Article AR2151e

DOI: HTTPS://DOI.ORG/10.23910/1.2021.2151e

International Journal of Bio-resource and Stress Management

February 2021

Crossref

Print ISSN 0976-3988

Online ISSN 0976-4038

IJBSM 2021, 12(1):007-015

Research Article *Natural Resource Management*

Effect of Next Generation Fertilizers on Yield Potential of Rice (*Oryza sativa* L.)

M. A. A. Faroque[1], Alok Kumar Paul[2], Asaduzzaman[2], Parimal Bissus[2] and M. S. Islam[3]

[1]National Agricultural Technology Program Phase II Project, Bangladesh Agricultural Research Council, Farmgate, Dhaka (1215), Bangladesh

[2]Sher-e-Bangla Agricultural University, Dhaka (1207), Bangladesh

[3]Bangladesh Agricultural Research Institute, Gazipur (1701), Bangladesh

Corresponding Author

M. A. A. Faroque

e-mail: faroquekbd@gmail.com

Citation: Faroque et al., 2021. Effect of Next Generation Fertilizers on Yield Potential of Rice (*Oryza sativa* L.). International Journal of Bio-resource and Stress Management 2021, 12(1), 007-015. HTTPS://DOI.ORG/10.23910/1.2021.2151e.

Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

Conflict of interests: The authors have declared that no conflict of interest exists.

Acknowledgement: The authors are very grateful to Sayed Monena Montaj Foundation and National AgriCare Group, Dhaka for their kind and financial support to conduct research work.

Abstract

The experiment was carried out to evaluate the effects of next-generation fertilizers along with other recommended fertilizers on the growth and yield during the period from January 2015 to May 2015 at the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh. The experiments were laid out in RCBD method with three replications. The experiment was conducted in *boro* rice with six treatments including control *viz* Treatment$_0$=Control (no fertilizer), Treatment$_1$=Recommended dose $N_{140}P_{20}K_{60}S_{18}Zn_2$ kg ha^{-1}, Treatment$_2$=Bio-forge+$N_{140}P_{20}K_{60}S_{18}Zn_2$, Treatment$_3$=Wuxal Super+$N_{140}P_{20}K_{60}S_{18}Zn_2$, Treatment$_4$=Root feed+$N_{140}P_{20}K_{60}S_{18}Zn_2$, Treatment$_5$=Nitro Plus+$N_{140}P_{20}K_{60}S_{18}Zn_2$ and three rice varieties namely Variety$_1$=BRRI dhan29, Variety$_2$=BRRI dhan28 and Variety$_3$=BRRI dhan58. Next-genaration fertilizer is a mixed fertilizer with the first generation and second generation fertilizer that provide required nutritions to plants. Among the next generation fertilizers, Bio-forge along with other recommended fertilizers performed the best compared to other treatments of the study in an aspect of growth and yield contributing characters mainly plant height, effective tiller hill^{-1}, panicle length, filled grain panicle^{-1}, 1000-grain weight, harvest index and grain yield (8.61 t ha^{-1}). Among the varieties, BRRI dhan29 showed the best performance compared to the other two treatments. The next generation fertilizer viz. Bio-forge and Root feed along with other recommended fertilizers would be ideal for better crop growth and yield.

Keywords: Rice, next-generation, fertilizer, growth and yield

1. Introduction

Bangladesh is an agriculture-based country. Agriculture is the main stem of livelihood for more than 80% of the country's population (Anonymous, 2016). The main purpose of agriculture is to provide food for the increasing population. Fertilizer is considered one of the main inputs for increasing crop yields and farmer's profit. It is true for Bangladesh agriculture because it has virtually no possibility of increasing its cultivable land area. Besides, rice is the dominant staple food for many countries of the world. It is also the most important food crop and a major food grain for more than a third of the world population and 42% calories of the global population (Anonymous, 2009a). It covers about 77% of agricultural land and engages about 70% of the population in rice production activities. Nearly 50% of our employments are generated

Article History

RECEIVED in 05th September 2020 RECEIVED in revised form 24th January 2021 ACCEPTED in final form 13th February 2021

in the rice sector (Chowdury and Mian, 2013. However, the national average rice yield in Bangladesh (4.6 t ha^{-1}) is very low compared to other rice-growing countries, like China (6.70 t ha^{-1}), Japan (6.90 t ha^{-1}), and Korea (7.20 t ha^{-1}) (Anonymous, 2015).

In the early 1950s, farmers applied organic manures (*first generation*) such as cow dung, bone meal to *aus* and *aman* rice and farmyard manure (FYM), mustard oil cake, and fish meal to mustard and vegetable crops (Anonymous, 1958). The use of inorganic fertilizer (*second generation*) started in the country in 1951 with the import of 2,698 tons of ammonium sulphate, phosphates in 1957, and muriate of potash in 1960 (Ahmed, 1987). Bangladesh experienced a magnificent increase in food production through the effect of the green revolution. Thus, fertilizer consumption began to increase rapidly with the introduction of HYV rice (Quasem, 1978).

Food security has become a major and fast-growing concern worldwide. It is proposed that there is a need to double the world food production to feed the ever-increasing population which is set to reach the nine billion mark by 2050 (Anonymous, 2009b). The farmers of Bangladesh could not harvest additional yield from crops due to a lack of knowledge in using next-generation fertilizers, although the role of growth controlling in various physiological and biochemical processes is well known. But still, some hidden hunger is remaining in plants, even though some farmers are following recommended fertilizer done under IPNS basis. As a result, farmers are not getting the desired yield of the crops. So, Next-generation fertilizer is nutritional diversed fertilizers to provide total nutritional requirements for plants without compromising on productivity while protecting ecology and also address "First Generation" & "Second Generation" fertilizer.

