Original article

Performance of Nitrogen Phosphorus compound fertilizer in Boro rice

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Abstract

Objective: Evaluation of new nutrient sources plays an important role in crop production. A field experiment was conducted at BRRI, Gazipur and at BRRI regional station, Sonagazi, Feni during Boro season of 2014-15. A new fertilizer, NP compound (NPC) was evaluated and compared the performances with di-ammonium phosphate (DAP). Test crop was BRRI dhan29. At Gazipur site, phosphorus (P) control plot produced only 1.97 t ha^{-1} grain yield that increased with added P along with two N rates. At lower N doses, application of P either from DAP or NPC produced similar grain yield. It was observed that 30% less N produced statistically similar grain yield to 100% N, irrespective of P sources. It can be inferred that 30% N could be saved without significant reduction of rice yield. At Sonagazi site, application of P either from DAP or NPC could not increase rice grain yields compared to P control plot. From the results of both sites it can be concluded that NPC and DAP performed equally either with 100% N or 30% less N rates.

Keywords: *NPC, DAP, rice yield*

Introduction

Fertilizer plays an important role in modern agriculture, especially for increased rice production by supplying single or multiple nutrients. Single chemical fertilizers such as N as urea, P as triple super phosphate (TSP) or di-ammonium phosphate (DAP), K as potassium chloride (KCl), S as gypsum and Zn as zinc sulfates or physical mixer of different single fertilizers are used for rice cultivation in Bangladesh. With the development of improved rice varieties as well as better soil and fertilizer management technologies, paddy yield is generally increasing in Bangladesh and other rice growing countries over the years which causes gradual increase of N, P and K nutrient removal (kg ha^{-1}) and consequently fertilizer consumption in Bangladesh is generally increasing over the years [1]. In wet land rice soils, N fertilizer has been applied at higher doses than P and K fertilizers and thus creating nutrients mining from soils. On the other hand modern high-yielding rice varieties remove much higher amount of K than P or even N from the soil [1-3]. Recent study indicated that about 60% cultivable land of Bangladesh is deficient in N, P and K [4].

Crop yield reductions are strongly related to soil productivity degradation, particularly nutrient depletions [5] which can be attributed to either insufficient or imbalanced use of fertilizers [6].

The rate and types of fertilizers used depend on a farmer's financial ability and choice often made without considering indigenous supplying capacities of soils under varying agro ecological zones (AEZs) of Bangladesh. Besides, being cheaper and prompt visible response of N than P and K fertilizers, farmers apply more N for rice production [3 and 7] and thus create nutrients imbalance in many cases. The imbalanced fertilizer use in Bangladesh agriculture is speeding up nutrients depletion [8-10], which becomes a major problem in rice production.

Historically, flood plain soils of Bangladesh were fertile, although fertility varies greatly among different regions even in locations within a region itself. It is reported that the soils are generally content with low organic matter and so do N and S. Total N content of soils is generally very low to low (<0.09% to 0.18%) that is inadequate for rice and other cereal crop production [11]. Moreover, 12% of total cultivable land is below critical level of phosphorus and the rest belongs to low to very high level in Bangladesh [11].

Applying proper doses of major fertilizers and adopting improved management practices can increase yield of crops. Efficiency of Nr use can be increased by using slow releasing fertilizer, which reduces largely N loss by volatilization.

Management of soil fertility largely determines the availability of N and P for crop plants. Increased cropping intensity and use of high yielding modern varieties are responsible for luxury consumptions of N, P, K and many others require replenishments; but generally replenishments of removed nutrients do not happen resulting in mining of nutrients from soil. Moreover, nutrient losses also play a negative role in recuperating soil fertility. For example, 70% loss of urea-N occurs in wet land rice cultivation [12].

Rice yield in P-deficit soil was less than 50% compared to even moderate levels of P containing soils [13]. Although the rice requirement for P is much less than that for N, the continuous removal of P exploits the soil P reserve if the soil is not replenished through fertilizer or manure application [14]. Use of inadequate P for growing crops intensively has resulted in P deficiency in most soils of Bangladesh [11]. A rice crop depletes about 7-8 kg P ha^{-1} when P fertilizer is not used; while an application of soil test based doses may cause an accretion of about 9-49 kg P ha^{-1} [15]. The amount of P application obviously depends upon crop demand and soil-supplying capacity; although a P rich soil can be P deficient within four years in rice-rice cropping sequence [16].

