Research in
ISSN : P-2409-0603, E-2409-9325
AGRICULTURE, LIVESTOCK and FISHERIES
An Open Access Peer Reviewed Journal

Open Access
Research Article

Res. Agric. Livest. Fish.
Vol. 5, No. 2, August 2018 : 157-164.

DETERMINATION OF ECONOMIC EFFICIENCY OF DEEP PLACEMENT AND FOLIAR APPLICATION OF UREA FERTILIZER THROUGH THE PERFORMANCE OF BORO RICE cv. BRRI dhan29

Tahmina Aktar[1], Md. Rashedur Rahman[1*], Md. Anwarul Abedin[2] and A H M Jahangir Alam[3]

[1]Department of Agronomy, and [2]Department of Soil Science, Faculty of Agriculture, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh; [3]Department of Agricultural Extension, Paikgacha, Khulna, Bangladesh.

***Corresponding author:** Md. Rashedur Rahman; E-mail: rashedagron@bau.edu.bd

ARTICLE INFO

Received
02 August, 2018

Accepted
16 August, 2018

Online
30 August, 2018

Key words
Urea super granule
Foliar spray
Nitrogen
Rice crop

ABSTRACT

Rice is the most extensively cultivated cereal crops in Bangladesh and nitrogenous fertilizer, especially urea is the most pressing fertilizer to supply nutrient in the paddy field. With this view, an experiment was conducted to evaluate the effect of deep placement and foliar application of urea fertilizer on BRRI dhan29 rice cultivar in boro season at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh during December 2015 to May 2016. The experiment was laid out in a randomized complete block design considering twelve treatments with three replications. The treatments were- T0 (No N application), T1 [140 kg N/ha (as prilled urea)], T2 (1.8 g 1-USG + 5 foliar spray @ 1% N solution), T3 (1.8 g 1-USG + 5foliar spray @ 1.5% N solution), T4 (1.8 g 1-USG + 5 foliar spray @ 2% N solution), T5 (1.8 g 2-USG), T6 (2.7 g 1-USG), T7 (2.7 g 1-USG + 3 foliar spray @ 1% N solution), T8 (2.7 g 1-USG + 3 foliar spray @ 1.5% N solution), T9 (2.7 g 1-USG + 3 foliar spray @ 2% N solution), T10 (1.8 g 2-USG + 3 t/ha cowdung), T11 (2.7 g 1-USG + 3 t/ha cowdung). Results showed that the grain and straw yield of the rice variety responded significantly to the application of prilled urea (PU), deep placement of USG and foliar application of N. The highest grain yield (4.8 t/ha) was recorded in T8 which was identical to the yield (4.7 t/ha) obtained in T3. The highest straw yield (6.0 t/ha) was found in T5. The lowest grain yield (3.7 t/ha) and straw yield (4.5 t/ha) were found in T0. Considering the economic efficiency, the treatment T8 showed the maximum gross margin and marginal gross margin with lowest cost per unit of product. Therefore, to get highest grain yield (4.8 t/ha), 82 kg N/ha as USG and 3 foliar spray of N @1.5% concentration i.e. total 219 Kg urea/ha can be applied to the rice field of BRRI dhan29. This will save an amount of 81 Kg urea per rice growing season per hectare.

To cite this article: Aktar T, M R Rahman, M A Abedin and A H M J Alam, 2018. Determination of economic efficiency of deep placement and foliar application of urea fertilizer through the performance of boro rice cv. BRRI dhan29. Res. Agric. Livest. Fish. 5 (2): 157-164.