Bangladesh needs to continue its efforts to search for effective and usable means of improving NPKS use efficiency and alternative sources of fertilizer for reducing the yield gap. It has no alternative to maximize crop yields per unit area through the intensive use of land and soil resources. With this view, the research will be taken out on next-generation fertilizer products for soil fertility and increasing crop production. So many researches had taken initiative on fertilizer management like effect, doses, and timing, etc. but no enough research on next-generation fertilizer materials are still found.

Above aspect, the present study was conducted to investigate the effects of next-generation fertilizers in combination with NPK on the growth, yield potential of rice.

2. Materials and Methods

2.1. Study sites

The experiment was conducted for rice from January 2015 to May 2015. The experimental area was situated at 23°77°N latitude and 90°33°E longitude at an altitude of 8.6 meters above the sea level The experimental field belongs to the Agro-ecological zone of "The Modhupur Tract", AEZ-28 (Anonymous, 1988). The experimental area was flat having available irrigation and drainage system and above flood level. The area has a subtropical climate, characterized by high temperature, high relative humidity, and heavy rainfall with occasional gusty winds in January-May. Soil samples from 0-15 cm depths were collected from the experimental field. Physical and chemical properties of the initial soil sample were found Sand 30.0%, Silt 40.4%, Clay 29.6%, Textural class-Clay Loam, pH-6.8, Bulk density 1.47 g cc^{-1}, Particle density 2.50 g cc^{-1}, Organic carbon 0.68%, Organic matter 1.18%, Total N 0.06%, Available P 20.32 ppm, Exchangeable K 0.15 meq 100 g^{-1} soil and Available S 12.40 ppm.

2.2. *Method of data collection*

Three varieties of rice were used in this experiment for growth measurement under four next-generation fertilizers with control following a two-factor experiment in RCBD design with 03 (three) replications. Factor A: NGF+recommended fertilizers with control (8) Factor B: Rice Varieties (3).

On 03 January 2015, 45 days old seedlings were transplanted in the experiment field keeping plant to plant distance 15 cm and row to row distance 25 cm. Gap filling was made up to 7 days after transplanting to maintain proper treatment and similar plant population density for each plot. The full triple superphosphate (TSP), muriate of potash (MoP), gypsum, and zinc fertilizers were applied in the experimental plots @ P_{20}, K_{60}, S_{18}, Zn_2 kg ha^{-1} respectively as basal dose in the experimental plots except for control plots. The recommended dose of N was 140 kg ha^{-1}. N was applied as per treatment in three equal splits. The first split was applied after 15 days of transplanting, the second split was applied after 35 days of transplanting i.e. at the active vegetative stage and the third split was applied after 60 days of transplanting i.e. at the panicle initiation stage. The next generation fertilizers e.g. Wuxal super, Bio-forge, Root feed, and Niro-Plus were sprayed at 20, 40, and 60 DAS on plants of the experimental plots @ 5.0 l ha^{-1}, 1.20 l ha^{-1}, 1.20 kg ha^{-1}, and 1.2 l ha^{-1} respectively.

The crop was harvested at maturity stage and started on 02 May 2015 for BRRI dhan28 and BRRI dhan58 and BRRI dhan29 was harvested on 14 May 2015. The harvested crop was collected plot-wise. Grain and straw yields were recorded separately plot-wise and moisture percentage was calculated after sun drying. Dry weight for both grain and straw were also recorded.

Data recorded for yield and yield contributing characters were compiled and tabulated in proper form for statistical analyses. Analysis of variance was done with the help of the MSTAT-C computer package program developed by Russel (1986). The mean differences among the treatments were evaluated with the DMRT test (Gomez and Gomez, 1984).

3. Results and Discussion

3.1. Plant height of rice

Plant height was varied significantly due to the effect of next-

generation fertilizers (NGF) along with other recommended fertilizers while plant height ranges from 86.10 to 94.83 cm ($LSD_{0.05}$=2.602, Table 1). The tallest plant of 94.83 cm was found from the treatment T_2 receiving Bio-forge along with other recommended fertilizers which were statistically similar to treatment T_4 (92.23 cm). The shortest plant height (86.10 cm) was found in T_0 control treatment. These results expressed that the plant height of rice increased in apply of Bio-forge along with other recommended fertilizers. Various physiological processes including cell division and cell elongation of the plant might be influenced by the application of Bio-forge along with other recommended fertilizers. These findings are in agreement with the findings of Rogaciano and Rosill (2015) who researched to determine the effects of three liquid fertilizers (Nitrofert, crop gaint, and nutriplant AG) on the growth of glutinous corn. Findings revealed that the height of corn was not significantly affected by the supplementation of different liquid fertilizers. Plant height was significantly influenced by the effect of variety ($LSD_{0.05}$=3.890, Table 2). The highest plant (98.31 cm) was found in the variety V_3 (BRRI dhan58). The lowest plant highest was found in the treatment V_2 (87.81 cm) which was statistically similar to V_1 treatment (89.06 cm). The above variation in plant height was observed due to the variation of the genetic character. Similar findings were also obtained by Islam et al. (2013) who found significant and genetic variation among the varieties on plant height. Mahamud et al. (2013), who found that the variation in plant height was indicated by the differentiation of genotypic characters and their genetic makeup also. Besides, the climatic and soil condition of the studied area were favorable for better growth of BRRI dhan58 which ultimately showed the highest plant height among the other two.

