



Effects of Some Major Plant Nutrients on Growth and Yield of Wet Season Rice

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Abstract

Nitrogen (N), phosphorus (P), potassium (K) and sulphur (S) are the most important plant nutrients in terms of the extent of their deficiencies in the soils, and their potential for crop yield increases or losses. Present experiment was conducted in wet season of 2014 at the Bangladesh Rice Research Institute (BRRRI) farm, Gazipur in a permanent layout first designed in dry season of 1985. Objectives of the research were to (i) study the effects of NPKS on growth and yield of wet season rice (ii) determine the yield limiting nutrient (s) in BRRRI farm soil and NPKS doses for wet season rice (iii) examine the relationship between grain yield and some agronomic parameters of wet season rice. A popular modern rice variety BRRRI dhan49 was tested with five fertilizer treatments: NPKS (complete), PKS (-N), NKS (-P), NPS (-K) and NPK (-S). The NPKS were applied @ 100-7-80-3 kg/ha. Considerable reduced plant height, tiller/m², panicle/m², grain and straw yield of BRRRI dhan49 was recorded due to omission of N, K, P and S nutrients from the complete treatments. The highest yield reduction was recorded due to N omission and was found the most limiting nutrient in BRRRI farm soil followed by K, P and S. Phosphorus omission delayed the flower initiation by 5 days and extended the life cycle of wet season rice by 4 days. Estimated doses of major plant nutrients for BRRRI dhan49 rice cultivation were 116, 19, 54 and 3 kg/ha N, P, K and S, respectively.

Keywords: Limiting nutrient, NPKS doses, Yield, Harvest index

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1. INTRODUCTION

Rice (*Oryza sativa* L.) is the major cereal food crop in Bangladesh which is grown in pre-monsoon (April to June), monsoon (wet season, July to November) and Boro (dry season irrigated, December to June) seasons [1]. Population of Bangladesh will reach 215.4 million in 2050, when 44.6 million ton of clean rice will be required [2]. Several hurdles, such as increasing population, decreasing resources (shrinking net cropped area, scarcity of water for irrigation), increasing climate vulnerability and increasing pressure on soil fertility can hinder achieving the target. A crop production system with high yield targets cannot be sustainable unless nutrient inputs to soil are at least balanced against nutrient removal by crops. Proper soil fertility management, therefore, is one of the prime importances in an endeavor to increase crop productivity [3]. Among many factors, adequate use of essential nutrient elements greatly influences rice growth and development and thus productivity. On the other hand, 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. As a consequence, nitrogen (N), phosphorus (P) and potassium (K) nutrient removal is increasing gradually [4]. Besides NPK, sulphur (S) is also used for rice cultivation.

Nitrogen is the most limiting nutrient for crop production in many areas of the world and its efficient use is not only important for the economic sustainability of cropping systems [5], but also for safeguarding environment from pollution. It is considered as a key element for rice yield [6-9]. Moreover, nutritional management in rice is mainly associated with N fertilization, which is difficult to adjust in field conditions due to variations in soil types and climatic conditions. Efficient use of N is an important complementary strategy for improving rice yield and reducing cost of production [10]. Phosphorus is intimately associated with all life processes and thus it is a vital constituent of every living cell. This element tends to be concentrated in the seed and stimulates early root formation and growth of the plant. Its deficiency in soil extends the lifespan of rice plants, delayed flowering and maturity. Without adequate supply of P plant cannot reach its maximum yield. Since in many soils much of the available P is derived through the mineralization of organic matter, the repeated addition of P fertilizer appears to be the only satisfactory way of supplying plant needs for this very important nutrient [11]. Potassium is a major nutrient element that is luxuriously absorbed by plants. Modern high-

yielding rice varieties remove much higher amount of K than P or even N from the soil [1, 4, 12-15]. It stimulates over sixty (60) enzymes. It also increases crop yields by accelerating photosynthesis, controlling stomata opening, efficient utilization of N, promoting the transport of assimilates. Sulphur is one of the major essential nutrient elements to synthesis certain amino acids such as methionine, cystine, cysteine and some plant hormones; such as thiamine and biotin [16]. The effect of S deficiency on yield is more pronounced during vegetative growth e.g. reduced plant height and stunted growth, reduced number of tillers, fewer and shorter panicles, reduced number of spikelets per panicle etc. [17]. Problem of S deficiency in soil can be aggravated with the use of excess P fertilizer [11].