Selection of a fertilizer depends on supplying capability of nutrients to rice plants at right time and optimal amount based on crop demand, capability to increase yield and to reduce nutrient losses to the environment. Therefore, it is necessary to determine an appropriate type of fertilizer for rice cultivation that can help in minimizing environmental pollution. In many countries, like Vietnam, Cambodia, Philippines farmer use N P compound (NPC) as a slow released N fertilizer for crop production. It was found that use of 80-140 kg N ha^{-1} from NPC fertilizer resulted in about 220-810 kg ha^{-1} more rice yield which saved about 20-30 kg N ha^{-1} [17]. Moreover, NPC fertilizer is the source of Ca and S for plant nutrition which might be beneficial in Ca and S deficient soil. It can also be stored easily. Its performance with Boro rice at BRRI, Gazipur was comparable with TSP [18] but a detailed study with NPC fertilizer has not been conducted in our country. After formal procedures this product has been included in the present investigation to evaluate its performance in terms of N and P supplying capacity for improving rice yield in Bangladesh.

Method

A field experiment was conducted in Boro season of 2014-15 at two locations: one at Bangladesh Rice Research Institute (BRRI) H/Q farm, Gazipur and another at BRRI R/S farm, Sonagazi, Feni. Soil characteristics (along with the methods of soil analysis) of these two locations are presented in Table 1. Soil texture of both locations was clay loam. Soil of BRRI H/Q farm, Gazipur was neutral in reaction and very low in P level; while soil at BRRI R/S farm, Sonagazi was non saline and slightly alkaline in reaction with medium P level. The chemical composition of applied fertilizer is given in Table 2. The experiment of both locations was laid out in a randomized complete block design with three replications. Unit plot size was 6 m × 3 m. Treatment details are presented in Table 3.

Nitrogen from prilled urea and its application schedule are presented in Table 4. Phosphorus (P) was applied @ 9 kg P ha^{-1} from DAP and NPC fertilizer except P control-T_1 plot (Table 3). Amount of DAP and NPC was applied on the basis of 9 kg P ha^{-1}. Nitrogen at 150 kg ha^{-1} for T_1, T_2, T_3, and T_4 treatments and 105 kg ha^{-1} (30% less N of T_3) for T_5 and T_6 was used. Treatment T_2 was treated as S control. Sulfur dose was also adjusted with gypsum in case of NPC fertilizer use (Table 3). All treatments received a blanket dose of K-Zn @ 60-4 kg ha^{-1}, respectively.

Table 1. Initial soil properties of the experimental sites, Boro season, 2014-15

Parameters	**Methods of analysis**	**Locations**			
		BRRI H/Q, Gazipur		**BRRI R/S, Sonagazi**	
		Soil test value	**Interpre-tation**	**Soil test value**	**Interpre-tation**
Texture	Hydrometer		Clay loam		Clay loam
pH (1:2.5)	Glass electrode	6.9 -7.0	Neutral	7.6-7.9	Slightly alkaline
Org. C (%)	Walkley and Black	1.24±0.02	Medium	0.60±0.16	Low
Total N (%)	Micro-kjeldahl	0.12±0.00	Low	0.06±0.02	Very low
Avail. P (ppm)	Modified Olsen	1.84 ± 0.73	Very low	12.45 ± 0.48	Medium

Exch. K (cmol/kg))	1 N NH_4OAc	0.21 ± 0.00	Medium	0.37	High
Avail. S (ppm)	0.01M Ca $(H_2PO_4)_2$	15.55±0.48	Low	81.47±9.77	Very high
Avail. Zn (ppm)	DTPA	4.25±0.35	Very high	1.67±0.19	Optimum

N.B. Interpretation was done for rice crop following the FRG, 2012 [10].

All fertilizers except urea were applied at final land preparation. Urea was applied at basal, active tillering stage and 7 days before panicle initiation stage in equal splits. Since DAP and NPC contain N, it was adjusted by using pilled urea (Table 3 and Table 4).
As cold spell was longer, 60 days old seedlings of BRRI dhan29 were transplanted on last week of January in both the locations. Irrigation, weeding and other management practices were done equally at per requirement. At maturity, the crop was harvested manually from an area of 5 m^2 at 15 cm above ground level from each plot for grain yield and 16 hills from each plot at ground level for straw yield data. Grain yield was recorded at 14% moisture content and straw yield as oven dry basis (72^0C, 72 hours). Panicle numbers per square meter, % sterility, grains per panicle and 1000-grain weight were recorded. All data were analyzed statistically with software Crop Stat 7.2 version.