Table 1: Effect of NGF along with other recommended fertilizers on growth and yield contributing characters of rice

Treatment	Plant height (cm)	Effective tiller hill^{-1} (nos)	Non-effective tiller hill^{-1} (nos)	Panicle length (cm)	Filled grain panicle^{-1} (nos)	Non-filled grain panicle^{-1} (nos)	1000 seed weight (g)
T_0	86.10^{c}	11.33^{c}	6.00^{a}	24.16^{c}	132.1^{c}	8.60^{a}	23.90
T_1	92.09^{b}	15.10^{b}	4.00^{b}	25.13^{b}	140.3^{bc}	6.60^{b}	25.60
T_2	94.83^{a}	17.33^{a}	3.11^{c}	26.09^{a}	154.9^{a}	5.71^{bc}	25.60
T_3	91.30^{bc}	15.10^{b}	3.91^{bc}	25.13^{b}	142.2^{b}	6.40^{bc}	24.90
T_4	92.23^{ab}	16.78^{ab}	3.80^{bc}	25.76^{ab}	150.9^{ab}	6.51^{bc}	25.60
T_5	90.87^{bc}	14.78^{bc}	4.11^{b}	25.09^{b}	141.9^{bc}	7.05^{bc}	24.70
LSD (p=0.05)	2.602	3.219	1.98	0.900	10.96	1.98	-
Level of Significance	*	*	*	*	*	*	NS

Figures having similar letter (s) do not differ significantly; *, **: Significant at (p=0.05) and (p=0.01) level of probability. Here, T_0: Control (No fertilizer); T_1: Recommended N_{140} P_{20} K_{60} S_{18} Zn_2 kg ha^{-1}; T_2: Bio-forge (1.20 l ha^{-1})+Recommended N_{140} P_{20} K_{60} S_{18} Zn_2; T_3: Wuxal Super (5.00 l ha^{-1})+Recommended N_{140} P_{20} K_{60} S_{18} Zn_2; T_4: Root Feed (1.20 kg ha^{-1})+Recommended N_{140} P_{20} K_{60} S_{18} Zn_2; T_5: Nitro Plus (1.20 l ha^{-1})+Recommended N_{140} P_{20} K_{60} S_{18} Zn_2

Table 2: Effect of variety on growth and yield contributing characters of rice

Treatment	Plant height (cm)	Effective tiller hill^{-1} (nos)	Non-effective tiller hill^{-1} (nos)	Panicle length (cm)	Filled grain panicle^{-1} (nos)	Non-filled grain panicle^{-1} (nos)	1000 seed weight (g)
V_1	89.06^{b}	16.61^{a}	3.07^{b}	26.03^{a}	168.70^{a}	5.57^{b}	28.6^{a}
V_2	87.81^{b}	14.32^{b}	4.63^{a}	24.62^{b}	123.70^{b}	7.13^{a}	23.2^{b}
V_3	98.31^{a}	13.89^{b}	4.47^{a}	24.93^{b}	128.00^{b}	6.97^{a}	23.6^{b}
LSD (p=0.05)	3.890	2.276	1.531	0.933	12.000	1.53	2.10
Level of Significance	*	*	*	*	*	*	**

Figures having similar letter (s) do not differ significantly; *, **: Significant at (p=0.05) and (p=0.01) level of probability. Here, V_1: BRRI dhan29; V_2: BRRI dhan28; V_3: BRRI dhan58

At the harvest stage, plant height varied significantly due to the effect of the interaction of variety and NGF along with other recommended fertilizers where plant height significantly varied from 80.63 cm to 101.70 cm ($LSD_{0.05}$=8.530, Table 3). The highest plant height (101.70 cm) was found in the treatment combination of T_2V_3 which was statistically similar to T_2V_1, T_2V_2, and T_4V_1 treatment combination. The shortest plant (80.63 cm) was found from the variety BRRI dhan28

while it did not receive any levels of fertilizer (T_0V_2) which was statistically similar to the treatment combination of T_0V_3 (84.48 cm).

3.2. Number of effective tillers hill^{-1} of rice

The numbers of effective tillers are an important parameter that influences the yield of rice. The supply of nutrients plays a great role in the production of effective tillers per hill. The NGF along with other recommended fertilizers had a significant effect on the increased number of effective tillers hill^{-1} ($LSD_{0.05}$=3.219, Table 1). The highest number of effective tillers hill^{-1} (17.33) was found in treatment T_2 having Bio-forge along with other recommended fertilizers which were statistically similar with treatment T_4 (Root feed along with other recommended fertilizers (16.78). The lowest number of effective tillers hill^{-1} (11.33) was produced in T_0 control treatment. These results revealed that Bio-forge along with other recommended fertilizers influenced to produce the more effective tillers due to the rice plant can be utilized more nutrient from the soil. The maximum number of effective tillers hill^{-1} (16.61) was found in V_1 (BRRI dhan29) ($LSD_{0.05}$=2.276). The lowest number of effective tillers hill^{-1} was found in treatment V_3 which was statistically similar to V_2 treatment. Results revealed that BRRI dhan29 produced the maximum number of effective tillers hill^1 than BRRI dhan28 and BRRI dhan58 due to variation in their genetic characteristics or genetic makeup and environmental condition. Similarly, significant variation among the rice varieties regarding tillers hill^{-1}were also found by Panwar et al. (2012) and Alam et al. (2012). The effect of interaction between treatment and varieties was significant to the number of effective tillers hill^{-1} ($LSD_{0.05}$=4.575, Table 3). The significant variation was found that the number of effective tillers varied from 10.00 to 19.67 where the maximum number of effective tillers hill^{-1} (19.67) was produced from the variety BRRI dhan29 receiving of Bio-forge along with other recommended fertilizers which were statistically insignificant with T_2V_2. The minimum number of effective tillers hill^{-1} (10.00) was produced in the treatment combination of T_0V_1 (BRRI dhan29 having no fertilizer treatment) which was statistically similar to the treatment combination of T_0V_2 and T_0V_3.

