in the study (dry weight basis).*

Chemical composition	Compost	Sheep manure	Cattle manure	Poultry manure
Organic matter (%)	13.7	13.4	13.3	13.5
Total P_2O_5 (%)	0.08	0.08	0.1	0.1
Total potassium (K) (%)	0.34	0.18	0.25	0.26
Total calcium (%)	2.5	1.1	0.9	1.1
Total magnesium (%)	0.1	0.1	0.2	0.2
Total sodium (%)	0.1	-	0.1	0.3
Total iron(mg/kg)	0.9	11.2	23.0	92.0
Total copper (mg/kg)	12.6	9.0	8.3	12.2
Total manganese (mg/kg)	8.6	27.6	26.3	23.0
Total zinc (mg/kg)	10.4	15.9	21.7	187.4

Available P has been considered as an important indicator of soil P supply capacity [22]. At all stages of plant growth it was observed that T1- control (no fertilizer) had the lowest available P and total P Figure 2. a and b.At the vegetative stage, the highest level of total P (111.19 mg/kg) was found in T7 (TSP + poultry manure).The maximum amount of total

P (81.19 and 107.71 mg/kg) at the reproductive stage and at harvesting wasin T6 (TSP + cattle manure) Figure 3). Total P content in the soil without fertilizer application (T1) decreased from the initial value of 81.11 to 40.18 mg/kg at harvesting. This result clearly showed that without fertilizer application, soil total P content decreased with cultivation.This finding is in agreement with [10] found that without P fertilization decreased of total soil P. In contrast, total P concentration in soils with T6 (TSP + cattle manure) increased with cultivation time, and the accumulation of P in soils was affected by slow release of P from manure and reduction in Fe and Al fixation. Mineral fertilizer or organic manures application either only Organic Manure or as combined applications significantly improved the total P concentration above the original level, demonstrating that addition ofmineral P fertilizer and organic manures leads to increase of total P stocks in soil [46].



T1- control, T2- TSP, T3- TSP + recommended fertilizer, T4- TSP + compost, T5- TSP + sheep manure, T6- TSP + cattle manure, T7- TSP + poultry manure

Figure 2. *Effect of chemical fertilizer and organic manures on available P (a) and total P b).*

Saloid-P was the most part of the readily available P form among the inorganic P. The lowest Saloid-P content was also found in T1- control at vegetative stage and at harvesting while T5 – TSP + sheep manure it was at the reproductive stage (Figure 3.a). This was due to the removal of P from soil by plant uptake [48].The highest amount of available P (10.09 and 3.36 mg/kg) and Saloid-P (10.3 and 8.18mg/kg) occurred in T6 (TSP + cattle manure) for vegetative stage and at harvest respectively T7 (TSP + poultry manure) (7.96 mg/kg) of available P and (6.04 mg/kg) of Saloid-P maintained in reproductive stage. The influence of cattle manure and poultry manure on available P was possibly due to the high content of P_2O_5 (0.1%) than other manures. It is in accordance with [23] shown that organic sources may provide a slow releasing of P which participate a vital role of the cycling of soil P. A combination of P fertilizer and organic manure is able to benefit for increasing the availability of P to plants. This is in agreement with the findings of [46]; P from manure was transformed into moderately stable form for the initial stage subsequent to application, and then they would be in steadily available form. Although, the uptake of added inorganic fertilizer by the plant is direct it is easily lost from soil because addition of P was fixed by Al and Fe or Ca. It was viewed that organic materials increased Saloid-P than the mineral fertilizer. Synergistic effect of combination of mineral and organic fertilizer due to: (1) a supplementary of P during organic manure decomposition; (2) reduces the organic or inorganic P from irreversible adsorption process in soil [26] and (3) mobilization of indigenous soil P [29].