The above mentioned NPKS nutrients are frequently deficient in rice soils throughout the world including Bangladesh. However, different soils have different capacity to supply these nutrients to crop plants for desired yield. The fertilizer requirement of a crop is therefore, depends upon the nutrient supplying capacity of particular soil. Many authors reported various amount NPKS requirement of wet season rice. These variable findings make a scope for further study on the NPKS requirement of wet season rice. Keeping these points in mind a field experiment was conducted in transplanted Aman (T. Aman) 2014 season (wet season), with a popular modern rice variety BRRI dhan49 to fulfill the following objectives:

(i) to study the effects of NPKS on growth and yield of wet season rice (ii) to determine the yield limiting nutrient (s) in BRRI farm soil and NPKS doses for wet season rice (iii) to examine the relationship between grain yield and some agronomic parameters of wet season rice.

2. MATERIALS AND METHODS

2.1 Soil, Crop, experimental design and treatments

The experiments were conducted in the research field of BRRI farm, Gazipur in a permanent layout. The permanent layout was first designed in Boro (dry) season 1985. The initial soil of the experimental field was clay loam in texture having pH 5.70, organic carbon 1.14%, total N 0.08%, available P 9.80 ppm, exchangeable K 70 mg/kg, available S 9.00 ppm and available Zn 3.30 ppm.

In transplanted Aman (T. Aman, wet season) 2014 season, a popular BRRI modern variety BRRI dhan49 was tested with five fertilizer treatments: NPKS (complete), PKS (-N), NKS (-P), NPS (-K) and NPK (-S). NPKS @ 100-7-80-3 kg/ha. Dates of sowing and transplanting were 15.06.2014 and 21.07.2014, respectively. The experimental design was randomized complete block (RCB) design with three replications. The sources of N, P, K, and S were urea, triple super phosphate, muriate of potash and gypsum, respectively. One-third of N and the whole amount of P, K and S were applied at the time of final land preparation. The remaining two-third N was applied in two equal installments 25-30 days after transplanting and 7 days before panicle initiation stage (PI stage). Two rice seedlings (36 day-old) were transplanted in hills with 20 cm × 20 cm spacing under irrigated condition. Appropriate cultural and management practices including plant protection measures were followed during growing season. All plots were surrounded by 30 cm soil levees to avoid contamination between plots.

2.2 Data collection and analysis

2.2.1 Tillering pattern

Number tiller/m² was counted at 15, 22, 29, 36, 42 and 49 days after transplanting (DAT) of rice seedlings. Ten hills from each treatment were selected randomly and marked with bamboo sticks. Then tiller number of each hill under a treatment was counted manually at above mentioned time. Tillers were expressed in number per square meter.

2.2.2 Flowering time

Flowering time was recorded at the initiation of flowering. First flowering, 50% flowering and maturity time were recorded with eye estimation and regular field observation.

2.2.3 Agronomic and yield contributing parameters

Plant height was determined by measuring the distance from the soil surface to the tip of the panicle of 10 random hills from each plot excluding border hills. Tillers and panicles/m² were determined by hand counting from 16 hill samples collected for straw yield estimation. At last the collected data were statistically analyzed.

2.2.4 Yield and harvest index

2.2.4.1 Grain yield

The crops were harvested at maturity from 2.5 m × 2 m area (5 m², 125 hills) at 15 cm above ground level for grain yield calculation. The weight of grain in individual plot was recorded with the respective moisture content. Moisture content was recorded three times

from each sample and averaged for grain yield calculation. Grain yields were recorded at 14% moisture and calculated with the following formula:

$$\text{Grain yield (t/ha)} = \frac{GW \times 10 \times (100 - M)}{A \times 86}$$

Where, GW = Grain weight in kg

M = % moisture of grain

A = Area of sample in m²

2.2.4.2 Straw yield

Straw yields were recorded from 16-hill sample harvested at the ground level from four corners (4 hills from each corner excluding border hills) of each plot at maturity and were adjusted to oven dry basis as mentioned earlier in dry matter yield calculation.

$$\text{Straw yield (kg/ha)} = \frac{ODW \times FWT \times 10}{A \times FWS}$$

Where, ODW = Oven dry weight of sub-sample in g

FWT = Total fresh weight of harvested sample in g

FWS = Sub-sample fresh weight in g

A = Area of sample in m²

2.2.5 Grain Harvest index (GHI)

Harvest index (HI) were computed as

$$HI = \left(\frac{\text{Grain yield}}{\text{Grain yield} + \text{Straw yield}} \right)$$