Table 3: Interaction of fertilizer×variety on plant height, effective tiller hill^{-1}, panicle length, and filled grain panicle^{-1} of rice

Fertilizer×Varieties	Plant height (cm)	Effective tiller hill^{-1} (nos)	Non effective tiller hill^{-1} (nos)	Panicle length (cm)	Filled grain panicle^{-1} (nos)	Non-filled grain panicle^{-1} (nos)
$T_0\times V_1$	85.91^{bc}	10.00^{c}	5.80^{a}	23.85^{b}	122.7^{cd}	8.50^{a}
$T_0\times V_2$	80.63^{d}	10.33^{c}	7.53^{a}	23.71^{c}	103.3f^{d}	10.23^{a}
$T_0\times V_3$	84.48^{cd}	10.12^{c}	6.81^{a}	23.73^{b}	119.3^{cd}	9.51^{a}
$T_1\times V_1$	100.30^{ab}	14.67^{b}	3.67^{b}	24.57^{bc}	164.0^{b}	6.37^{b}
$T_1\times V_2$	91.94^{bc}	14.33^{b}	3.70^{b}	24.04^{bc}	137.3^{bc}	6.40^{b}
$T_1\times V_3$	92.19^{bc}	14.33^{b}	3.71^{b}	24.01^{bc}	133.7^{cd}	6.41^{b}
$T_2\times V_1$	99.46^{ab}	19.67^{a}	3.33^{bc}	26.79^{a}	193.7^{a}	6.03^{bc}
$T_2\times V_2$	99.49^{ab}	17.67^{ab}	3.66^{b}	24.50^{ab}	171.3^{ab}	6.36^{b}
$T_2\times V_3$	101.70^{a}	15.00^{b}	3.70^{b}	24.98^{ab}	174.0^{ab}	6.40^{b}
$T_3\times V_1$	92.20^{bc}	15.00^{b}	3.68^{b}	24.57^{bc}	161.7^{bc}	6.38^{b}
$T_3\times V_2$	87.87^{bc}	14.67^{b}	3.69^{b}	24.42^{bc}	123.3^{cd}	6.39^{b}
$T_3\times V_3$	86.53^{bc}	14.33^{b}	3.72^{b}	24.66^{bc}	132.7^{cd}	6.42^{b}
$T_4\times V_1$	95.66^{ab}	17.30^{b}	3.34^{bc}	26.96^{a}	129.0^{cd}	6.04^{bc}
$T_4\times V_2$	92.44^{bc}	16.80^{b}	3.71^{b}	25.01^{ab}	128.3^{cd}	6.41^{b}
$T_4\times V_3$	91.38^{bc}	16.31^{b}	3.72^{b}	25.31^{ab}	134.0^{cd}	6.42^{b}
$T_5\times V_1$	89.72^{bc}	15.00^{b}	3.68^{b}	25.36^{bc}	125.7^{cd}	6.38^{b}
$T_5\times V_2$	87.24^{bc}	14.33^{b}	3.70^{b}	24.14^{bc}	124.7^{cd}	6.40^{b}
$T_5\times V_3$	88.81^{bc}	13.33^{b}	3.69^{b}	24.19^{bc}	147.3^{bc}	6.39^{b}
LSD (*p*=0.05)	8.530	4.575	5.655	2.287	29.380	5.654
Level of Significance	*	*	*	*	*	*

3.3. Number of non-effective tillers hill^{-1} of rice

The NGF along with other recommended fertilizers showed significant variation in the number of non-effective tillers hill^{-1} of rice ($LSD_{0.05}$=1.98, Table 1). The maximum number of non-effective tillers hill^{-1} (6.00) was observed from T_0 treatment whereas the minimum number of non-effective tillers hill^{-1}

(3.11) from T_2 treatment was statistically similar (3.91 and 3.80) with T_3 and T_4 treatment. The maximum number of non-effective tillers hill^{-1} (4.63) was found in V_2 (BRRI dhan28) which was statistically similar to V_3 treatment ($LSD_{0.05}$=1.531, Table 2). Result revealed that V_1 (BRRI dhan29) produced less number of effective tillers hill^{-1} than BRRI dhan28 and BRRI dhan58. Significant variation was found in the number of non-effective tillers hill^{-1} ($LSD_{0.05}$=5.655, Table 3). The maximum number of non-effective tillers hill^{-1} (7.53) was produced from the treatment combination of T_0V_2 which was statistically similar to T_0V_1 (5.80) and T_0V_3 (6.81) combination. The minimum number of non-effective tillers hill^{-1} (3.33) was produced in the treatment combination of T_2V_1 which was statistically similar to the treatment combination of T_4V_1 (3.34).

3.4. Panicle length of rice

Panicle length was showed statistical variation among the NGF along with other recommended fertilizers ($LSD_{0.05}$=0.900, Table 1). The longest panicle (26.09 cm) was obtained from the treatment T_2 having Bio-forge along with other recommended fertilizers which were statistically similar to T_4 treatment. The shortest panicle (24.16 cm) was found in the treatment T_0. These results revealed that Bio-forge along with other recommended fertilizers had effective influence than other treatment combinations to produce the longest panicle. So, the above findings were agreed by the research work of Rashid et al. (2011); Hoshain (2010), and other researchers of the home and abroad. Panicle length was significantly influenced by the variety ($LSD_{0.05}$=0.933, Table 2). It was found that the longest panicle (26.03 cm) was observed in BRRI dhan29 (V_1) and the shortest panicle (24.62 cm) was found in the treatment V_2 which was statistically similar with V_3 treatment. These results showed that there was a significant difference among the cultivar might be due to its genetic variation. This result is in agreement with the findings Shiyam et al. (2014); Sarker et al. (2014) and many other scientists. A significant variation was found in panicle length of yield character due to the treatment combination ($LSD_{0.05}$=2.287, Table 3). The longest panicle (26.96 cm) was recorded from the variety BRRI dhan29 containing Root Feed (T_4V_1) which was statistically similar with T_2V_1, T_2V_2, T_2V_3, T_4V_2, and T_4V_3 while the shortest panicle (23.71 cm) was obtained from the variety BRRI dhan28 with the treatment combination of T_0V_2.