The highest Al-P and Fe-P levels were maintained by T1-control (no fertilizer) during reproductive stage and at harvesting (Figure 3.b; c).This is also expected under acidic condition, rich of Fe and Al oxides cause more fixation of P [20]. Al ions are released from clay lattices onto clay surfaces and soil solution at pH below 5.0. High content of Al at low pH levels seems to be the major limiting factor in growth of plants in acidic and highly weathered tropical soils [13]. However, the maximum content of Al-P occurred in T6 (TSP + cattle manure) in vegetative stage and the maximum content of Fe-P observed in T5 (TSP + sheep manure) in vegetative stage. This is due to impact of organic acids cause the Fe stable complexes form which blockage of available P retention sites [41]. Increased reductant soluble-P in T3 (TSP + recommended fertilizer) and T2 (TSP) was directly due to the input of P from mineral fertilizers and rapidly water-soluble phosphate was converted to the relatively less soluble compounds within a short time (Figure 3.d). The effectiveness and efficiency of P fertilizers can be enhanced by increasing P solubility in soil solution or by reducing P fixation in soil [16]. Maximum Ca-P was found in T7 (TSP + poultry manure) during all growth stages (Figure 3.e). It may be poultry manure typically contains high concentrations of Ca and inorganic P in addition, leads to transformation of Ca-P.

Table3. *P availability and inorganic P fractions in soil at vegetative stage.*

Treatment	Available P	Saloid-P	Al-P	Fe-P	Reductant soluble-P	Ca-P	Total P
	mg/kg						
T1	0.35 b (0.14)	1.03 a (0.73)	10.60 b (0.43)	5.48 a (0.21)	0.10 a (0.00)	4.75 a (1.58)	81.11 a (5.54)
T2	3.62 ab (2.13)	3.13 a (2.53)	14.35 ab (2.58)	6.65 a (0.90)	0.10 a (0.00)	3.23 a (2.29)	102.1 a (26.40)
T3	6.34ab (2.25)	6.93 a (2.60)	15.63ab (1.78)	8.20 a (0.72)	0.23 a (0.13)	1.95 a (1.56)	94.43 a (12.14)
T4	6.36ab (4.59)	5.08 a (3.20)	16.2ab (5.07)	8.33 a (2.27)	0.10 a (0.00)	4.68 a (1.40)	80.51 a (8.54)
T5	7.73 ab (3.49)	9.38 a (4.40)	20.08 ab (4.50)	8.95 a (1.63)	0.10 a (0.00)	3.43 a (0.93)	98.10 a (9.10)
T6	10.09 a (3.28)	10.30 a (4.90)	22.20 a (4.84)	8.58 a (1.50)	0.10 a (0.00)	4.80 a (1.74)	81.19 a (15.35)
T7	4.31ab (2.18)	8.53 a (5.41)	14.98ab (2.83)	7.58 a (1.51)	0.10 a (0.00)	4.95 a (1.27)	111.19 a (35.50)

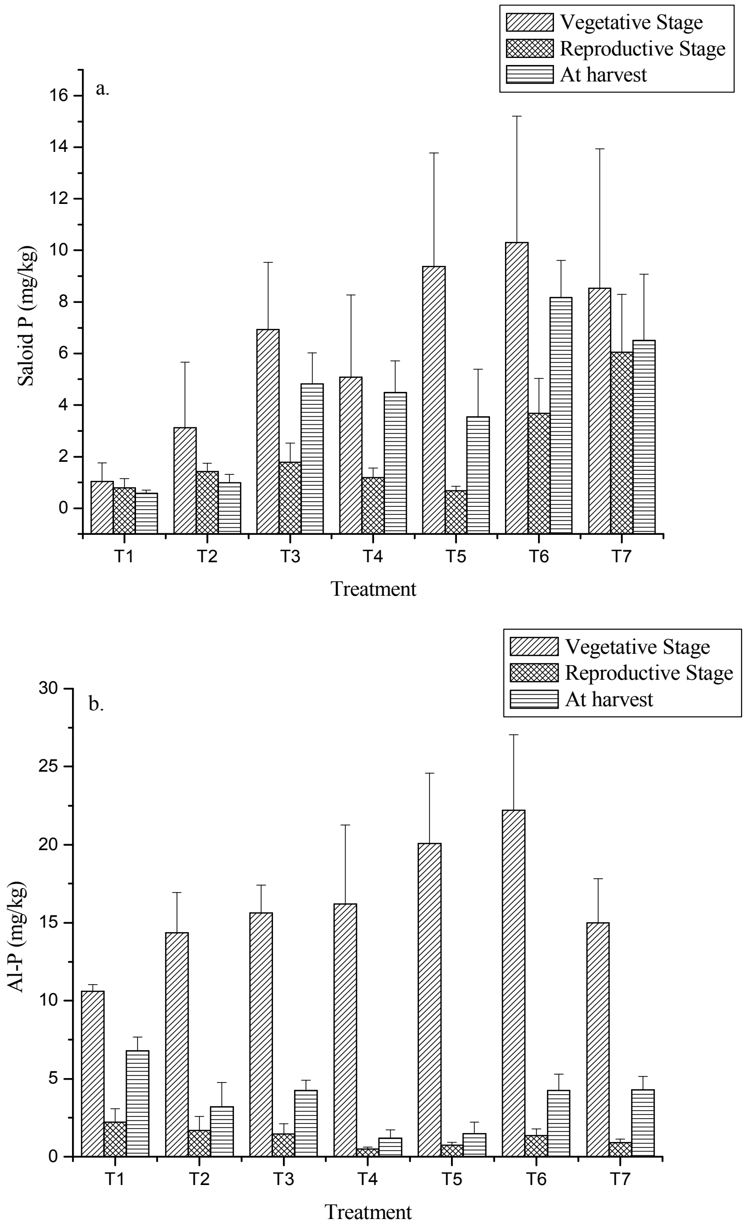
Table 4. *P availability and inorganic P fractions in soil at reproductive stage.*

