J. BIOL. ENVIRON. SCI.,
2020, 14(42), 127-135

Original Research Article

Zinc as a Micronutrient It's Foliar and Soil Application Effect on Seed Yield and Quality of Jute Seed

Md. Meftahul Karim[1*], Md. Abdul Alim[1] and Jannatul Ferdush[1]
[1]Bangladesh Jute Research Institute, Dhaka, BANGLADESH

Received: 23.11.2020; Accepted: 09.12.2020; Published Online: 25.12.2020

ABSTRACT

Present study was undertaken to determine the optimum level of zinc fertilizer for yield and quality of jute seed. There were eleven fertilizer levels (T_1: 0 kg ha^{-1} Zn, T_2: 04 kg ha^{-1} Zn as basal, T_3: kg ha^{-1} Zn as basal, T_4: kg ha^{-1} Zn as basal, T_5: kg ha^{-1} Zn as basal, T_6: 12 kg ha^{-1} Zn as basal, T_7: kg ha^{-1} Zn- half as basal and half as foliar in two split, T_8: 06 kg ha^{-1} Zn- half as basal and half as foliar in two split, T_9: 08 kg ha^{-1} Zn- half as basal and half as foliar in two split, T_{10}: 10 kg ha^{-1} Zn- half as basal and half as foliar in two split, T_{11}: 12 kg ha^{-1} Zn- half as basal and half as foliar in two split. Plant population/m^2 (26.83), branches plant^{-1} (3.43) and 1,000 seed weight (2.67g) was maximum in T_6. Capsule plant^{-1} (11.67), capsule length (67.89 mm), seed yield (0.84 ton ha^{-1}) and BCR (1.80) were maximum in T_9. Maximum germination (92.67) and field emergence percentage (86.33) were recorded in T_{10} and seed vigour (36.41%) in T_8. Application of zinc as basal and foliar ensures better seed yield and quality.

Keywords: Jute seed, Zinc, Basal and Foliar application

INTRODUCTION

After cotton jute is the second most important fibre crops in terms of consumption. It is an important cash crop in Bangladesh and India, which together accounts for about 84% of world production of jute fibre (Hossain et al. 2002). In 2015-2016, 1,360,608.12 tons of jute fibre was produced from 677,678 hectares of land that covers about 4.46% of total land area of Bangladesh (BBS 2018). Jute is a completely biodegradable, recyclable and eco-friendly lingo-cellulose fiber (Mir et al. 2008). Jute and jute products not only retard ecological degradation but also conserve green environment and atmosphere as a whole (Ghosh et al. 2013, Mamun et al. 2017). Seed is a basic input for any crop production program, which leads inevitably for agricultural change of a country but Bangladesh has been facing an acute shortage of quality jute seed every year (Hossen et al. 2008). Annual requirement of jute seed in Bangladesh is about 5,500-6,000 tons, of which only 10-15% is produced and distributed by the BADC (Ali et al. 2003). As a result, every year a huge amount of jute seeds are introducing through official and unofficial trades from neighboring country. Unofficial imports of jute seed have no guarantee of its quality and are one of the major causes of low yield (Islam 2009).

For the production of jute seed, late jute seed production technology is well known. In this technology jute seed is sown directly in to the field for the production of seed during mid-August to mid-September and harvested within January of the following year (Alam et al. 2002). Seed yield depends on various yield contributing characters such as plant population, plant height, number of branches/plant, number of capsules/plant, capsule length, number of seeds/capsule and weight of 1,000 seed. The potential of jute seed yield can be improved through effective manipulations of those yield contributing characters, which have positive contribution towards seed yield. Full expression of genetic potentiality depends upon management practices such as fertilization, irrigation, weeding etc. Fertilization is one of the most important management practices because plant growth is directly related to plant nutrition i.e. fertilization. Crop nutrient uptake and crop yields are the principal factors that determine optimal fertilization practices (Ju and Christie 2011). Therefore, it is very important to apply fertilizers in an efficient way to minimize loss and to improve the nutrient use efficiency (Li et al. 2009). Cultivation of high yielding varieties, intensive cropping (Islam et al. 2017), loss of fertile top soil and losses of nutrient through leaching (Rahman et al. 2008, Singh et al. 2011, Somani 2008).At global scale, about one-third of arable soils are deficient in micronutrients, particularly in zinc (Cakmak et al. 2017). As well documented by plant physiologists, zinc exerts a great influence on basic plant life processes, such as (i) nitrogen metabolism – uptake of nitrogen and protein quality; (ii) photosynthesis – chlorophyll