2.2.6 Nutrient dose calculation:

$$\text{Nitrogen (kg/ha)} = \frac{(\text{Yield}_{NPKS} - \text{Yield}_{PKS}) \times 18}{0.30}$$

$$\text{Phosphorus (kg/ha)} = \frac{(\text{Yield}_{NPKS} - \text{Yield}_{NKS}) \times 3.0}{0.20}$$

$$\text{Potassium (kg/ha)} = \frac{(\text{Yield}_{NPKS} - \text{Yield}_{NPS}) \times 20}{0.50}$$

$$\text{Sulphur (kg/ha)} = \frac{(\text{Yield}_{NPKS} - \text{Yield}_{NPK}) \times 2}{0.60}$$

2.3 Statistical analysis

All data were analyzed statistically using CropStat software version 7.2.

3. RESULTS AND DISCUSSION

3.1 Dynamics of tiller production

Fig. 1 represents the dynamics of tiller production by BRRI dhan49 a popular transplanted Aman (T. Aman) rice variety in Bangladesh. Tiller production increased significantly ($P < 0.05$) in a quadratic fashion with the advancement of plant age. Maximum tillers were achieved at an age of 86 days after sowing and then started to decline at booting stage (100 days after sowing). Hasanuzzaman et al. (2010) [18] reported that tiller numbers in BRRI dhan40 was decreased 115 days after sowing due to tiller mortality and the senescence of plants. Tillering is associated with panicle number and hence grain yields [19]. The period in which the increase of tiller number per unit length of time is great is defined as the active tillering stage. The stage, in which the number of tillers reaches maximum, is known as maximum tiller number stage. Tillers without producing panicles degenerate and their number decreases until they become equal to the number of panicles. The growth juncture of this period is called the ineffective tillering

stage [20]. The major plant nutrients showed distinct effects on the tillering dynamics of rice plant (Fig. 1). The NPKS treatments produced the higher tiller number throughout the growth cycle compared to other treatments. Omission of different major nutrients from NPKS significantly reduced the tiller production. The lowest tiller production was observed in P omission plot followed by N, K and S omission. Omission of P hampered the root formation of rice plants; N omission reduced the photosynthetic capacity, K omission restricted the transportation of photoassimilates and S omission obstacle the amino acid synthesis which in turn affected the tiller production by BRRI dhan49. Guowei et al. (1998) [21] reported that rice (*Oryza sativa* L.) crop functions as a population of tillers produced at different times and possessing specific growth characteristics. They showed significant contribution of cultivar tillering ability to dry matter accumulation, yield components, and grain yield. Singh et al. (2003) [22] reported that crop growth rate and relative growth rate was significantly influenced by NPK.