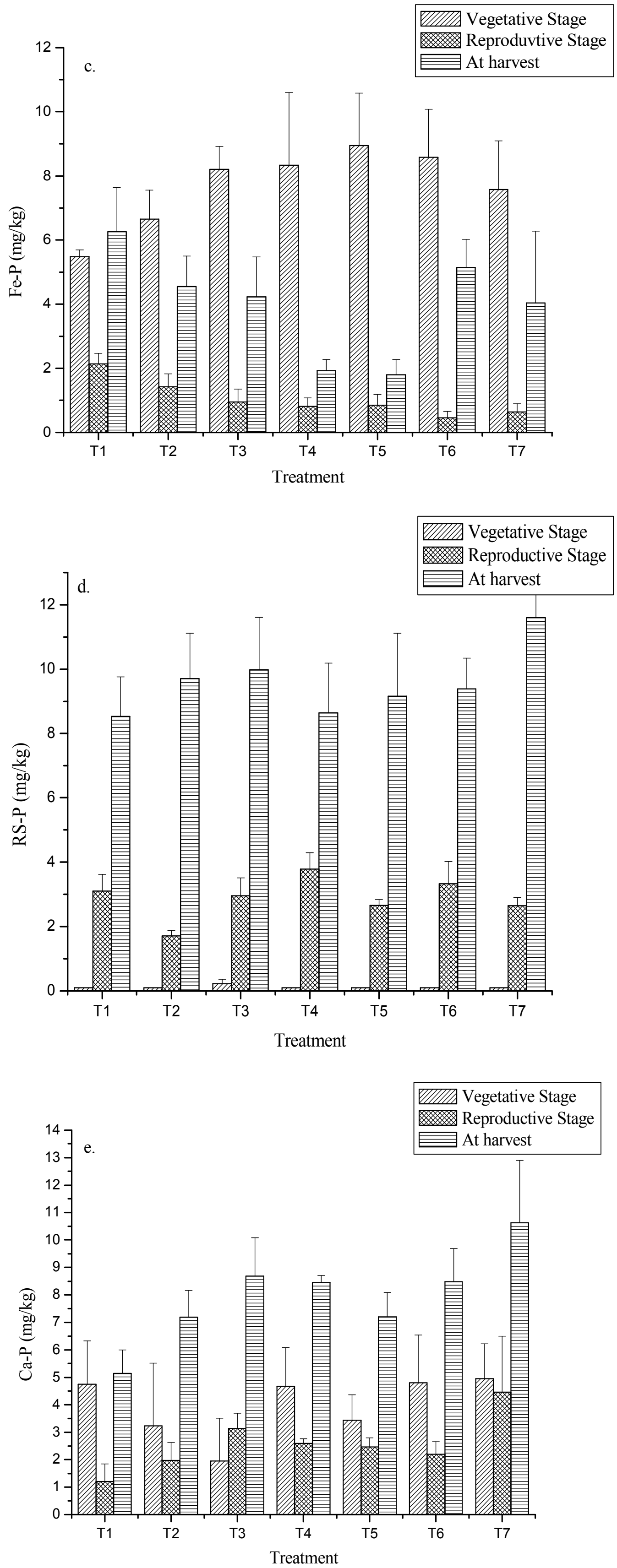
Treatment	Available P	Saloid-P	Al-P	Fe-P	Reductant soluble-P	Ca-P	Total P
	mg/kg						
T1	0.76 ab (0.12)	0.79 b (0.36)	2.23 a (0.85)	2.14 a (0.33)	3.10 a (0.52)	1.21 b (0.64)	49.91 a (15.56)
T2	3.30 b (0.92)	1.43 b (0.32)	1.69 ab (0.90)	1.43 ab (0.40)	1.71 b (0.17)	1.98 ab (0.64)	76.17 ab (12.46)
T3	4.03 ab (2.76)	1.78 b (0.75)	1.46 ab (0.66)	0.95 bc (0.40)	2.96 ab (0.55)	3.13 ab (0.56)	84.00 ab (10.98)
T4	5.17 ab (2.57)	1.19 b (0.36)	0.49 b (0.14)	0.81 bc (0.27)	3.78 a (0.51)	2.59 ab (0.17)	96.75 a (7.78)
T5	5.53 ab (1.65)	0.68 b (0.18)	0.74 ab (0.20)	0.85 bc (0.34)	2.66 ab (0.18)	2.46 ab (0.34)	90.39 a (17.14)
T6	5.39 ab (2.40)	3.68 ab (1.35)	1.36 ab (0.42)	0.46 c (0.20)	3.33 a (0.69)	2.19 ab (0.46)	99.71 a (16.31)
T7	7.96 a (1.56)	6.04 a (2.25)	0.91 ab (0.22)	0.64 bc (0.26)	2.65 ab (0.25)	4.46 a (2.04)	83.06 ab (13.55)