[*] Corresponding author: karimmeftahul@gmail.com

synthesis, carbon anhydrase activity; (iii) resistance to abiotic and biotic stresses – protection against oxidative damage (Alloway 2008, Cakmak, 2008, Yadavi et al. 2014). Zinc is known to have an important role either as a metal component of enzymes or as a functional, structural or regulatory cofactor of a large number of enzymes (Grotz and Guerinot 2006). Zinc also plays an important role in the production of biomass (Kaya and Higgs 2002, Cakmak 2008). Kenbaev and Sade (2002) and Hosseini (2006) reported improvement in yield components for application of zinc. Zinc is involved in biosynthesis of plant hormone, indole acetic acid (IAA), auxin metabolism and is component of variety of enzymes like, carbonic anhydrase, alcohol dehydrogenase, glutamic dehydrogenase *etc*. and plays an important role in enhancing the seed germination and vigor (Boonchuay et al. 2013). Furthermore, zinc may be required for chlorophyll synthesis, pollen function and fertilization (Kaya and Higgs 2002, Pandey et al. 2006, Jenik and Barton 2005, Pandey and Gautam 2009, Reid et al. 2011, Vasconcelos et al. 2011).

Foliar application of Zn reduces the micronutrient deficiencies and it is an efficient method because nutrients are easily absorbed through leaves and is best option to compensate micronutrient deficiencies in shorter period of time under rainfed regions (Nasiri et al. 2010). It was recently documented that zinc foliar application is a simple way for making quick correction of plant nutritional status, as reported for wheat (Erenoglu et al, 2002) and maize (Grzebisz et al. 2008). It is concluded that foliar application of zinc improves lentil productivity (Singh and Bhatt 2013). Therefore, efforts have been made to find the effect on different yield contributing characters and their effectiveness towards seed yield and quality through zinc fertilization. Since there is no sufficient information on interactive effect of soil and foliar applications of zinc on late jute seed production for that reason this experiment has undertaken.

MATERIALS AND METHODS

Experimental site and soil

The experiment was conducted at the research field in Jute Agriculture Experimental Station, Manikganj, during the month of August to December, 2019 in order to study the effect of zinc on morpho-physiology and yield attributes of BJRI Tossa Pat-8.

Table 1. Physio-chemical properties of experimental soil.

Properties	Average content
Soil texture	Silt loam
Soil pH	6.5
Organic matter	1.6%
Total Nitrogen (%)	0.08%
available P	7.65 ppm
K (100g-1)	0.23meq
available S	12.87 ppm

Weather Condition

The weather conditions during the crop growing season, monthly mean minimum, maximum and average temperatures of the field site are presented in fig. 1a. Monthly rainfall of the experiment site is presented in Figure 1b.