Table 2. Chemical composition of NPC fertilizer and DAP.

Nutrient	**NP compound fertilizer (as given by the supplier)**	**DAP**
Total N (%)	20.9	18.0
Urea N (%)	19.3	-
Ammoniacal N (%)	1.6	-
Total P_2O_5 (%)	10.2	45.8
Citrate soluble P_2O_5 (%)	9.7	-
Water soluble P_2O_5 (%)	9.2	-
SO_3 (%)	16.2	-
H_2O (%)	1.0	-
CaO (%)	15.0	-

Table 3. Treatment details of the experiment

Treatments	**Nutrient rate (kg/ha)**				
	N	**P**	**K**	**S**	**Zn**
T_1= P control	150	0	60	20	4
T_2= S control (P as DAP)	150	9	60	0	4
T_3= DAP (100% N)	150	9	60	20	4
T_4= NPC (100% N)	150	9	60	20	4
T_5= DAP (30% less N of T_3)	105	9	60	20	4
T_6= NPC (30% less N of T_3)	105	9	60	20	4

Table 4. Amount (kg ha^{-1}) and N application schedules as urea

Treatment	**Basal (N) at final land preparation**	**1^{st} top dress (N) at 25-30 DAT**	**2nd top dress (N) at 55-60 DAT**
T_1= P control	50	50	50
T_2= S control (P as DAP)	42	50	50
T_3= DAP (100% N)	42	50	50
T_4= NPC (100% N)	10	50	50
T_5= DAP (30% less N of T_3)	27	35	35
T_6= NPC (30% less N of T_3)	0	30	35

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1. Result and Discussion

3.1 Gazipur site

Panicle number per square meter, percent sterility, 1000-grain weight, straw and grain yields were significantly influenced by P from DAP and NPC sources at N_{150} and N_{105} as compared with P control; whereas grains in a panicle did not vary significantly (Table 5). Panicle production was not influenced by S fertilization (Table 5). Panicle production in unit area (176) was the lowest in P-control plot (T_1). Application of P with two rates of N resulted in increased panicle production than P-control. However, two rates of N did not influence panicle production (Table 5). Percent sterility in P-control plot was 19%. The percent sterility significantly decreased in those treatments where NPC fertilizer was applied and the lowest (8%) being in T_6 treatment.

Table 5. Effect of DAP and NPC fertilizer on some plant parameters of BRRI dhan29, Boro 2015, BRRI, Gazipur.

Nutrient rate (kg/ha) N-P-K-S-Zn*	**Panicle /m^2 (No)**	**Grains $panicle^{-1}$ (No)**	**Spikelet sterility (%)**	**1000 grain wt (g)**	**Straw yield (t/ha)**	**Grain yield (t/ha)**
T_1 (150-0-60-20-4)	176	121	19	23.68	2.94	1.97
T_2 (150-9-60-0-4)	242	131	15	24.41	4.48	5.11
T_3 (150-9-60-20-4)	249	132	16	22.61	4.38	4.83
T_4 (150-9-60-20-4)	251	122	13	22.37	3.90	4.29
T_5 (105-9-60-20-4)	252	131	13	22.61	3.34	4.16
T_6 (105-9-60-20-4)	218	125	8	23.08	3.61	4.24
$LSD_{0.05}$	40	NS	4	0.88	0.93	0.87
CV (%)	9.4	9.5	15.8	2.10	13.5	11.7

NS = Not significant, *T_1 = P control, T_2 = S control (P as DAP), T_3 = DAP (100% N), T_4 = NPC (100% N), T_5 = DAP (30% less N of T_3) and T_6 = NPC (30% less N of T_3)

The highest 1000-grain weight (24.41 g) was obtained with T_2 followed by T_1 (23.68 g) and T_6 (23.08 g). Phosphorus control plot gave only 1.97 t ha^{-1} that increased with added P from two different sources along with two N rates (Table 5). Sulphur fertilization was irresponsive in terms of grain yield (Table 5). Sulphur status of the soil (15.55±0.48 ppm) was above critical level (10.0 ppm) and this might explain the result. Moreover, some S was added to soil from Zn fertilizer. On the other hand, in the dry season rice field remained under alternate wetting and drying situation because there was no rainfall in this season. This situation might help to increase S availability in the soil. At lower N doses, application of P either from DAP or NPC produced similar grain yield (Table 5). Grain yields in T_2, T_3 and T_4 were statistically similar with T_6. It was observed that 30% less N produced statistically similar grain yield with 100% N irrespective of P sources. Similar trend was also found with straw yield (Table 5). Straw yield ranged from 2.94 t ha^{-1} in T_1 to 4.48 t ha^{-1} in T_2. From this result, it can be inferred that 30% N could be saved without significant reduction in grain. Granger (2005) [17] also reported similar findings.