INTRODUCTION

Bangladesh is an agro based country where agriculture is the single largest sector and the main stay of the country's economy (Sabnam, 2013). Rice (*Oryza sativa* L.) is the most extensively cultivated cereal crop in Bangladesh. Rice (*Oryza sativa* L.) is also the staple food for more than two billion people in Asia and four hundred millions of people in Africa and Latin America (Aktar, 2017). In 2016-2017, 475.64 million metric tons of rice were consumed worldwide (Statista, 2018). Nitrogen is one of the major plant nutrients required for plant growth. Farmers of Bangladesh use mainly urea in rice field to meet the demand of nitrogen. For maximizing yield of rice, nitrogenous fertilizer is the kingpin in rice farming. Therefore, excessive use of nitrogen fertilizer is one of the major concerns in sustainable agriculture for its decreased N-utilization efficiency by crops and increased N released to the environment, resulting atmosphere and water systems pollution (Zhu et al., 1997). In Bangladesh, N fertilizer input is as high as 265 kg $Nha^{-1}yr^{-1}$ in rice-rice cropping pattern (BBS, 2011).

Fertilizer is a critical input in Bangladesh for rice production and most farmers broadcast prilled urea to fertilize their rice fields. This method for supplying nitrogen to rice plants leads to losses in effective nitrogen uptake in the rice plants. On the other hand, the urea deep placement (UDP) technology represents a possible alternative to increase rice yields and to reduce the nitrogen loss associated with broadcasted urea (Bautista *et al.,* 2000). However, foliar spray of fertilizer did not only increase the crop yields but also reduce the quantities of fertilizer applied through soil (Rahman et al., 2017). Foliar application can also reduce the lag time between application and uptake by the plant (Stefan *et al.,* 1990). The use of foliar application in agriculture has been a popular practice within farmers since the 1950s, when it shows that foliar-applied fertilizers passed through the leaf cuticle and into the cells. Various studies have shown that a small amount of nutrients (nitrogen or phosphate) applied by foliar spraying increases significantly the yield of crops (Vaiyapuri et al., 2003; Alam, 2009). In this connection, Bangladesh has a good stock of data for the fertilizer management of high yielding rice. However, minimal efforts have been made to study in particular the nitrogen use efficiency of rice varieties with nitrogen efficient fertilizer management practice. Therefore, the present investigation is undertaken to develop a combined approach of using N fertilization via deep placement and foliar application for maximizing rice yield as well as minimizing N loss to the environment. Therefore the present study aimed to find out the economic efficiency of different urea application method through the performance of boro rice cv. BRRI dhan29.

MATERIALS AND METHODS

Description of experimental site

The study was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh from December 2015 to May 2016. The experimental site is located at 240 75´ N latitude and 900 50´ E longitude in the south-west part of Brahmaputra at an elevation of 18 m above the sea level. This site belongs to non-calcareous dark grey floodplain soil under the agro-ecological zone Old Brahmaputra Floodplain "AEZ-9" (UNDP and FAO, 1988).

Characteristics of test variety

BRRI dhan29, a high yielding variety of rice was used as the test crop in this experiment. This variety was released for boro season by the Bangladesh Rice Research Institute (BRRI); Joydebpur, Gazipur in 1992 after regional and zonal trial and evaluation. It is a transplant boro rice cultivar and matures after 103 days after transplanting with average yield of 5.0-7.5 t ha^{-1}. Life cycle of this variety ranges from 155 to 160 days, which however may vary due to changes in climatic condition. The plant height is 90-95 cm and the cultivar is of non-lodging type. It is somewhat resistant to pests and diseases and especially blast diseases.

Preparation of the experimental land and raising of crop

The land was first opened with a tractor drawn disc plough on 14 December, 2015. After two days, the land was irrigated slightly and subsequent ploughings and cross ploughings were given and leveled by laddering. The field layout was made on 28 January, 2016 according to experimental specification immediately after final land preparation. Weeds and stubbles were cleared off from individual plots and finally plots were leveled properly by wooden ladder so that no water pocket could remain in the field. Forty-five days old seedlings were carefully uprooted from nursery bed and transplanted in the plots on 1 February, 2016 maintaining a spacing of 25 cm × 15cm. Three healthy seedlings were transplanted in each hill. Various intercultural operations viz. irrigation, weeding, disease and pest management etc. were done as and when necessary to ensure and maintain the favorable condition for normal plant growth and development of crop.