Table 5. *P availability and inorganic P fractions in soil after harvest.*

Treatment	Available P	Saloid-P	Al-P	Fe-P	Reductant soluble-P	Ca-P	Total P
	mg/kg						
T1	0.94 b (0.36)	0.58 c (0.12)	6.79 a (0.87)	6.26 a (1.38)	8.53 a (1.23)	5.14 b (0.86)	40.18 b (19.08)
T2	1.54ab (0.87)	0.99 c (0.32)	3.20bcd (1.57)	4.55ab (0.95)	9.71 a (1.40)	7.19ab (0.97)	61.75ab (14.64)
T3	2.35ab (0.75)	4.83abc (1.20)	4.24abc (0.68)	4.23ab (1.24)	9.98 a (1.63)	8.69ab (1.39)	74.29ab (11.65)
T4	1.81ab (0.75)	4.48abc (1.24)	1.19 d (0.53)	1.93 b (0.35)	8.64 a (1.54)	8.45ab (0.26)	79.75ab (10.04)
T5	1.64ab (1.01)	3.54bc (1.86)	1.49 dc (0.72)	1.80 b (0.48)	9.16 a (1.95)	7.2ab (0.89)	93.00 a (17.16)
T6	3.36 a (0.66)	8.18 a (1.43)	4.25abc (1.04)	5.14ab (0.88)	9.39 a (0.95)	8.48ab (1.21)	107.71 a (15.25)
T7	1.98ab (0.77)	6.51ab (2.56)	4.29ab (0.85)	4.04ab (2.24)	11.60 a (0.74)	10.63 a (2.27)	98.40 a (21.92)

[a]T1- control, T2- TSP, T3- TSP + recommended fertilizer, T4- TSP + compost, T5- TSP + sheep manure, T6- TSP + cattle manure, T7- TSP + poultry manure
[b]Mean values are followed by the standard errors in parentheses, n = 4
[c]For each parameter, different letters within column indicate that treatment means are significantly different at 5% level of DMR