3.5. Filled grain panicle^{-1} of rice

The number of filled grains panicle^{-1} was varied due to the effect of treatment of NGF along with other recommended fertilizers. So, the maximum number of filled grains panicle^{-1} (154.90) was recorded in treatment T_2 which was statistically similar to T_4 treatment (150.90) ($LSD_{0.05}$=10.96, Table 1). On the other hand, the minimum number of filled grains panicle^{-1} (132.1) was produced from the treatment T_0 control. Similarly, Rashid et al. (2011) also found a significant variation in the production of grains panicle^{-1} due to the effect of urea–nitrogen, cow dung, poultry manure, and urban wastes produced the maximum number of filled grains panicle^{-1}. The number of filled grains panicle^{-1} was significantly influenced by the effect of variety ($LSD_{0.05}$=12.000, Table 2). The maximum number of filled grains panicle^{-1} (168.7) in the treatment V_1 (BRRI dhan29). The minimum number of filled grain panicle^{-1} (123.70) as found in the treatment V_2 which was statistically similar to V_3. Filled grains panicle^{-1} is the most important yield attribute, the increasing grains panicle^{-1} significantly increased the grain yield for any crops. Such the similar above findings of the present study were also found by Uddin et al. (2011) who reported the significant differences were found in filled grains panicle^{-1} while BRRI dhan44 produced the highest and Lalchicon produced the lowest. The number of filled grains panicle^{-1} was influenced by the effect of a combination of treatment and varieties ($LSD_{0.05}$=29.380, Table 3). The number of filled grains panicle^{-1} significantly varied from 103.3 to 193.70. It was found that the maximum number of filled grains panicle^{-1} was produced from the variety BRRI dhan29 receiving of Bio-forge along with other recommended fertilizers (T_2V_1) which were statistically similar to T_2V_2 and T_2V_3 treatment combination.

3.6. Unfilled grain panicle^{-1} of rice

The number of unfilled grains panicle^{-1} was varied due to the effect of treatment of NGF along with other recommended fertilizers ($LSD_{0.05}$=1.98, Table 1). The maximum number of unfilled grains panicle^{-1} (8.60) was recorded in treatment T_0. On the other hand, the minimum number of unfilled grains panicle^{-1} (5.71) was produced from the treatment T_2. The number of filled grains panicle^{-1} was significantly influenced by the effect of variety ($LSD_{0.05}$=1.53, Table 2). The maximum number of unfilled grains panicle^{-1} (7.13) in the treatment V_2 (BRRI dhan28) was statistically similar to treatment V_3. The minimum number of unfilled grain panicle^{-1} (5.57) is found in the treatment V_1 (BRRI Dhan 29). The number of unfilled grains panicle^{-1} was influenced by the effect of the combination of treatment and varieties ($LSD_{0.05}$=5.654, Table 3). The number of unfilled grains panicle^{-1} significantly varied from 6.03 to 10.23. It was found that the maximum number of unfilled grains panicle^{-1} (10.23) was produced from the variety BRRI dhan28 with control treatment (T_0V_2) which was statistically similar to T_0V_1 and T_0V_3 treatment combination.

3.7. Thousand-grain weight of rice

The different NGF along with other recommended fertilizers showed an insignificant effect on 1000-grain weight (25.60 g) (Table 4). Among the treatments, a maximum 1000-grain weight was found in T_1, T_3, and T_4 treatment. On the other hand, control treatment (T_0) produced the lowest (23.90 g) 1000-grain weight. These results indicated that grain size increases insignificantly with the application of NGF along with other recommended fertilizers. A significant variation in 1000-grain weight was also found by Fakhrul et al. (2013) who also conducted their study with the application of inorganic

Table 4: Effect of NGF along with other recommended fertilizers on yield and harvest index of rice

Fertilizer	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
T_0	2.53^{c}	6.31^{c}	8.84^{c}	28.61^{c}
T_1	6.45^{b}	7.51^{b}	13.96^{cd}	46.20^{b}
T_2	7.81^{a}	7.87^{a}	15.68^{a}	49.81^{a}
T_3	6.42^{b}	7.45^{b}	13.87^{cd}	46.29^{ab}
T_4	6.90^{ab}	7.30^{ab}	14.20^{bc}	48.59^{ab}
T_5	6.80^{b}	7.40^{b}	14.20^{bc}	47.88^{ab}
LSD (*p*=0.05)	0.91	0.67	0.79	3.60
Level of Significance	**	**	**	**

(RDF)+organic (PM) manures where T_5 (50% RDCF+4 ton PM ha^{-1}) showed the highest 1000 grain weight. The significant variation in 1000-grain weight might be due to the genetic makeup of particular genotype and sink strength. The results were revealed that the variety BRRI dhan29 (28.6 g) had more efficient to produce larger sizes grain than BRRI dhan28 (23.2 g) and BRRI dhan54 (23.6) ($LSD_{0.05}$=2.10, Table 2). Ali et al. (2014) found a similar result and they reported that 1000-grain weight differed significantly among the varieties, which was also supported by Shiyam et al. (2014); Islam et al. (2013); and many scientists of the home and abroad were also found significant variation in 1000-grain weight due to the variation in the genetic makeup of the variety. The effect of interaction significant varieties and NGF along with other recommended fertilizers was found in 1000-grain weight ($LSD_{0.05}$=5.20, Table 6). However, the maximum 1000-grain weight (30.00 g) was found in the treatment combination of T_2V_1 which was statistically insignificant with the treatment combinations in T_2V_2, T_2V_3, T_4V_1, T_4V_2, and T_4V_3.