Layout of the experiment

The experiment was laid out in a randomized complete block design (RCBD), where the experimental site was divided into 3 blocks representing the replications to reduce the heterogenic effects of soil. There were altogether 12 different treatment combinations. A total of 36 plots were prepared for the experiment and the treatments were distributed to the unit plots in each block. The size of each plot was 4m × 2.5m and plots were separated from each other by ails. There was 1m drain between the blocks that separated the blocks from each other.

Treatments and fertilizer application

The treatments used for the experiment were as follows:

Treatments	Treatment description	Urea added (kg/ha)
T0	No N application (control)	0
T1	140 kg N/ha (as prilled urea)	300
T2	1.8 g 1-USG (55kg N/ha) + 5 Foliar spray @ 1% N solution i.e. 9 g urea/spray	165
T3	1.8 g 1-USG (55 kg N/ha) + 5 Foliar spray @ 1.5% N solution i.e. 13.5 g urea/spray	188
T4	1.8 g 1-USG (55 kg N/ha) + 5 Foliar spray @ 2% N solution i.e. 18 g urea/spray	210
T5	1.8 g 2-USG (110 kg N/ha)	240
T6	2.7 g 1-USG (82 kg N/ha)	178
T7	2.7 g 1-USG (82 kg N/ha) + 3 Foliar spray @ 1%N solution i.e. 9 g urea/spray	205
T8	2.7 g 1-USG (82 kg N/ha) + 3 Foliar spray @ 1.5%N solution i.e. 13.5 g urea/spray	219
T9	2.7 g 1-USG (82 kg N/ha) + 3 Foliar spray @ 2%N solution i.e. 18 g urea/spray	232
T10	1.8 g 2-USG (55 kg N/ha) + 3 t/ha cowdung	292
T11	2.7 g 1-USG (82 kg N/ha) + 3 t/ha cowdung	230

Note: 1-USG means one piece of urea super granule and 2-USG means two pieces of urea super granule. Each urea super granule was applied for every four hills of rice plant

TSP, MOP, gypsum and Zinc sulphate were applied to all the experiment plots as basal during final land preparation to supply 100 kg/ha, 160 kg/ha, 110 kg/ha and 10 kg/ha, respectively (BRRI, 2016). In T_1 urea @ 300 kg/ha was applied. All prilled urea are applied in 3 equal split at 15, 35 and 55 days after transplanting (DAT). Five foliar sprays were applied in T_2, T_3 and T_4 at 20, 30, 40, 50 and 60 DAT, respectively. Three foliar sprays were applied in T_7, T_8 and T_9 at 30, 40 and 50 DAT, respectively. The USG were placed at 8-10 cm depth between four hills at alternative rows.

Sampling, harvesting and data collection

The crop was harvested at full maturity. The date of harvesting was confirmed when 90% of the grains became golden yellow in color. Harvesting of BRRI dhan29 was done on 10 May 2016. Five hills (excluding border hills) were selected randomly from each individual plot and uprooted before harvesting for recording data. After sampling the whole plot was harvested. The harvested crop of each plot was separately bundled, properly tagged and then brought to the threshing floor. The harvested crops were threshed manually. The grains were cleaned and dried to a moisture content of 14%. Straws were sun dried.