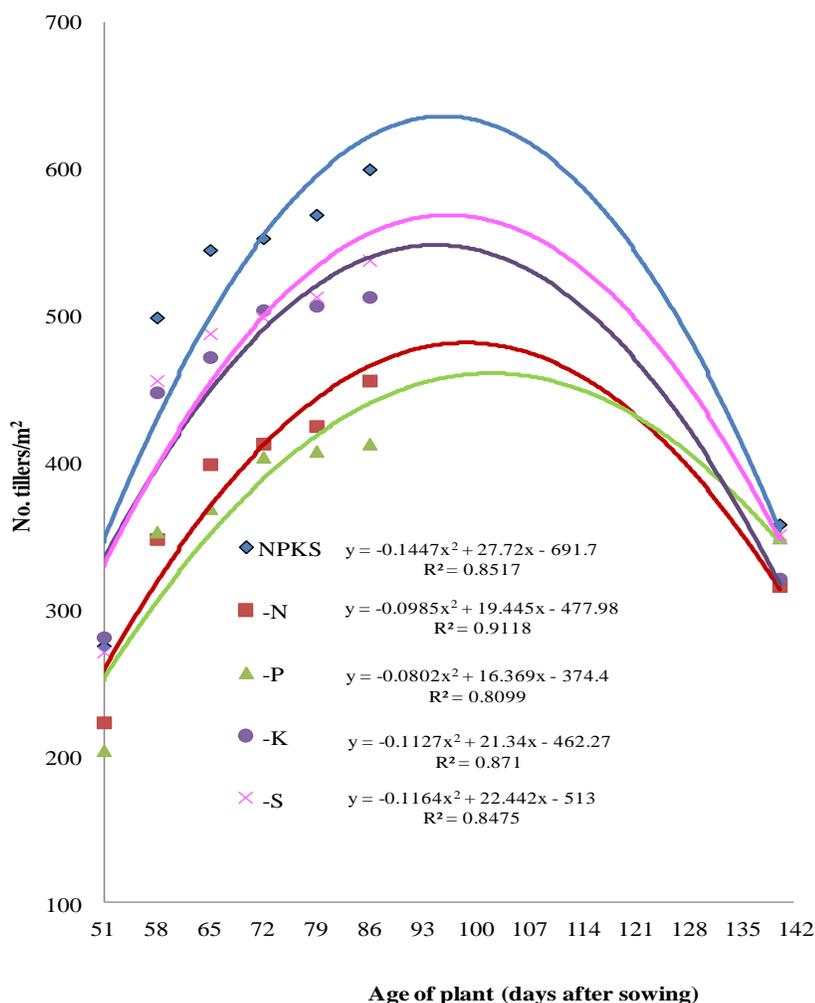


Fig. 1. Dynamics of tiller production in T. Aman (BRRI dhan49) rice variety affected by different major plant nutrients in Grey Terrace soil.

3.2 Plant height

Major plant nutrient elements significantly affected the plant height of BRRI dhan49 (Table 1). Complete fertilizer treatment (NPKS) produced the tallest rice plant (109.28 cm). The omissions of N, P, K and S from complete treatment significantly shorten the rice plant by 12.73, 9.45, 8.08 and 2.9 cm, respectively. Nitrogen omission plot produced the shortest plant of 96.55 cm followed by P (99.83 cm), K (101.20 cm) and S (106.38 cm) omission. However, S omission did not reduce the plant height significantly. Plant heights in the N and P omission plot were statistically similar. These findings corroborated with the results reported by other researchers [23-24]. They found that the higher plant height due to higher application of N. However, progressively increased plant height due to increasing levels of NPK was also reported by scientists [18, 25]. The variation in plant height due to nutrient sources

was considered to be due to variation in the availability of major nutrients. Chemical fertilizer offers nutrients which are readily soluble in soil solution and thereby instantaneously available to plants. Plant height was having significant positive association with rice grain yield. Grain yield increased linearly with the increase of plant height (Fig. 2). Hence increasing plant height can increase the grain yield of lowland rice. From this relationship it was observed from this study that 89.4% variability of grain yield was due to plant height while 85% and similar variability was reported by others [1, 26].

3.3 Tiller/m²

Production of tillers in T. Aman rice plant was also significantly influenced by different major nutrient treatments at different stage. Complete fertilizer treatment produced the highest 358 tiller/m². Omission of N, P, K and S from complete treatment significantly reduced the tiller by 42, 9, 37 and 7/m², respectively. Omission of S and P produced statistically similar tiller/m², while omission of K and N produced significantly lower tiller than S and P omission plot (Table 1).

Jacqueline et al. (2008) [27] found the similar relationship and reported that the linear fashion of tiller and panicle production with increasing level of nitrogen in lowland rice. Number of reproductive tillers and number of spikelets per panicle provide useful information for the rice breeders and those characters have direct effect on yield per plant [28]. The number of tillers increased significantly by the application of potassium over control [1, 4, and 29].

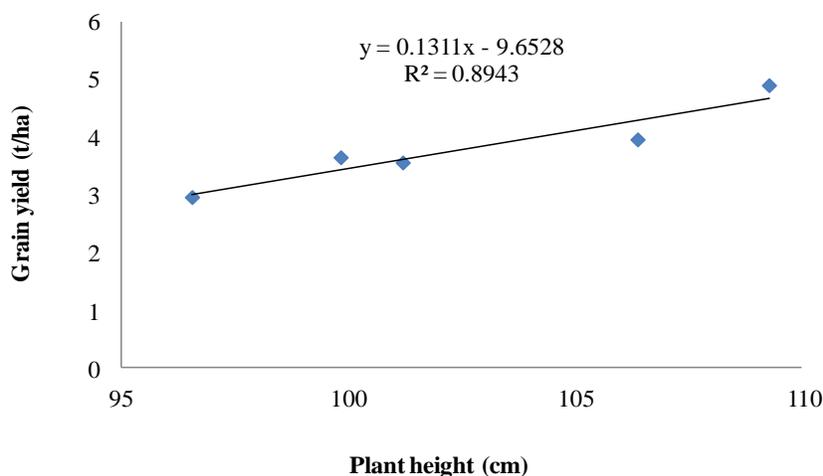


Fig. 2. Relationship between plant height and grain yield of T. Aman rice (BRRIdhan49).