3.2 Sonagazi Site

Panicle production, percent sterility and straw yields significantly varied because of P application from DAP and NPC fertilizers with higher and lower doses of N in BRRI dhan29. However, grains in a panicle, 1000-grain weight and grain yield did not vary significantly (Table 6). Application of P from different sources with higher rate of N (T_2, T_3 and T_4) produced more panicle than with lower N doses (T_5 and T_6). Comparatively, NPC fertilizer with lower N doses (T_6) resulted in reduced panicle production than other treatments. Similar trend was also found for straw yields (Table 6). In P-control plot, spikelet sterility was 15%. The highest sterility (21%) was found in T_3 (DAP with higher N rate). Spikelet sterility significantly decreased to 13% with the use of NPC fertilizer. Sulphur fertilization did not influence any plant parameters studied (Table 6). It was found that application of P from two different sources with higher and lower N rates slightly decreased grain yield in T_2 to T_6 treatments compared to P-control plot (Table 6), though the differences were statistically insignificant. The reason of such yield reduction could be related with reduced uptake of cationic micronutrients like Fe, Mn, Zn and Cu because of excessive P sources (indigenous and added P), which was supported by Ujwala Ranade-Malvi (2011) [19]. Besides, Dunne and Reddy (2005) [20] reported that the availability of P in alkaline mineral wetland soils is controlled by the solubility of Ca compounds. When P is added at high concentrations to soils, insoluble complex mineral phosphates can form with Fe, Al and/or Ca. This process significantly reduces bio-available P in soils. We believe that this phenomenon might have taken place for Sonagazi site resulting in reduced grain yield in T_2 to T_6, though it was not statistically significant.

Table 6. Effect of DAP and N P C fertilizer on some plant parameters of BRRI dhan29, Boro 2015, BRRI R/S, Sonagazi, Feni.

Nutrient rate (kg/ha) N-P-K-S-Zn*	Panicle /m^2 (No)	Grains panicle^{-1} (No)	Spikelet sterility (%)	1000 grain wt (g)	Straw yield (t/ha)	Grain yield (t/ha)
T_1 (150-0-60-20-4)	221	150	15	21.38	4.70	5.69
T_2 (150-9-60-0-4)	243	147	11	21.84	4.85	5.15
T_3 (150-9-60-20-4)	256	154	21	20.80	5.05	4.66
T_4 (150-9-60-20-4)	241	140	13	21.04	4.60	4.82
T_5 (105-9-60-20-4)	221	137	16	20.98	4.22	4.68
T_6 (105-9-60-20-4)	178	147	13	21.16	3.47	4.93
$LSD_{0.05}$	44	NS	5	NS	0.78	NS
CV (%)	10.8	8.0	17.2	3.80	9.5	8.1

*T_1= P control, T_2 = S control (P as DAP), T_3 = DAP (100% N), T_4 = NPC (100% N), T_5= DAP (30% less N of T_3) and T_6= NPC (30% less N of T_3)

3.3 Economic analysis

Economic analysis was done considering fertilizer cost, fertilizer application cost and labor cost, additional product and by-products due to fertilizer application. The estimated total variable cost (TVC), gross return, net additional income and benefit cost ratio (BCR) are presented in Tables 7 & 8. Application of N and P from DAP and NPC increased gross return and net additional income in all treatments in Gazipur site (Table 7). Gross return from the P-control plot was only about Tk. 58,040 ha^{-1}. Application of nutrients increased gross return ranging from Tk. 1,08,220 ha^{-1} in T_5 to Tk. 1,34,820 ha^{-1} in T_2. The highest net additional income of Tk. 1,21,787 ha^{-1} was obtained with T_2 (S control) followed by T_3 (Tk. 1,14,418 ha^{-1}). Net additional income of Tk. 1,00,316 ha^{-1} in T_6 (NPC with 30% less N of T_3) was superior to T_5 (DAP with 30% less N of T_3) (Table 8). The highest BCR of 9.34 was obtained with T_2 (S control) followed by T_6 (9.11).