Statistical analysis of data

Data were compiled and tabulated in proper form for statistical analysis. The recorded data were statistically analyzed to find out the significance of variation resulting from the experimental treatments. All the collected data were analyzed and adjudged by Duncan's Multiple Range Test (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Crop characteristics and yield attributes

Application of PU, deep placement of USG and foliar application of N significantly increased the plant height of BRRI dhan29 (Table 1). The plant height of rice varied from 93.87 cm to 104.1 cm. The tallest plant of 104.1 cm was observed from T4 treatment (1.8g 1-USG + 5 foliar spray @ 2.0% N solution). Second plant height 103.8 cm was recorded from T9 treatment which was statistically similar to T1, T2 and T8 treatments. The treatment T0, T7, T5, T10, T11 and T6 gave the medium plant height with the values of 99.40, 98.80, 98.33, 98.20, 97.53 and 96.80 cm, respectively among the fertilizer treatments. The treatment T3 had the smallest plant height (93.87 cm). This might be due to the application of urea by spraying five times and plant could effectively use the N from that spray.

According to the Table 1, the use of PU, deep placement of USG and foliar application of N showed significant influence on effective tillers hill^{-1} of BRRI dhan29. The maximum number of tillers hill^{-1} of 11.07 was found from T4 (1.8 1-USG + 5 foliar spray @ 2.0% N solution) which were statistically similar to T_5 and T2. The treatment T11, T7, T1, T8 and T0 gave the medium number of tillers hill^{-1} with the values of 10.00, 9.73, 9.27, 9.00 and 8.93 respectively among the fertilizer treatments. The minimum value of 7.200 was observed from T6.

Panicle length of BRRI dhan29 was significantly influenced by the application of PU, deep placement of USG and foliar application of N (Table 1). The highest panicle length of 25.07 cm was recorded from T9 (2.7 g 1-USG + 3 foliar spray @ 2.0% N solution). The treatment T_0, T1, T2, T3, T4, T5, T7, T8, T_{10} and T11 gave the medium panicle length with the values 24.40, 24.23, 24.73, 24.57, 24.87, 24.67, 24.50, 24.20, 24.40 and 24.53 cm respectively among the fertilizer treatments.

The effect of PU, deep placement of USG and foliar application of N on grains panicle^{-1} varied from 134.6 to 141.4. The highest grains panicle^{-1} (141.4) was measured from T0 (No N application) which was statistically similar to T8. The treatment T9, T6, T3, T7 and T10 gave the medium grains panicle^{-1} with the values of 139.2, 138.2, 137.5, 137.4 and 136.5 respectively among the fertilizer treatments. The lowest value (134.6) was recorded from T2 and T5 treatment.

The 1000-grain weight of BRRI dhan29 varied significantly due to application of PU, deep placement of USG and foliar application of N (Table 1). The 1000-grain weight ranged from 22.67 g from T_0 [No N application] to 25.07 g from T8 (2.7 1-USG + 3 foliar spray @ 2.0% N solution). The highest 1000-grain weight value (25.07 g) was recorded from T8 treatment. The lowest 1000-grain weight value (22.67 g) was observed from T0 treatment.

Table 1. Effect of PU, deep placement of USG and foliar application of N on yield and yield contributing characters of BRRI dhan29

Treatments	Plant height (cm)	No. of effective tillers hill^{-1}	Panicle length (cm)	Grains panicle^{-1}	1000 grain wt. (g)
T0	99.40abcd	8.93e	24.40	141.40a	22.67
T1	102.10abc	9.27de	24.23	135.80bcd	23.71
T2	101.70abc	10.40abc	24.73	134.60d	24.06
T3	93.87d	8.13f	24.57	137.50abcd	24.06
T4	104.10a	11.07a	24.87	139.80abc	24.07
T5	98.33abcd	10.73ab	24.67	134.60d	24.04
T6	96.80cd	7.20g	23.40	138.20abcd	23.71
T7	98.80abcd	9.73cd	24.50	137.40abcd	24.05
T8	101.10abc	9.00e	24.20	140.50ab	25.07
T9	103.80ab	8.80ef	25.07	139.20abcd	24.06
T10	98.20abcd	8.73ef	24.40	136.50abcd	24.07
T11	97.53bcd	10.00bcd	24.53	135.00cd	23.87
$LSD_{0.05}$	5.55	0.696	1.56	4.48	1.72
Level of significance	*	**	NS	*	NS
CV (%)	3.29	4.41	3.76	1.93	4.27