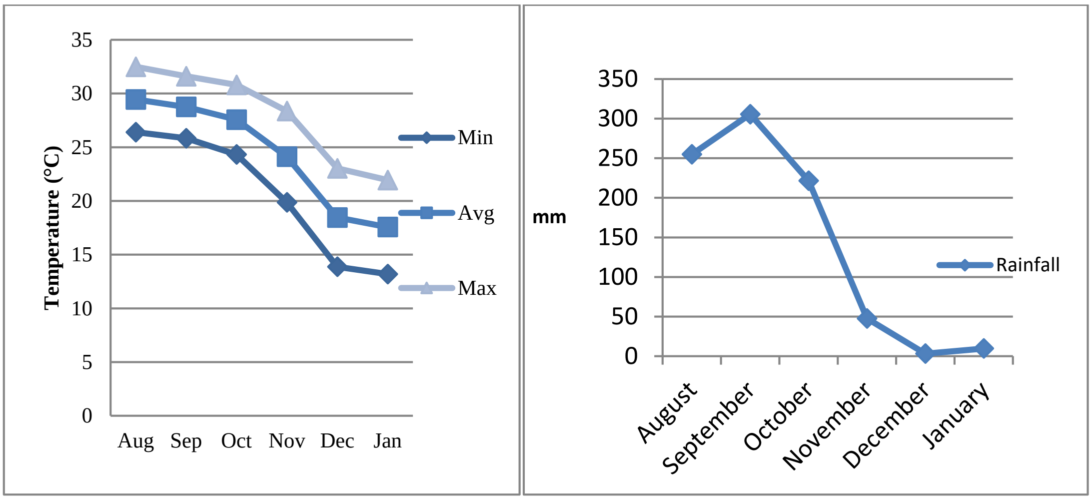

Figure 1. Weather conditions (1a. monthly mean of minimum, maximum and average temperatures and 1b. rainfall) at the field sites in Manikganj, Bangladesh.

Experimental treatments and design

The experiment was conducted with one variety viz., BJRI Tossa Pat-8 and there were eleven different doses of zinc viz., T_1: 0 kg ha^{-1} Zn as control, T_2: 04 kg ha^{-1} Zn as basal, T_3: 06 kg ha^{-1} Zn as basal, T_4: 08 kg ha^{-1} Zn as basal, T_5: 10 kg ha^{-1} Zn as basal, T_6: 12 kg ha^{-1} Zn as basal, T_7: 04 kg ha^{-1} Zn - half as basal and half as foliar in two split, T_8: 06 kg ha^{-1} Zn - half as basal and half as foliar in two split , T_9: 08 kg ha^{-1} Zn - half as basal and half as foliar in two split, T_{10}: 10 Kg ha^{-1} Zn - half as basal and half as foliar in two split, T_{11}: 12 kg ha^{-1} Zn - half as basal and half as foliar in two split. In case of foliar application @ 2% w/v was maintained. The experimental field was prepared with three ploughing and cross ploughing followed by laddering. A randomized complete block design (RCBD) was used for this experiment with three replications. The unit plot size was 3m X 4m. The crop was sown on 11th August, 2019.

The crop was fertilized with urea, triple super phosphate, muriate of potash and boron (100, 200, 100 and 10 kg ha^{-1}, respectively) at final land preparation. Rest of urea (100 kg ha^{-1}) was applied at 45 days after sowing. Zinc fertilizer was applied as per treatment and foliar application of zinc was done in full sunny day. All intercultural operation operations were done as per requirement.

Harvesting and Plant sampling

When the matured seed (about 80% seed matures) of jute turned into blackish in color the plant sample were collected from each plot in treatment wise with proper tagged. Ten randomly selected plants were taken from each plot for getting accurate data. After threshing of capsule, seeds were cleaned and sun dried.

Morpho-physiological characters yield & yield attributes

Morpho-physiological characters namely plant height (m) was measured with the help of scale meter. Morpho-physiological characters were analyzed by standard method. On the other hand yield and yield attributes *viz.* capsule length (mm), capsule plant^{-1}, seeds capsule^{-1}, 1,000 seed weight and seed yield (ton ha^{-1}) were determined by the standard method. Any height, length, number and yield were measured by using the manual count and scale meter.

Seed quality

After threshing, sun dried seed were taken for quality testing with 9% moisture. For germination seeds were surface-sterilized first by a fungicide treatment (1 g L^{-1} Benlate) for 30 min, immersed in 6% calcium hypochlorite solution for 5 min, and then rinsed in 70% ethanol for 5 min and thoroughly washed with sterilized distilled water. Seeds were plated onto glass petri dishes (9 cm in diameter) containing sterile perlite and placed in a growth chamber where the temperature and humidity were 25 °C and 80%, respectively, with a photoperiod of 16 h day^{-1}. Lighting was provided by OSRAM L36W/77 type lamps (FLUORA, white fluorescent tubes) providing an intensity of 1500 µmol h–^{1} photon–^{1}. Each petri dish contained 100 seeds. The parameters of the germination capacity (GC), seed vigour and field emergence were determined by following formulas.

1. Germination capacity (GC): GC (%) = n/N* 100

Here, n is the total number of germinated seeds and N is the total number of tested seeds.