3.8. Grain yield of rice

A significant variation was found for the character of grain yield of rice due to the effect of NGF along with other recommended fertilizers ($LSD_{0.05}$=0.91, Table 4). Among the treatments, Bio-forge along with other recommended fertilizers (T_2) produced significantly the highest grain yield (7.81 t ha^{-1}) which was statistically similar to the T_4 treatment. The lowest yield of grain (2.53 t ha^{-1}) was found in the treatment T_0. This result was revealed that Bio-forge and Root feed along with other recommended fertilizers showed the highest grain yield which might be due to the more effective tillers hill^{-1}, longest panicle, more grains panicle^{-1} and larger grain. The above findings indicated that the two treatments (T_2 and T_4) would be ideal for getting a higher grain yield. Similarly, organic+inorganic fertilizer application on *boro* rice was also conducted by Shaha (2014); Sarkar (2014); Liza et al. (2014); Hasan (2014); Islam et al. (2013) and many other researchers. There was a significant difference between the varieties in grain yield of rice. Among the varieties, BRRI dhan29 (V_1) produced the highest grain yield (8.35 t ha^{-1}). The lowest grain yield was found in the varietal treatment V_2 (5.82 t ha^{-1}) ($LSD_{0.05}$=0.64, Table 5). The yield was higher in BRRI dhan29 due to the production of the taller plant, more effective tillers, longest panicle, more grains panicle^{-1} as well as larger sizes grains. Shiyam et al. (2014)

Table 5: Effect of variety on yield and harvest index of rice

Treatment	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
V_1	8.35^{a}	8.66^{a}	17.01^{a}	49.09^{a}
V_2	5.82^{c}	7.25^{b}	13.07^{b}	44.53^{b}
V_3	6.96^{b}	7.34^{b}	14.30^{b}	48.67^{b}
LSD (*p*=0.05)	0.64	0.67	0.65	0.41
Level of Significance	**	**	**	**

reported that the varieties which produced a higher number of effective tillers hill^{-1} and a higher number of filled grains panicle^{-1} also showed higher grain yield ha^{-1}. Grain yield was significantly influenced by the interaction effect of varieties and the application of next-generation fertilizer along with other recommended fertilizers ($LSD_{0.05}$=0.59, Table 6). It was found that the grain yield was significantly varied from 2.75 to 8.61 t ha^{-1} while the treatment combination T_2V_1 (BRRI dhan29 receiving of that Bio-forge along with other recommended fertilizers) showed the highest grain yield (8.61 t ha^{-1}). BRRI dhan58 showed the lowest grain yield (2.75 t ha^{-1}) while it was cultivated without fertilizers under treatment T_0.

3.9. Straw yield of rice

The straw yield was significantly influenced by the effect of NGF along with other recommended fertilizers ($LSD_{0.05}$=0.67, Table 4). Among the treatments, Bio-forge along with other recommended fertilizers produced significantly the highest yield of straw (7.87 t ha^{-1}) which was statistically similar to treatment T_4 (7.30 t ha^{-1}). The lowest yield of straw (6.31 t ha^{-1}) was found in the treatment T_0. This result revealed that Bio-forge and Root feed showed a greater effect on straw yield which might be due to the higher plant height, effective tillers hill^{-1} and longest panicle. There was a significant difference between the varieties in respect of straw yield ($LSD_{0.05}$=0.67, Table 5). Among the varieties, BRRI dhan29 produced the highest straw yield (8.66 t ha^{-1}) than the other two varieties BRRI dhan28 (7.25 t ha^{-1}) and BRRI dhan54 (7.34 t ha^{-1}). The straw yield was higher in BRRI dhan29 and than that of others, two might be attributed to the production of the taller plant, more effective tillers, and longest panicle. The straw yield was significantly influenced by the interaction effect of varieties and the application of NGF along with other recommended fertilizer**s** ($LSD_{0.05}$=1.77, Table 6). The treatment T_4V_1 showed the highest straw yield (9.30 t ha^{-1}) which was very close with

Table 6: Effect of interaction of NGF along with other recommended fertilizers and varieties on the thousand seed weight, grain yield, straw yield, biological yield, and harvest index of rice

Fertilizer×Varieties	1000 seed weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
$T_0 \times V_1$	22.70^{c}	2.88^{e-g}	7.52^{b-c}	10.40^{ef}	27.69^{e}
$T_0 \times V_2$	22.69^{c}	2.96^{g}	5.76^{e}	08.72^{f}	33.94^{e}
$T_0 \times V_3$	22.71^{c}	2.75^{h}	5.66^{e}	08.41^{f}	32.70^{e}
$T_1 \times V_1$	24.00^{bc}	6.58^{d-f}	6.81^{cd}	13.39^{cd}	49.14^{b}
$T_1 \times V_2$	23.70^{bc}	6.31^{d-g}	7.51^{b-d}	13.82^{cd}	45.66^{cd}
$T_1 \times V_3$	23.30^{bc}	7.38^{b-f}	7.51^{b-d}	14.89^{bc}	49.56^{ab}
$T_2 \times V_1$	30.00^{a}	8.61^{a}	8.81^{a-c}	17.42^{ab}	49.43^{ab}
$T_2 \times V_2$	29.30^{ab}	8.01^{bc}	9.19^{a}	17.02^{ab}	47.06^{bc}
$T_2 \times V_3$	29.90^{ab}	8.00^{bc}	8.49^{de}	16.49^{ab}	48.51^{bc}
$T_3 \times V_1$	23.30^{bc}	7.46^{b-e}	8.53^{a-c}	17.02^{ab}	49.88^{a}
$T_3 \times V_2$	24.31^{bc}	6.59^{d-f}	7.53^{ab}	14.12^{cd}	46.67^{c}
$T_3 \times V_3$	24.40^{bc}	7.40^{b-f}	8.25^{b-d}	15.65^{bc}	47.28^{bc}
$T_4 \times V_1$	29.30^{ab}	8.00^{bc}	9.30^{a}	17.69^{a}	46.24^{bc}
$T_4 \times V_2$	29.00^{ab}	8.01^{bc}	7.59^{a-c}	15.69^{bc}	51.95^{a}
$T_4 \times V_3$	28.30^{ab}	7.77^{bc}	7.78^{b-d}	15.55^{bc}	49.97^{a}
$T_5 \times V_1$	24.10^{bc}	5.59^{fg}	8.59^{a-c}	16.66^{ab}	48.44^{bc}
$T_5 \times V_2$	24.30^{bc}	6.88^{c-f}	8.32^{a-c}	15.20^{bc}	45.26^{cd}
$T_5 \times V_3$	24.00^{bc}	6.98^{c-f}	7.35^{cd}	14.33^{c}	48.71^{ab}
LSD (*p*=0.05)	5.20	0.59	1.77	1.67	0.83
Level of Significance	*	*	*	*	*