Table 1. Effect of major nutrient elements on plant height, tiller and panicle production by T. Aman rice plant (var. BRRIdhan49) at maturity, BRRIdhan farm, Gazipur, 2014

Treatment	Plant height (cm)	Tiller/m ²	Panicle/m ²
NPKS	109.28	358	340
-N	96.55	316	299
-P	99.83	349	334
-K	101.20	321	306
-S	106.38	351	333
LSD (0.05)	3.81	27	25
CV (%)	2.4	6.6	6.8

3.4 Panicle/m²

Major plant nutrient elements significantly affected the number of panicle/m² of BRRIdhan49 (Table 1). Complete fertilizer treatment produced the highest number (340) of panicle/m². Omission of N, P, K and S from complete treatment significantly reduced the number of panicle by 41, 6, 34 and 7 no./m² respectively. Omission of S and P produced statistically similar number of panicle/m², while omission of K and N produced significantly lower number of panicle than S and P omission plot. Adequacy of nitrogen increased the total dry matter [30] and probably favored the cellular activity during panicle formation and development, which led to, increased number of effective tillers/hill [31-32]. On the other hand, deficiency of K reduces the transfer of N and P within plant [12] while P deficiency reduces the root growth [33] which led to decreased number of tiller/hill.

Tiller and panicle m⁻² had a significant quadratic association with grain yield (Fig. 3 and 4). Tiller and panicle production described the variability of grain yield by 80.8% and 72.4%, respectively.

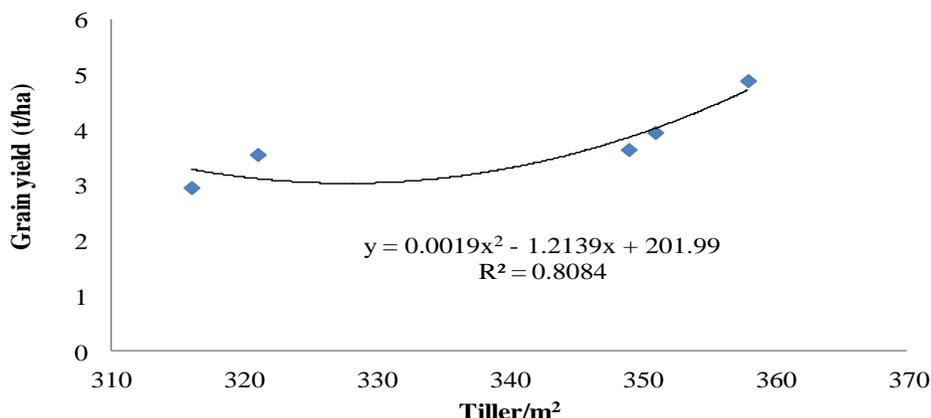


Fig. 3. Relationship between tiller production and grain yield of T. Aman rice (BRRIdhan49).

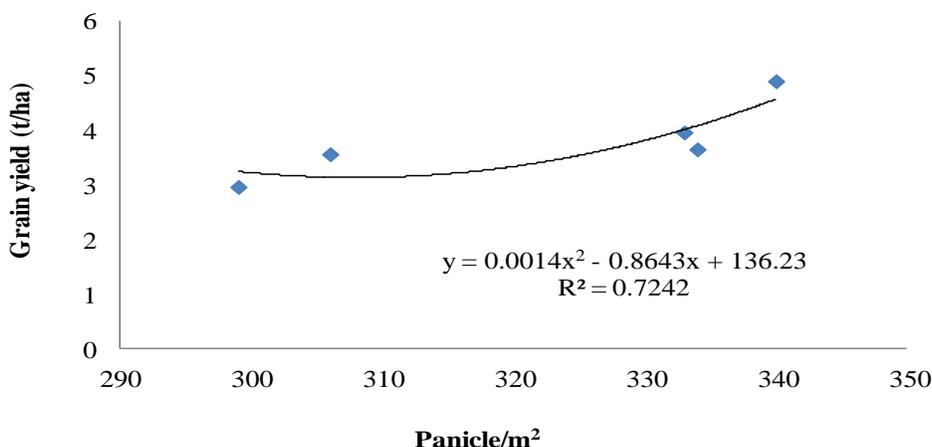


Fig. 4. Relationship between panicle production and grain yield of T. Aman rice (BRRIdhan49).