2. Field Emergence (%): FE(%)=n/N* 100

Here, n is the total number of germinated seeds in field condition and N is the total number of tested seeds

3. Vigour test**:**

The test was conduct in laboratory with the same procedure as laboratory standard germination test. Vigour (Vigour value) was calculated following V=a/1+b/2+c/3+…..where V= Vigour value and a, b and c are the number of seed germinated after 1, 2 and 3 days. The final count was made at the end of 6th days.

Statistical analysis
The recoded data on different parameters were statistically analyzed and partitioning the variance with the help of "Statistix 10" software.

Economic analysis
For economic analysis, Jute seed production cost (cost required for land preparation, purchasing of seed, seed sowing, fertilizers application, weeding cost, crop protection measures, irrigation, and harvesting) were added for the evaluation of jute seed production cost with different zinc application method and quantity. Existing average market price (2.38 US$/kg) of jute seed and by product (35.72 US$ t−1) was used to asses gross income (1 USD=84 BDT). Net income was attained by excluding all expenses from gross income; and by dividing gross income with production cost, benefit-cost ratio (BCR) was investigated (Shah et al. 2013).

RESULTS AND DISCUSSION

Plant Population
Maximum plant population (26.83) was recorded in treatments T_6 (12 kg ha^{-1} as basal dose) which was statistically similar to all treatments except T_9 and T_8 (Table 2).

Plant height
The effect of zinc on plant height was insignificant (Table 2). However numerically the maximum plant height (182.87) was recoded in T_9 and minimum (169.78) was in T_2. Munirah et al. (2015) also found that zinc has no effect on plant height. This experiment was conducted at field condition that plant might accumulate somewhat concentration of soil-Zn, therefore the external application of Zn might not affect plant height.

Branch plant^{-1}
Branch plant^{-1} of late jute plant showed significant difference due to application of zinc fertilizer (table 2). Highest branch/plant was (3.43) was found in T_6 treatment which was statistically alike to T_9 and T_{11} treatment and lowest was found in control plot. Use of zinc fertilizer stimulates plant growth and better development of plants, leads to the increase in morphological characters such as branch number this result supported by Shah et al. (2016).

Capsule plant^{-1}

A significant difference was recorded in number of capsule per plant due to application of zinc (table 2). Highest number of capsule per plant (11.67) was recorded in T_9 and lowest (9.03) was found in T_1 and T_3. Capsule number per plant showed maximum response in case of basal and foliar application of zinc. Zinc plays positive role to pollen function and fertilization that ultimately create positive impact on the number of capsule. Salehin and Rahman (2012) showed that zinc spray had a significant effect in 1% probability level on number of capsules per plant of *Phaseolus vulgaris* L. Liu et al. (2016) also stated the same thing.

Capsule length

Capsule length of late jute seed plant was significant due to the application of zinc (Table 2). Numerically maximum capsule length (67.89 mm) was found in T_9 and lowest (62.57 mm) for T4. Length of capsule was increased with the application of zinc by improving cell size or cell number.

Table 2. Comparison among different zinc treatments on growth and yield contributing characters of late jute seed.

Treatment	Plant population/m^2	Plant height (cm)	Branch plant^{-1}	Capsule Plant^{-1}	Capsule Length (mm)
T_1	23.89 ab	176.2 a	2.67 c	9.03 c	64.75 abc
T_2	24.97 ab	169.78 a	2.68 bc	9.2 bc	66.35 abc
T_3	24.33 ab	182.77 a	2.72 bc	9.03 c	66.34 abc
T_4	24.83 ab	170.67 a	2.77 bc	9.17 bc	62.57 c
T_5	25.25 ab	178.20 a	2.77 bc	9.7 bc	64.28 abc
T_6	26.83 ab	178.87 a	3.43 a	10.70 ab	64.90 abc
T_7	25.09 ab	175.07 a	2.83 bc	9.90 bc	66.53 abc
T_8	23.37 b	180.77 a	2.90 bc	9.67 bc	67.64 ab
T_9	23.56 b	182.87 a	3.03 ab	11.67 a	67.89 a
T_{10}	23.89 ab	181.67 a	2.99 bc	10.47 abc	65.06 abc
T_{11}	25.61 ab	181.53 a	3.10 ab	10.33 abc	62.78 bc
CV%	7.08	5.16	8.57	9.58	4.28