the treatment combination T_2V_2 (9.19 t ha^{-1}). BRRI dhan58 showed the lowest straw yield (5.66 t ha^{-1}) under T_0 treatment which was statistically similar to T_0V_2 treatment combination. This result revealed that the growth of BRRI dhan29 had highly efficient in Root feed along with other recommended fertilizers for getting the tallest plant, maximum effective tillers hill^{-1} and the longest panicle which resulting in the higher straw yield.

3.10. Biological yield of rice

The biological yield was significantly influenced by the effect of NGF along with other recommended fertilizers ($LSD_{0.05}$=0.79, Table 4). Among the treatments, Bio-forge along with other recommended fertilizers produced significantly the highest biological yield (15.68 t ha^{-1}). The lowest biological yield (10.84 t ha^{-1}) was found in the treatment T_0. There was a significant difference between the varieties in respect of biological yield ($LSD_{0.05}$=0.65, Table 5). Between the varieties, BRRI dhan29 produced a higher biological yield (17.01 t ha^{-1}) than the other two varieties BRRI dhan28 and BRRI dhan54 (13.07 and 14.30 t ha^{-1}, respectively. The biological yield was higher in BRRI dhan29 and that of the other two might be attributed to the production of taller plant, more effective tillers, and longest panicle and grain yield. The biological yield was significantly influenced by the interaction effect of varieties and the application of NGF along with other recommended fertilizers ($LSD_{0.05}$=1.67, Table 6). The treatment T_4V_1 showed the highest biological yield (17.69 t ha^{-1}). This result revealed that the growth of BRRI dhan29 had highly efficient in Root feed along with other recommended fertilizers for getting the tallest plant, maximum effective tillers hill^{-1}, longest panicle, and grain yield which resulting in the higher biological yield.

3.11. Harvest index of rice

A significant variation was found due to different treatment of NGF along with other recommended fertilizers regarding harvest index ($LSD_{0.05}$=3.60, Table 4). The highest harvest index (49.81%) was recorded in T_2 treatment having Bio-forge along with other recommended fertilizers while it was statistically similar to T_3 (46.29%), T_4 (48.59%), and T_5 (47.88%) treatments. On the other hand, the control treatment T_0 showed the lowest harvest index (28.61%). Harvest index (HI) was very significant due to the effect of varieties ($LSD_{0.05}$=0.41, Table 5). The highest harvest index (49.09%) was found in the varietal treatment V_1 and the lowest harvest index (44.53%) was found in V_2 treatment which was statistically similar to V_3 treatment. Such variation in the genetic makeup of the varieties regarding HI was also found by Yao et al. (2012); Sritharan

and Vijayalakshmi (2012); Baset Mia and Shamsuddin (2011) any another many scientist. Harvest index (HI) was very significant due to the effect of treatment combination of varieties and NGF along with other recommended fertilizers ($LSD_{0.05}$=0.83, Table 6). The highest harvest index (51.95%) was found in the treatment combination of T_4V_2 which was statistically similar to treatment combinations of T_4V_3, T_1V_3, and T_2V_1. The lowest harvest index (27.69%) was found in the treatment combination of T_0V_1 which was statistically similar to the treatment combination of T_0V_2 and T_0V_3.

4. Conclusion

The effect of next-generation fertilizers along with other recommended fertilizers on growth, yield attributes, and grain yield of rice was investigated in this experiment. Bio-forge (1.20 l ha^{-1}) + recommended dose N_{140} P_{20} K_{60} S_{18} Zn_2 performed the best compared to other fertilizers treatments of the study in an aspect of growth and yield contributing characters mainly plant height, effective tiller $hill^{-1}$, panicle length, filled grain $panicle^{-1}$, 1000 seed weight, harvest index, and grain yield (8.61 t ha^{-1}). Among the varieties, BRRI dhan29 performed the best compare to other treatments of the study in the aspect of yield contributing characters and yield of rice.

5. Acknowledgment

The authors are very grateful to Sayed Monena Montaj Foundation and National AgriCare Group, Dhaka for their kind and financial support to conduct research work.

6. References

Ahmed, R., 1987. Structure, dynamics and related policy issues of fertilizer subsidy in Bangladesh, 281−380.

Alam, M.S., Baki, M.A., Sultana, M.S., Ali, K.J., Islam, M.S., 2012. Effect of variety, spacing and number of seedlings per hill on the yield potentials of transplant *aman* rice. International Journal of Agricultural Research 2(12), 10−15.

Ali, A., Khalifa, A., Elkhoby, W., Okasha, E.M., 2014. Effect of sowing dates and seed rates on some rice cultivars. Afrrical Journal of Agriculture Research 9(2), 196–201.

Anonymous, 1958. The provincial statistical board and bureau of commercial industrial intelligence. Statistical Abstract for East Pakistan, East Pakistan Bureau of Statistics, Dacca, 517.