3.5 Days to flower and maturity

Different major plant nutrient elements significantly affected the days to flower initiation, 50% flower and maturity (Table 2). Omission of N significantly enhanced the days to flower initiation, 50% flower and maturity of BRRIdhan49. Omission of this element shortens the life span of BRRIdhan49 by 6 days. On the other hand omission of P delayed days to flower initiation by 5 days, 50% flower by 4 days and maturity by 4 days. But omission of K and S did not influence the days to flower initiation, 50% flower and maturity of T. Aman rice (Var-BRRIdhan49). Flower initiation falls into the reproductive stage of rice plants. In this stage rice plants need more energy for their physiological activity.

Table 2. Effect of major nutrient elements on days to flower maturity in T. Aman rice plant (var. BRRIdhan49) at maturity.

Treatment	Flower initiation	50% flowering	Maturity
NPKS	112	117	140
-N	108	113	134
-P	117	121	144
-K	112	117	140
-S	111	117	139
LSD _(0.05)	3	2	2
CV (%)	2	1	1

Energy rich compound like ADP, ATP supply this energy for plant metabolic activity [11]. Phosphorus deficiency restricts the production these compounds and flower initiation become delayed. Ultimately life cycle of rice plant expanded. Phosphorus deficiency in the soil not only deteriorates the P nutrition of crop but also reduces rice yield and delays flowering as well as maturity of the crop [34].

3.6 Grain yield

Different major plant nutrients significantly affected the grain yield of T. Aman rice (BRRI dhan49). Complete fertilizer treatment produced the highest grain yield of 4.90 t/ha (Table 3). Omission of N, P, K and S from complete treatment significantly reduced the grain yield by 1.94, 1.25, 1.34 and 0.94 t/ha respectively. However, omission of N, P and K sharply decreased the grain yield of BRRI dhan49. Omission of S and P produced statistically similar grain yield, while omission of K and N produced significantly lower grain yield than S and P omission plot. This finding was similar with the observations made by Bowen et al. (2005) [35] and Miah et al. (2004) [36]. Increased doses of urea helped to increase panicle length, total tillers/hill, effective tillers/hill and filled grains/panicle. So, ultimately the grain yield was increased. The application of recommended dose of N, P and K increased the crop yields and substantially improved the available N, P and K over its initial value there by indicating significant contribution towards sustaining the soil health [37] while the highest grain yield of 6.76 t/ha was obtained with the application of 150 kg N/ha [38]

Table 3. Effect of major nutrient elements on yield and harvest index of T. Aman rice (var. BRRI dhan49).

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index
NPKS	4.90	6.79	0.42
-N	2.96	4.90	0.38
-P	3.65	6.47	0.36
-K	3.56	6.05	0.37
-S	3.96	7.14	0.36
LSD _(0.05)	0.40	0.68	0.03
CV (%)	6.8	7.0	5.9

The higher grain yield with NPKS fertilizer might be due to the contribution of these nutrients, which positively influenced all the yield contributing characters of rice plant as described earlier. The application of nitrogen increased the protein percentage, which in turn increased the grain weight [39]. Potassium application helps to produce large amount of starch due to K-mediated carbohydrate metabolism [40]. Besides, it helped in efficient translocation of photo-assimilates to the developing sinks/spikelets [41] and enabled the plants to utilize fully applied N and P fertilizers [42]. Sulphur application also helps to protein synthesis in rice grain and increases the grain weight which is reflected in grain yield of rice [43].

3.7 Straw yield

Different major plant nutrients significantly affected the straw yield of T. Aman rice (BRRI dhan49). Omission of S produced the highest straw yield of 7.14 t/ha (Table 3) which was statistically identical with complete treatment (6.79 t/ha) and P omission plot (6.47 t/ha). Omission of N produced the lowest straw yield followed by K omission. Omission of N, P, K from complete treatment reduced the straw yield by 1.89, 0.32 and 0.74 t/ha respectively. Omission of K and N produced significantly lower straw yield than S omission plot. This result is in an agreement with the findings of Dhane et al. (1989) [44] who reported that straw yield increases with increasing nitrogen level. Maximum paddy yield (3.24 t/ha) and straw yield (3.92 t/ha) were obtained with an application of 100 kg K/ha [45].