T_1: 0 kg ha^{-1} Zn, T_2: 04 kg ha^{-1} Zn as basal, T_3: kg ha^{-1} Zn as basal, T_4: kg ha^{-1} Zn as basal, T_5: kg ha^{-1} Zn as basal, T_6: 12 kg ha^{-1} Zn as basal, T_7: kg ha^{-1} Zn- half as basal and half as foliar in two split, T_8: 06 kg ha^{-1} Zn- half as basal and half as foliar in two split, T_9: 08 kg ha^{-1} Zn- half as basal and half as foliar in two split, T_{10}: 10 kg ha^{-1} Zn- half as basal and half as foliar in two split, T_{11}: 12 kg ha^{-1} Zn- half as basal and half as foliar in two split

Table 3. Comparison among different zinc treatments on seed/capsule, 1000 seed weight and seed yield (t/ha) of late jute seed**.**

Treatment	Seed Capsule^{-1}	1000 seed weight (g)	Seed yield(ton ha^{-1})
T_1	174.27 a	2.20 c	0.68 c
T_2	170.40 a	2.20 c	0.65 c
T_3	178.30 a	2.23 c	0.68 c
T_4	169.40 a	2.45 abc	0.67 c
T_5	175.10 a	2.15 c	0.68 c
T_6	179.97 a	2.67 a	0.79 ab
T_7	180.40 a	2.29 c	0.66 c
T_8	171.90 a	2.63 ab	0.69 c
T_9	184.55 a	2.30 bc	0.84 a
T_{10}	172.33 a	2.29 c	0.73 bc
T_{11}	174.33 a	2.44 abc	0.70 c
CV%	7.14	8.13	7.42

T_1: 0 kg ha^{-1} Zn, T_2: 04 kg ha^{-1} Zn as basal, T_3: kg ha^{-1} Zn as basal, T_4: kg ha^{-1} Zn as basal, T_5: kg ha^{-1} Zn as basal, T_6: 12 kg ha^{-1} Zn as basal, T_7: kg ha^{-1} Zn- half as basal and half as foliar in two split, T_8: 06 kg ha^{-1} Zn- half as basal and half as foliar in two split, T_9: 08 kg ha^{-1} Zn- half as basal and half as foliar in two split, T_{10}: 10 kg ha^{-1} Zn- half as basal and half as foliar in two split, T_{11}: 12 kg ha^{-1} Zn- half as basal and half as foliar in two split

Seed capsule^{-1}

Zinc had no significant effect on number of seed capsule^{-1} (Table 3). However maximum number (184.55) of seed per capsule was recorded in T_9.

Thousand seed weight

1,000 seed weight of jute was significantly different by the application of zinc fertilizer (table 3). Maximum 1,000 seed weight (2.67g) was recorded in T_6 treatment and lowest 1,000 seed weight (2.20) was found in T_1 and T_2.

Seed yield (ton ha^{-1})

Seed yield of late jute seed was significantly influenced by application of zinc (table 3). Highest seed yield (0.84 ton ha^{-1}) was observed in T_9 that is statistically analogous to T_6 treatment. Lowest seed yield (0.65 ton ha^{-1}) was found in T_2. Kaya and Higgs (2002) and Cakmak (2008) reported that zn plays as an activator of several enzymes in plants, and it is directly involved in the biosynthesis of growth substances such as auxin which produces more plant cells and more dry matter that in turn will be stored in seeds as a sink. In T_9 treatment half of the total used zinc (8 kg ha^{-1}) fertilizer used as foliar application. Dunsim et al. (2019) also found similar result. Foliar application of zinc fertilizer increases the efficiency of zinc that is also supported by Umer et al. (1999).

Table 4. Comparison among different zinc treatments on seed quality attributes of late jute seed.