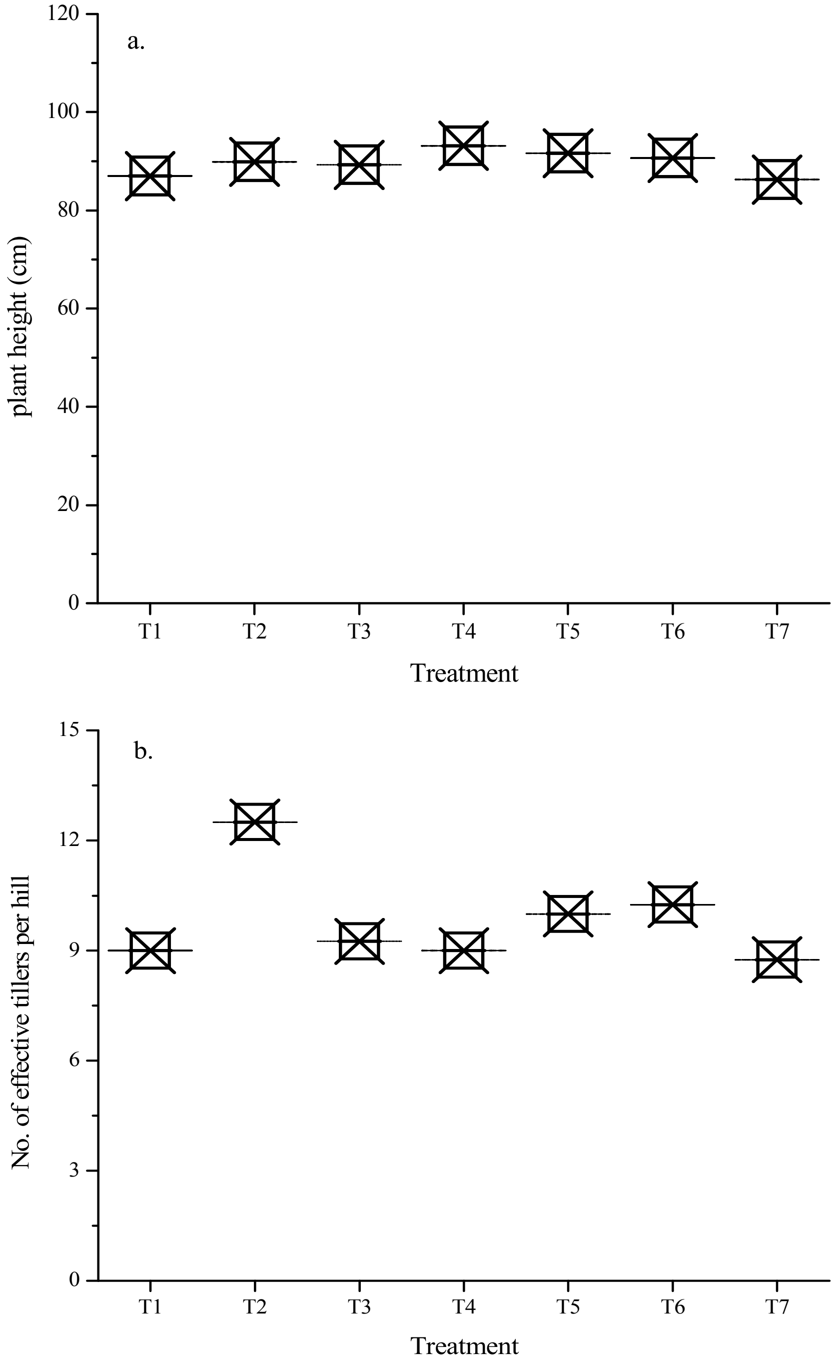


T1- control, T2- TSP, T3- TSP + recommended fertilizer, T4- TSP + compost, T5- TSP + sheep manure, T6- TSP + cattle manure, T7- TSP + poultry manure

Figure 3. *Influence of chemical fertilizer and organic manures on inorganic phosphorus fractions at different stages (a) Saloid-P, (b) Al-P, (c) Fe-P, (d) Reductant soluble-P and (e) Ca-P.*