In a column, figures with the same letters do not differ significantly as per DMRT, * = Significant at 5% level of probability, ** = Significant at 1% level of probability, NS = Non-significant

T_0 = No N application, T_1 = 140 kg N/ha as prilled urea (three equal splits at final land preparation, 15 DAT and 35 DAT, T_2 = 1.8 g 1 USG (55 kg N/ha) + 5 foliar spray @ 1.0% N solution (9g urea/spray), T_2 = 1.8 g 1 USG (55 kg N/ha) + 5 foliar spray @ 1.0% N solution (9g urea/spray), T_3 = 1.8 g 1 USG (55 kg N/ha) + 5 foliar spray @ 1.5% N solution (13.5 g urea/spray), T_4 = 1.8 g 1 USG (55 kg N/ha) + 5 foliar spray @ 2.0% N solution (18 g urea/spray), T_5 = 1.8 g 2 USG (110 kg N/ha), T_6 = 2.7 g 1 USG (82 kg N/ha), T_7 = 2.7 g 1 USG (82 kg N/ha) + 3 foliar spray @ 1.0% N solution, T_8 = 2.7 g 1 USG (82 kg N/ha) + 3 foliar spray @ 1.5% N solution, T_9 = 2.7 g 1 USG (82 kg N/ha) + 3 foliar spray @ 2.0% N solution, T_{10} = 1.8 g 1 USG (55 kg N/ha) + 3 t/ha Cowdung (assuming Cowdung contains 0.8% N), T_{11} = 2.7 g 1 USG (82 kg N/ha) + 3 t/ha Cowdung (assuming Cowdung contains 0.8% N)

Grain yield and straw yield

Significant response of the grain yield of BRRI dhan29 was found due to the application of PU, deep placement of USG and foliar application of N. The grain yield ranged from 3.74 t/ha to 4.75 t/ha where the highest grain yield was (4.75 t/ha) recorded from T8 (2.7 g 1-USG + 3 foliar spray @ 1.0% N solution) and the lowest value was observed from T0 (no N application]. Second highest grain yield (4.70 t/ha) was recorded from T3 [1.8 g 1-USG + 5 foliar spray @ 1.5 % N solution). The treatment T7 (2.7 g 1-USG + 3 foliar spray @ 1.0% N solution), T9 (2.7 g 1-USG + 3 foliar spray @ 2.0% N solution), T10 (1.8 g 2-USG + 3 t/ha cowdung), T11 (2.7 g 1-USG + 3 t/ha cowdung) gave the medium yield with the values of 4.66, 4.69, 4.30 and 4.36 t/ha, respectively among the fertilizer treatments. The treatment T1 (140 kg N/ha (prilled urea)), T5 (1.8 g 1-USG), T6 (2.7 g 1-USG) gave lowered yield with the values of 4.10, 3.97 and 3.90 t/ha, respectively (Figure 1).