In Sonagazi site, application of P from DAP and NPC fertilizers was responsible for decreased gross return and net additional income compared to P-control (Table 8). The reason of higher grain yield in P-control plot has already been discussed earlier. Gross return from P-control plot was Tk. 1,48,680 ha^{-1}. It was found that net additional income was comparatively greater in T_6 than T_5 when 30% less N was used (Table 9). The highest BCR of 14.14 was obtained with T_1 (P-control) followed by T_6 (13.54).

Table 7. Yield and economy of fertilizer used (DAP and NPC) for Boro rice production, BRRI H/Q, Gazipur, 2014-15

Treatment	Yield (t ha^{-1}) (BRRI dhan29)		Gross return** (Tk ha^{-1})	TVC* (Tk ha^{-1})	Net additional Income (Tk ha^{-1})	BCR
	Grain	Straw				
T_1 = P control	1.97	2.94	58040	9823	48218	4.91
T_2 = S control (P as DAP)	5.11	4.48	134820	13033	121787	9.34
T_3 = DAP (100% N)	4.83	4.38	128160	13742	114418	8.33
T_4= NPC (100% N)	4.29	3.90	113880	12530	101350	8.09
T_5= DAP (30% less N of T_3)	4.16	3.34	108220	11580	96640	8.35
T_6= NPC (30% less N of T_3)	4.24	3.61	111330	11014	100316	9.11

* Total variable cost (TVC) included fertilizer cost (chemical fertilizer), fertilizer application cost and labor cost for additional product. Price (Taka/kg): Urea = 15.00; DAP = 27.00; NPC=11.22[a]; MP = 16.00; Gypsum = 9.00; $ZnSO_4$ = 135.00. Labor wage rate = Tk.260 day^{-1} **Price (Taka kg^{-1}): Paddy = 22.00; straw = 5.00. Two additional man-days/ha are required for applying fertilizer and four man-days ha^{-1} for per ton additional products including byproducts. [a] Price of NPC fertilizer was determined based on market value of urea (N) and DAP (P) with subsidy.

Table 8. Yield (t ha^{-1}) and fertilizer use economy as affected by N and P nutrients using DAP and NPC fertilizers at BRRI R/S, Sonagazi, Feni, 2014-15.

Treatment	Grain	Straw	Gross return** (Tk ha^{-1})	TVC* (Tk ha^{-1})	Net additional income (Tk ha^{-1})	BCR
T_1 = P control	5.69	4.70	148680	9823	138858	14.14
T_2 = S control (P as DAP)	5.15	4.85	137550	9768	127783	13.08
T_3 = DAP (100% N)	4.66	5.05	127770	10768	117003	10.87
T_4= NPC (100% N)	4.82	4.60	129040	10118	118923	11.75
T_5 = DAP (30% less N of T_3)	4.68	4.22	124060	9303	114757	12.34
T_6 = NPC (30% less N of T_3)	4.93	3.47	125810	8653	117157	13.54

* Total variable cost (TVC) included fertilizer cost (chemical fertilizer), fertilizer application cost and labor cost for additional product. Price (Taka kg^{-1}): Urea = 15.00; DAP = 27.00; NPC = 11.22[a]; MP = 16.00; Gypsum = 9.00; $ZnSo_4$ = 135.00. Labor wage rate = Tk.260 day^{-1} **Price (Taka kg^{-1}): Paddy = 22.00; straw = 5.00. Two additional man-days ha^{-1} are required for applying fertilizer and four man-days ha^{-1} for per ton additional products including by-products. [a] Price of NPC fertilizer was determined based on market value of urea (N) and DAP (P) with subsidy.

Soil salinity in Bangladesh both in terms of magnitude and extent are increasing over time. Total area in coastal regions of Bangladesh affected by varying degrees of salinity was about 0.83 million hectares (M ha) in 1966-75, which has been increased to 3.05 M ha during last two decades [21]. Saline-alkali or alkali soils are found to have abundance of sodium (Na) salts. To replace all exchangeable Na from the soil micelle, a fixed quantity of Ca salt or gypsum is needed. According to Schoonover one milli-equivalent of Na per 100 g of soil corresponds to 1.72 tons of gypsum acre^{-1} foot of soil [22]. Since NPC fertilizer contains 15% CaO and 6.5% S, it may provide Ca and S for replacing Na from the soil micelle and thus might be beneficial for increased rice production in saline areas.

Conclusions

From one year study the effect of NPC fertilizer on Boro rice yield found promising. It helped in obtaining comparable grain yield with DAP. Further trials in different locations might be conducted for conclusive results.

Conflict of interest

No potential conflict of interest was reported by the authors

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