Anonymous, 1988. Land resources appraisal of Bangladesh for agricultural development. Report No. 2. Agroecological Regions of Bangladesh, UNDP and FAO, 472−496.

Anonymous, 2009a. The global staple rice as food. Ricepedia the online authority on rice. A project of CGIAR-Research program on Rice. http://ricepedia.org/rice-as-food/the-global-staple-rice-consumers.

Anonymous, 2009b. Food production must double by 2050 to meet demand from world's growing population, innovative strategies needed to combat hunger. Sixty-fourth General Assembly, Second Committee GA/EF/3242, Panel Discussion (AM), United Nations. 9 October 2009. http://www.un.org

Anonymous, 2015. FAO Statistics, food and agriculture organization, Rome, Italy,. http://www.fao.org/faostat/en/#data/QC/visualize

Anonymous, 2016. Bangladesh: growing the economy through advances in agriculture. https://www.worldbank.org/en/results/2016/10/07/bangladesh-growing-economy-through-advances-in-agriculture

Baset Mia, M.A., Shamsuddin, Z.H., 2011. Physio–morphological appraisal of aromatic fine rice (*Oryza sativa* L.) in relation to yield potential. International Journal of Botany 7(3), 223−229.

Chowdhury, M.A.H., Hassan, M.S., 2013. Hand book of agricultural technology. Bangladesh Agricultural Research Council. 230p http://www.barc.gov.bd

Fakhrul, I., Asaduzzaman, M.K., Fazle, B.A.S.M., Hosain, M.T., Sabikun, N., 2013. Effect of fertilizer and manure on the growth, yield and grain nutrient concentration of *boro* rice (*Oryza sativa* L.) under different water management practices. The Agriculturists 11, 44−51.

Gomez, K.A., Gomez, A.A., 1984. Statistical procedure for agricultural research. 2nd ed. John Wiley and Sons. New York, 64.

Hasan, M.N., 2014. Effect of USG with cowdung on nitrogen use efficiency of rice and nitrogen dynamics in porewater. MS Thesis, Department of Soil Science, Bangladesh Agricultural University, Mymensingh, 1−66.

Hoshain, S., 2010. Effect of cowdung and nitrogen (urea) on growth, yield and yield contributing characters of aromatic rice cv. BRRI dhan50. MS Thesis. Department of Agronomy, Bangladesh Agricultural University, Mymensingh, 4−20.

Islam, M.R., Akther, M., Afroz, H., Bilkis, S., 2013. Effect of nitrogen from organic and inorganic sources on the yield and nitrogen use efficiency of BRRI dhan28. Bangladesh Journal of Progressive Science and Technology 11(2), 179−184.

Liza, M.M.J., Islam, M.R., Jahiruddin, M., Hasan, M.M., Alam, M.A., Shamsuzzaman, S.M., Samsuri, A.W., 2014. Residual effects of organic manures with different levels of chemical fertilizers on rice. Life Science Journal 11(12), 6−12.

Mahamud, J.A., Haque, M.M., Hasanuzzaman, M., 2013. Growth, dry matter production and yield performance of transplanted aman rice varieties influenced by seedling densities per hill. International Journal of Sustainable Agricultural Research 5(1), 16−24.

Panwar, C.S., Vishwakarma, S.K., Verma, N., 2012. Comparative performance of different rice varieties in relation to growth and yield. Bioinfolet 9(4A), 631−632.

Quasem, M.A., 1978. Fertilizer use in Bangladesh: 1965-66 to 1975-76. Bangladesh Institute of Development Studies,

Dhaka, (BIDS Research Report Series No. 25), 37.

Rashid, M.M.U., Solaiman, A.R.M., Jahiruddin, M., Karim, A.J.M.S., Islam, M.S., Nasim, A.S.B.M., 2011. Effect of urea nitrogen, cowdung, poultry manure and urban wastes on yield and yield components of *boro* rice. International Journal of Agriculture Environment & Biotechnology 4(1), 9−13.

Rogaciano, D.D.J., Rosill, A.C., 2015. Effect of different liquid fertilizers on yield and economic analysis of glutinous corn (*Zea mays* L.). International Journal of Multidisciplinary Research and Development 2(2), 558−562.

Russel, D.F., 1986. MSTAT-C Package programme. Crop and Soil Science Department, Michigan State University, USA.

Sarkar, S.K., Sarkear, M.A.R., Islam, N., Paul, S.K., 2014. Yield and quality of aromatic fine rice as affected by variety and nutrient management. Journal of the Bangladesh Agricultural University 12(2), 279–284

Shaha, U., 2014. Integrated use of cowdung and inorganic fertilizer on the performance of modern varieties of transplanted aman rice. MS Thesis, Department of Agronomy, Bangladesh Agricultural University, Mymensingh, Bangladesh, 1−70.

Shiyam, J.O., Binang, W.B., Ittah, M.A., 2014. Evaluation of growth and yield attributes of some lowland Chinese hybrid rice (*Oryza sativa* L.) varieties in the Coastal Humid Forest Zone of Nigeria. IOSR Journal of Agriculture and Veterinary Science 7(2), 70−73.

Sritharan, N., Vijayalakshmi, C., 2012. Physiological basis of rice genotypes under aerobic condition. Plant Archives 12(1), 209−214.

Uddin, M.J., Ahmed, S., Harun-or-Rashid, M., Hasan, M.A. and Asaduzzaman, M. (2013). Effect of spacing on the yield and yield attributes of transplanted aman rice cultivars in medium lowland ecosystem of Bangladesh. Journal of Agricultural Research 49(4), 465−476.

Yao, F., Huang, I., Cui, K., Nie, L., Xiang, I, Liu, X., Wu, W., Chen, M., Peng, S., 2012. Agronomic performance of high–yielding rice variety grown under alternate wetting and drying irrigation. Field Crops Research 126, 16−22.