Treatment	Germination (%)	Field emergence (%)	Seed vigour (%)
T_1	81.33 ab	75.33 ab	29.63 bc
T_2	87.00 ab	80.67 ab	30.64 b
T_3	81.33 ab	78.33 ab	27.97 bc
T_4	88.67 ab	82.00 ab	28.93 bc
T_5	84.33 ab	78.00 ab	28.89 bc
T_6	87.00 ab	81.00 ab	30.63 b
T_7	76.67 b	70.33 b	25.40 c
T_8	92.33 a	86.00 a	36.41 a
T_9	90.00 a	84.00 a	32.79 ab
T_{10}	92.67 a	86.33 a	36.36 a
T_{11}	85.67 ab	79.67 ab	32.71 ab
CV (%)	8.94	9.66	7.46

T_1: 0 kg ha^{-1} Zn, T_2: 04 kg ha^{-1} Zn as basal, T_3: kg ha^{-1} Zn as basal, T_4: kg ha^{-1} Zn as basal, T_5: kg ha^{-1} Zn as basal, T_6: 12 kg ha^{-1} Zn as basal, T_7: kg ha^{-1} Zn- half as basal and half as foliar in two split, T_8: 06 kg ha^{-1} Zn- half as basal and half as foliar in two split, T_9: 08 kg ha^{-1} Zn- half as basal and half as foliar in two split, T_{10}: 10 kg ha^{-1} Zn- half as basal and half as foliar in two split, T_{11}: 12 kg ha^{-1} Zn- half as basal and half as foliar in two split

Seed quality

Basal and foliar application of zinc associated with higher germination percentage, field emergence and seed vigour (table 4). Numerically maximum germination percentage was found in T_{10} treatment. Minimum seed germination percentage was found in T_7 treatments. Basal and foliar application of zinc fertilizer were more effective compare to the only basal application that means foliar application ensure better utilization of nutrients similar result also found by previous study on cotton (sawan et al. 2011). Highest field emergence of jute seed was recorded in T_{10} treatment and lowest in T_7 treatment. Maximum seed vigour was found in T_8 treatment and lowest in T_7. Application of zinc ensures better seed germination and seed vigour (Boonchuay et al. 2013).

Economic performance

The economic performance of different treatments is presented in table 5. The highest gross return, net return and BCR (2,157.5 US$ ha−1, 954.80 US$ ha−1 and 1.80, respectively) was recorded in T_9 treatment. The lowest gross return, net return and BCR (1,695.83 US$ ha−1, 548.83 US$ ha−1 and 1.48, respectively) was found in T2 treatment.

Table 5. Cost and return analysis of Jute seed due to application of zinc as basal and foliar.

Treatment	Seed yield (ton ha^{-1})	By product yield (ton ha^{-1})	Gross return (US$ ha−1)	Cost of cultivation (US$ ha−1)	Net return (US$ ha−1)	BCR
T_1	0.68	4.10	1767.26	1135.5	631.76	1.56
T_2	0.65	4.15	1695.83	1147	548.83	1.48
T_3	0.68	4.21	1769.40	1152	617.40	1.54
T_4	0.67	4.25	1747.02	1158.81	588.21	1.51
T_5	0.68	4.35	1774.40	1164.76	609.64	1.52
T_6	0.79	4.41	2027.38	1170.71	856.67	1.73
T_7	0.66	4.31	1725.36	1188.33	537.03	1.45
T_8	0.69	4.36	1798.57	1196.67	601.90	1.50
T_9	0.84	4.41	2157.5	1202.62	954.80	1.79
T_{10}	0.73	4.45	1897.02	1208.57	788.45	1.57
T_{11}	0.70	4.45	1825.60	1214.52	611.08	1.50

T_1: 0 kg ha^{-1} Zn, T_2: 04 kg ha^{-1} Zn as basal, T_3: kg ha^{-1} Zn as basal, T_4: kg ha^{-1} Zn as basal, T_5: kg ha^{-1} Zn as basal, T_6: 12 kg ha^{-1} Zn as basal, T_7: kg ha^{-1} Zn- half as basal and half as foliar in two split, T_8: 06 kg ha^{-1} Zn- half as basal and half as foliar in two split, T_9: 08 kg ha^{-1} Zn- half as basal and half as foliar in two split, T_{10}: 10 kg ha^{-1} Zn- half as basal and half as foliar in two split, T_{11}: 12 kg ha^{-1} Zn- half as basal and half as foliar in two split

CONCLUSIONS

The results of this study suggest that the application of zinc have some positive impact on maximum yield contributing characters that ultimately improve the seed yield. Application of zinc as basal and foliar was more effective compare to only basal application of zinc. Plant received 8 kg ha^{-1} zinc (Half as basal and half as foliar in two split) produced maximum seed yield and BCR for jute seed production. More research is needed to evaluate the potentiality of only foliar zinc fertilizer application, as well as fertilizer nutrient blends, in addition to evaluating application timing. Considering the present soil status, there is greater potential for application of zinc. The challenge is balancing crop Zn demand and timely application of Zn to maximize both uptake and efficiency.