3.2. Plant Growth Parameters, Grain and Straw Yield and Harvest Index (HI)

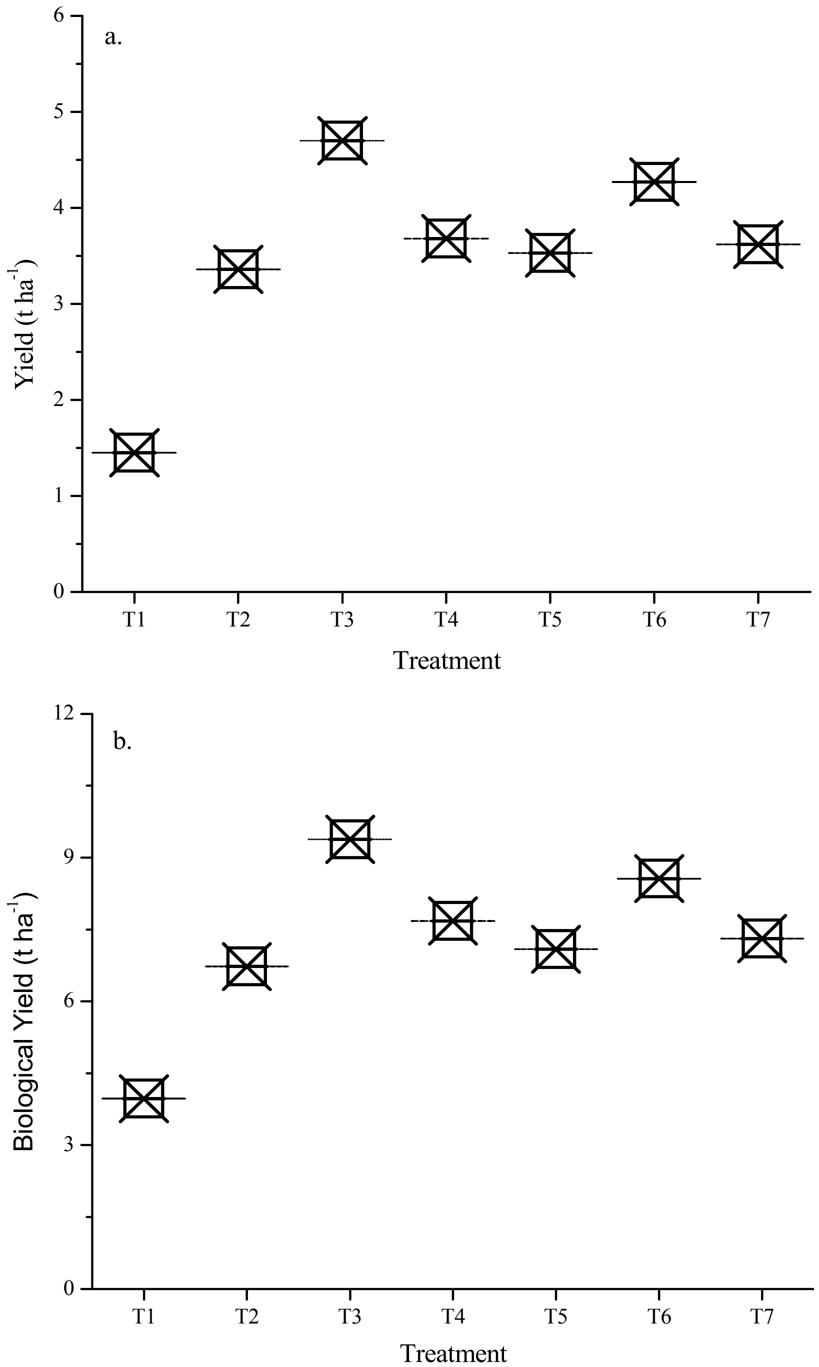
Plant growth and tillers due to application of TSP and organic fertilizer application presented in Figure 4. a and b. Plant height and effective tiller numbers weresignificant in different fertilizer treatments similar in all treatments compared toT1- control (no fertilizer). The highest plant height (93.13 cm) was in T4 (TSP + compost) and maximum tiller number (12.5) was observed in T2 (TSP), respectively. The combination of TSP and organic manures application influenced on plant height compared to the mineral fertilizer alone except T7 (TSP + poultry manure). When organic sources of nutrients were applied and supplemented with inorganic sources of nutrients enhanced the nutrient availability and helped in increasing the plant height [6]. P is essential for plant growth and promotes root development, tillering, and early flowering and performs other metabolic functions [33]. Moreover, organic sources positively affect number of tiller in plants because it provides the nutrient balance to plants, especially micro nutrients [28].