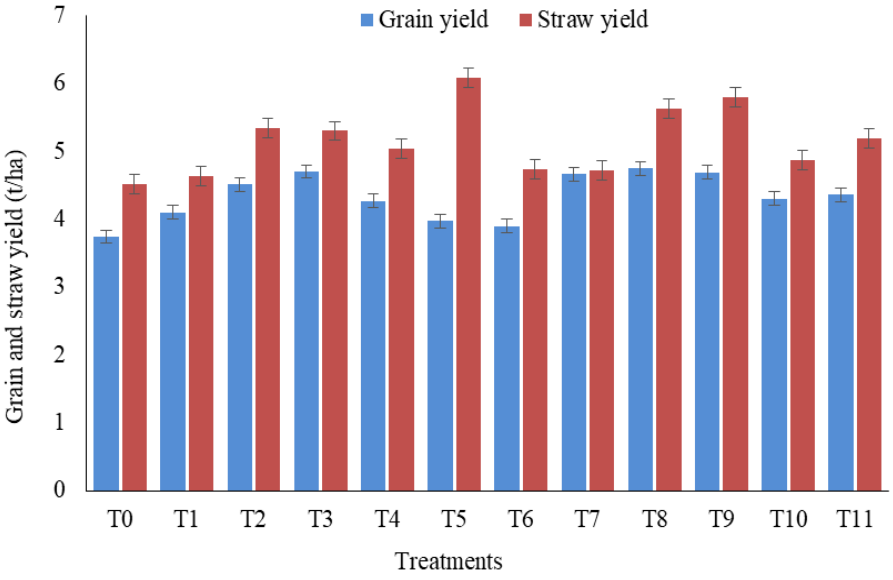

Figure 1. Effect of deep placement of USG and foliar application of N on the grain yield of BRRI dhan29

Treatment T8 gave the highest yield that might be due to the combined application of urea as super granule and foliar application for three times. Due to the combined application of urea with two different methods, the loss of urea was less and uptake and assimilation was greater and probably this phenomenon leads to the highest grain yield with the treatment T8. Straw yield of BRRI dhan29 responded significantly to different treatments under study. The highest straw yield (6.083 t/ha) was found from T_5 [1.8 g 2-USG (240 kg N/ha)] and the lowest value (4.520 t/ha) was observed from T_0 (No N application). The straw yields obtained due to different treatment ranked in order of $T_5>T_9>T_8>T_2>T_3>T_{11}>T_4>T_{10}>T_6>T_7>T_1>T_0$.

Economic performance

The economic performance of different treatments was evaluated through economic analysis (Table 2). The analysis showed that the highest total cost of production (Tk. 69,370) was obtained from T1 and the lowest one (Tk. 64,570) was obtained from T0 treatment. The analysis also showed that the highest gross income was recorded in T8 (Tk. 95,000) and the lowest one was recorded from the treatment T0 (Tk. 74,800). Net income also varied due to different treatments. The highest BCR (Beneficial cost ratio) was obtained (1.39) from T3 treatment which is similar to T8 treatment and the lowest one (1.15) was obtained from T6 treatment. From the economic analysis the highest CPUP (cost per unit of product) was obtained (9.6) from T1 treatment which is similar to T5 treatment and the lowest one was obtained (8.0) from T3 treatment which is similar to T8 treatment.

Table 2. Economic analysis of BRRI dhan29 as influenced by the application of PU, USG and foliar application of N

Treatments	Total cost	Yield t/ha	Gross income	Net income	BCR	CPUP
T0 [No N application (control)]	64570	3.740	74800	10230	1.16	9.2
T1 [140 kg N/ha (as prilled urea)]	69370	4.100	82000	12630	1.18	9.6
T2 [1.8 g 1-USG (55kg N/ha) + 5 Foliar spray @ 1%N solution]	67210	4.510	90200	22990	1.34	8.3
T3 [1.8 g 1-USG (55 kg N/ha) + 5 Foliar spray @ 1.5% N solution]	67578	4.700	94000	26422	1.39	8.0
T4 [1.8 g 1-USG (55 kg N/ha) + 5 Foliar spray @ 2% N solution/ha i.e. 90 kg N]	67930	4.270	85400	17470	1.24	8.9
T5 [1.8 g 2-USG (110 kg N/ha)]	68410	3.970	79400	10990	1.16	9.6
T6 [2.7 g 1-USG (82 kg N/ha)]	67418	3.900	78000	10582	1.15	9.5
T7 [2.7 g 1-USG (82 kg N/ha) + 3 Foliar spray @ 1%N solution]	76850	4.660	93200	25350	1.37	8.1
T8 [2.7 g 1-USG (82 kg N/ha) + 3 Foliar spray @ 1.5%N solution]	68074	4.750	95000	26926	1.39	8.0
T9 [2.7 g 1-USG (82 kg N/ha) + 3 Foliar spray @ 2%N solution/ha]	68282	4.690	93800	25518	1.37	8.2
T10 [1.8 g 2-USG (55 kg N/ha) + 3 t/ha cowdung]	69242	4.300	86000	16758	1.26	9.1
T11 [2.7 g 1-USG (82 kg N/ha) + 3 t/ha cowdung]	68250	4.367	87200	18950	1.27	8.8