3.8 Harvest index

Harvest index significantly affected by different major plant nutrients (Table 3). The highest harvest index of 0.42 was observed with complete fertilizer treatment (NPKS). Omission of N, P, K and S from complete treatment significantly reduced the harvest index by 0.04, 0.06, 0.05 and 0.06, respectively. However, omission of N, P, K and S plots showed statistically identical harvest index. The GHI is significantly and quadratically associated with grain yield (Fig. 5). The equation was as follows. The GHI accounted 67.09% variability of T. Aman rice grain yield.

Generally, GHI of rice and noted variations from 0.23 to 0.50 [46], however, it was also reported that GHI values varied greatly among cultivars, locations, seasons, and ecosystems, and ranged from 0.35 to 0.62 [47]. The GHI is an important trait for yield improvement in field crops. An increase in grain yield can be achieved by increasing the harvest index, which indicates the partitioning of assimilation products to grain, and/or total biomass production [48-49].

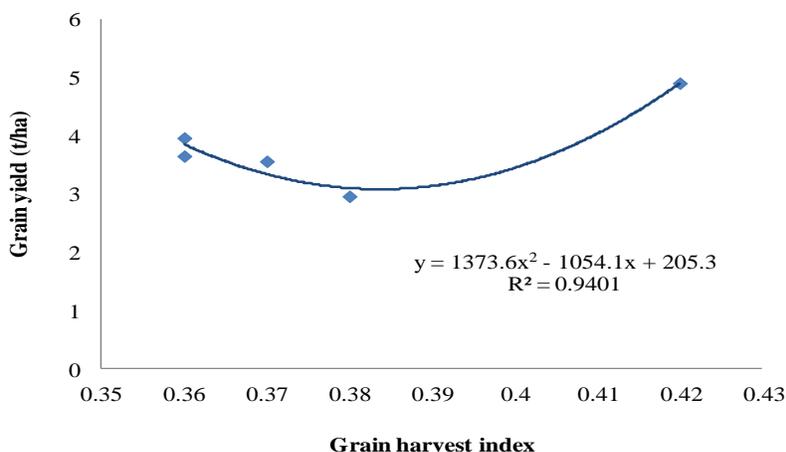


Fig. 5. Relationship between harvest index and grain yield of T. Aman rice (BRRI dhan49).

3.9 Estimated major plant nutrient doses for wet season rice cultivation

Estimated major plant nutrients for T. Aman rice (Var- BRRI dhan49) cultivation is given in Table 4). Estimated N, P, K and S requirements of BRRI dhan49 for optimum grain yield were 116, 19, 54 and 3 kg/ha, respectively. This estimation is in the actual field condition or site specific. In this experiment N, P, K and S were applied @ 100-7-80-3 kg/ha, respectively. So, lower dose of N and P compared to estimated dose (116 and 19 kg/ha N and P, respectively) are applied while a higher dose of K is used in this long-term field experiment. Estimated and applied S dose found same.

Islam et al. (2016) [30] found the highest grain yield (4.4 t/ha) with 120 kg N/ha. Islam et al. (2010) [50] reported that the economic optimum P dose for T. Aman rice cultivation was 20 kg/ha. Islam et al. (2015) [1] found a positive response of K fertilizer to 80 kg/ha. However, the S requirement of this experiment was comparatively lower. This may be due to the industrial pollution of the study area which may contribute S deposition in the soil.

Table 4. Estimated major nutrient elements requirement of T. Aman rice (var. BRRI dhan49).

Nutrient element	Requirement (kg/ha)
N	116.40
P	18.75
K	53.60
S	3.13

4. CONCLUSION

The following conclusion can be drawn from the present study:

- Major plant nutrients significantly affected the yield and yield contributing characters as well as nutrient uptake and concentration in grain and straw of T. Aman rice cultivated in Grey Terrace soil of AEZ 28.
- The yield limiting nutrients in this AEZ for rice cultivation were N, K, P and S.
- Phosphorus omission delayed maturity time of T. Aman rice while N omission enhanced the maturity time.
- The estimated N, P, K and S requirements to cultivate T. Aman rice under Grey Terrace soil were 116, 19, 54 and 3 kg/ha, respectively.

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