T1- control, T2- TSP, T3- TSP + recommended fertilizer, T4- TSP + compost, T5- TSP + sheep manure, T6- TSP + cattle manure, T7- TSP + poultry manure

Figure 4. *Effect of fertilization on plant height (a) and number of effective tillers per hill (b).*

The effect of fertilization on the grain yield, straw yield and HI were shown in Table 6. It was found that P fertilization through TSP and organic manures increased the rice yield significantly as compared to the control, T1 (no fertilizer), indicated that P deficiency in soil is the major constraint for rice production. Decrease of rice yield in tropical and subtropical areas was caused by low availability of P and high fixation by Fe and Al [40]. So,P fertilizer management is needed to ensure high and stable overall productivity in this region. Maximum grain yield (4.7 t ha^{-1}) and biological yield (9.38 t ha^{-1}) was observed with T3 (TSP and recommended fertilizer)but no significant variation inT3 and T6 (TSP + cattle manure) treatments (Figure 5.a and b). The results of a high grain yield and biological yield under inorganic sources of nutrient might be due to immediate release and availability of nutrients and supplied enlarge of N, P and K to crops. High grain and biological yield could be increase of yield components (number of panicles per hill, number of filled grains per panicle and 1000 grain weight) consequently [7]. This implies that by combining inorganic fertilizers with cattle manure could reduce the need for inorganic fertilizers and increasing their productivity.



T1- control, T2- TSP, T3- TSP + recommended fertilizer, T4- TSP + compost, T5- TSP + sheep manure, T6- TSP + cattle manure, T7- TSP + poultry manure

Figure 5. *Grain yield (a) and biological yield (b) of rice as affected by mineral fertilizer and organic manure application.*

No significant effects on the yield were found among the treatments such as T4 (TSP + compost), T7 (TSP + poultry manure), T5 (TSP + sheep manure) andT2 (TSP). Studies indicated that the addition of P was effective in increasing paddy yield but combination of P and organic manures was higher than the TSP fertilizer only. This is also agreement with the findings of [15]. From the result it was clear that organic fertilizer can be a better supplement with inorganic fertilizer to produce better growth and yield. Organic manure is releasing the necessary nutrients for plant growth and development through mineralization process [3] and when combined with P fertilizers it increased nutrient supply which enhanced vegetative growth, affecting plant height and yields [44].

Straw yield and HI was not significantly different in all the treatments but T1- control (no fertilizer) showed the lowest value in Table.6 and these in line with findings of [34]. The combination effects promote plant growth and increased rice straw yield. Fertilization, especially with N and P can increase dry matter production up to two-to three-fold [9]. Maximum HI was (50.11%) observed for T3 (TSP + recommended fertilizer). It might be due to better grain yield with corresponding to biological yield. The higher the HI, the greater was the grain yield. HI is an important factor in agricultural production because it indicates part of production of total plant [45].

Table 6. *Grain yield, Straw yield, Biological yield and Harvest index (HI).*

Treatment	Plant height (cm)	No. of effective tillers per hill	Grain yield (t ha-1)	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (HI)%
T1	87.00 ab (3.06)	9.00 a (0.81)	1.45 b (0.10)	2.52 a (0.28)	3.97 b (0.24)	36.52 a (3.51)
T2	89.88 ab (2.44)	12.50 a (2.63)	3.36 ab (0.84)	3.37 a (0.81)	6.73 ab (1.14)	49.93 a (6.91)
T3	89.25 ab (0.95)	9.25 a (0.63)	4.70 a (0.66)	4.68 a (0.78)	9.38 a (1.19)	50.11 a (2.12)
T4	93.13 a (1.39)	9.00 a (0.71)	3.68 ab (0.94)	4.00 a (1.44)	7.68 ab (2.35)	47.92 a (2.69)
T5	91.63 ab (1.97)	10.00 a (1.35)	3.53 ab (0.65)	3.56 a (0.50)	7.09 ab (0.92)	49.79 a (5.25)
T6	90.63 ab (2.97)	10.25 a (1.31)	4.27 a (1.26)	4.29 a (0.59)	8.56 a (1.55)	49.88 a (8.27)
T7	86.25 b (1.16)	8.75 a (0.85)	3.62 ab (0.67)	3.69 a (0.94)	7.31 ab (1.04)	49.52 a (8.45)

[a]T1- control, T2- TSP, T3- TSP + recommended fertilizer, T4- TSP + compost, T5- TSP + sheep manure, T6- TSP + cattle manure, T7- TSP + poultry manure
[b]Mean values are followed by the standard errors in parentheses, n = 4
[c]For each parameter, different letters within column indicate that treatment means are significantly different at 5% level of DMRT