CONCLUSION

The overall results indicated that the highest grain yield of BRRI dhan29 was found in treatment [2.7 g 1-USG (82 kg N/ha) + 3 foliar spray @ 1.5% N solution (13.5g urea/spray)]. This reveals that the deep placement of USG fertilizer with foliar application enhanced the N use efficiency. As a consequence, the grain yield of BRRI dhan29 was increased to significant extent. The treatment also demonstrated the highest gross income followed by with the value of 95,000 (Tk/ha) and lowest value was obtained in with the value of 74,800 (Tk/ha). Therefore, the treatment [2.7 g 1-USG (82 kg N/ha) + 3 foliar spray @ 1.5% N solution/ha (13.5g urea/spray)] i. e. total 219 kg urea/ha can be recommended for successful cultivation of boro rice, BRRI dhan29. This will save an amount of 81 kg urea per rice growing season per hectare.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the Ministry of Science and Technology (MOST-39.009.002.01.00.053. 2014- 015 / BS-36), Peoples Republic of Bangladesh for providing financial support to conduct this research work.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interests regarding the publication of this paper.

REFERENCES

1. Aktar R, 2017. Performance of boro rice (BRRI dhan29) as affected by deep placement and foliar application of urea fertilizer. MS Thesis, Department of Agronomy, Bangladesh Agricultural University, Mymensingh.
2. Alam SS, 2009. Soil and foliar application of nitrogen in Boro rice (BRRI dhan29). MS Thesis, Department of soil science, Bangladesh Agricultural University, Mymensingh.
3. Bautista EU, Suministrado DC and Kokike M, 2000. Mechanical deep placement of fertilizers in puddled soils. Journal of Japanese society of Agricultural Machinery, 62(10): 146-157.
4. BBS (Bangladesh Bureau of statistics) 2011. Statistical Year Book of Bangladesh. Statistical Division, Ministry of planning, Govt. Peoples Republic Bangladesh.
5. BRRI (Bangladesh Rice Research Institute) 2016. Adhunik dhaner chas (In Bengali), published by Bangladesh Rice Research Institute, Joydevpur, Gazipur, 25-26.
6. Rahman MR, Khan MAH, Mahzabin IA, 2017. Efficacy and Economics of Urea Spray Technology for a Locally Discovered Rice Cultivar Haridhan in Bangladesh. American Journal of Plant Biology, 2 (4): 136-141.
7. Sabnam F, 2013. Effect of prilled urea, urea super granule and NPK briquettes under continuous flooded condition on N use efficiency and yield of BR22 rice. MS Thesis, Department of Soil Science, Bangladesh Agricultural University, Mymensingh.
8. Statista, 2018. The Statistical Portal. Downloaded from https://www.statista.com/statistics/255977/total-global-rice-consumption/
9. Stefan S and Stefan A, 1990. Results on the foliar application of urea and liquid fertilizers on rice. Analale Institului de cercetari pentru Cereal is planet Technical, Fundulea pp. 221-229.
10. Vaiyapuri V and Sekharan MV, 2003. Foliar spray of growth hormones and nutrients on growth, yield and nutrient uptake of lowland rice. Journal of Exobiology 15(3): 197-201.
11. Zhu ZL, Wan QX and Fernery JR, 1997. Nitrogen in Soils of China. Kluwer Academic Publishers, Dordrecht.