3.3. P content and Uptake in Grain, Husk and Straw

The P uptake did not differ significantly among all treatments (Table 7) but the inorganic and organic fertilizers considerably increased the uptake of P than T1- control (no fertilizer). The highest P uptake occurred in T3 with TSP and recommended fertilizer. It may be due inorganic fertilizer is soluble and immediately supplies soluble P for immediate plant uptake and accumulation. Increase in nutrient uptake due to concomitant increase in biomass has also been reported by [5]. The concentration of P in all plant parts such as grain, husk and straw were not significantlydifference among treatments (Table 7). P concentration in plant parts varied within a narrow range across different treatments. Variation of nutrient concentration in plant parts might be due to difference in absorption rate from the soil resulting from changes in nutrient availability and element translocation from root to top [35].

Significant increase in dry matter production in fertilizer treatments observed compared to the T1- control (no fertilizer). Dry matter weight in T3 (TSP + recommended fertilizer) was the highest in amount but did not significantly from T6 (TSP + cattle manure). Difference in dry matter weight under different fertilizer treatments was due to balance supply of nutrient from manure and chemical fertilizers throughout the growing period [27]. The application of organic and inorganic fertilizers is beneficial to sustain rice production in the tropics [38].

Table 7. *P uptake and concentration of P in grain, husk and straw of rice.*

Treatment	P (%)			Dry matter (kg ha^{-1})	P uptake(kg ha^{-1})
	Grain	Husk	Straw		
T1	0.013 a (0.001)	0.016 a (0.005)	0.002 a (0.000)	3604.4 b (218.6)	1.1 a (0.2)
T2	0.013 a (0.007)	0.034 a (0.007)	0.023 a (0.008)	6101.2ab (962.8)	4.2 a (0.7)
T3	0.086 a (0.080)	0.038 a (0.005)	0.025 a (0.009)	8503.6 a (1259.9)	15.9 a (11.6)
T4	0.010 a (0.001)	0.030 a (0.010)	0.018 a (0.009)	6972.9 ab (2128.8)	4.0 a (1.8)

Treatment	P (%)			Dry matter (kg ha^{-1})	P uptake(kg ha^{-1})
	Grain	Husk	Straw		
T5	0.014 a (0.004)	0.022 a (0.006)	0.018 a (0.009)	6435.2 ab (832.1)	3.1 a (0.6)
T6	0.012 a (0.003)	0.026 a (0.001)	0.009 a (0.007)	7765.5 a (1400.9)	3.5 a (0.5)
T7	0.006 a (0.002)	0.030 a (0.003)	0.016 a (0.008)	6625.4ab (941.2)	3.3 a (0.5)

T1- control, T2- TSP, T3- TSP + recommended fertilizer, T4- TSP + compost, T5- TSP + sheep manure, T6- TSP + cattle manure, T7- TSP + poultry manure
[b]Mean values are followed by the standard errors in parentheses, n = 4
[c]For each parameter, different letters within column indicate that treatment means are significantly different at 5% level of DMRT

4. Conclusion

The study showed the impact of use of different fertilizer combinations on rice yield, P availability and the proportion of P fractions as well as the balance P in the soil. Highest grain and straw yield was found in T3 (TSP + recommended fertilizer) and the lowest was at T1- control (no fertilizer). It clearly indicated that the soil P availability is the limiting factor in acid soils and that an adequate supply of P through added fertilizers is essential for maintaining rice productivity. Therefore, the soil P supply capacity at the study site was an important factor limiting yield increasing effect, providing an explanation for the decreased yields without P fertilization in relation to the lower level of available soil P.However, the yields of T3 (TSP + recommended fertilizer) was not significant compared toT6 (cattle manure along with TSP). Cattle manure offered better nutritional quality and favorable balance of nutrients when supplemented with TSP which provided the optimum yield. The combination of inorganic fertilizer and organic manures led to greater P accumulation than mineral fertilizer alone. Thus, combination of inorganic and organic manure application was the best practices enhance P availability and maintaining of soil P levels. It is concluded that cattle manure along with TSP is the best option for obtaining high yield of rice particularly BDR-5. However, further research needs to be conducted to evaluate the consistence of these findings, and the response of rice to TSP fertilizer under field condition.

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