ACKNOWLEDGEMENTS

This study was funded by the Bangladesh Jute Research Institute. We are grateful to the authority of Bangladesh Jute Research Station for their financial and other support. We are also grateful to field staff of Jute Agricultural Research Station Manikganj for their cordial help during field work.

REFERENCES

Alam. M.M., Alam, A.K.M.M., Khandker, S., Gani, M.N., Ahmed, S.A. and Haque, A. (2002). Fertilizer management of late jute seed production in different agro-ecological zones of Bangladesh. Pakistan J. Bio Sci 5:410-412. doi: 10.3923/pjbs.2002.410.412

Ali, S.M., Haque, M.M., Siddique, A.B., Mollah, A.F. and Islam, M.N. (2003). Phenology growth and seed yield of tossa jute (*Corchorus olitorius* L.) in late sown technology. Bangladesh J Agr 27 & 28:91-97.

Alloway, B. (2008). Zinc in soils and crop nutrition. IZA and IFA. Paris.

BBS, (2018). Statistical Yearbook of Bangladesh. Bangladesh Bureau of Statistics. Ministry of Planning and Statistics Division, Govt. of People's Republic of Bangladesh, Dhaka. Pp. 170. Retrived from: http://bbs.portal.gov.bd/sites/default/files..bd/files/bbs.portal.gov.bd/page/a.1d32f13_8553_44f1_92e6_8ff80a4ff82e/Bangladesh%20%20Statistics-2018.pdf

Boonchuay, P., Cakmak, I., Rerkasem, B. and Thai, C.P. (2013). Effect of different growth stages on seed zinc concentration and its impact on seedling vigor in rice. J Soil sci plant nutr 59(2):180-188. doi: 10.1080/00380768.2013.763382.

Cakmak, I. (2008). Enrichment of cereals grains with zinc agronomic or genetic biofortification? Plant soil 302(1):1-17. doi: 10.1007/s11104-007-9466-3.

Cakmak, I., McLaughin, M.J. and White, P. (2017). Zinc for better production and human health. Plant soil 411:1-4. doi: 10.1007/S11104-016-3166-9.

Dunsin, O., Aruna, A.O., Chinedum, C., Suleiman, K.O., Okunlola, F.O., Aremu, C.O., Owolabi I.O. and Olofintoye, T.A.J. 2019. Zinc sulphate and boron-based foliar fertilizer effect on growth, yield, minerals, and heavy metal composition of groundnut (*Arachis hypogaea* L) grown on an alfisol. Int j Agron 2019:1-7. doi: 10.1155/2019/5347870

Erenoglu, B., Nikolic, M., Römhold, V. and Cakmak, I. (2002). Uptake and transport of foliar applied zinc (65Zn) in bread and durum wheat cultivars differing in zinc efficiency. Plant Soil 241(2):251–257.

Ghosh, R.K., Sreewongchai, T., Nakasathien S., and Phumichai, C. (2013). Phenotypic variation and the relationships among jute (*Corchorus* species) genotypes using morpho-agronomic traits and multivariate analysis. Australian J Crop Sci 7(6):830-842.

Grotz, N. and Guerinot, M.L. (2006). Molecular aspects of Cu, Fe and Zn homeostasis in plants. Biochimica et Biophysica Acta (BBA) - Molecular Cell Research 1763: 595–608. doi: 10.1016/j.bbamcr.2006.05.014.

Grzebisz, W., Wrońska, M., Diatta, J.B. and Dullin, P. 2008. Effect of zinc foliar application at early stages of maize growth on patterns of nutrients and dry matter accumulation by the canopy. Part I. Zinc uptake patterns and its redistribution among maize organs. J Elem 13(1): 17–28.

Hossain, M.B., Haque, S. and Khan, H. (2002). DNA Fingerprinting of jute germplasm by RAPD. KSBMB 35:414-419. doi: 10.5483/BMBRep.2002.35.4.414.

Hosseini, S.M. (2006). Zinc- Boron interaction effects on yield, yield components and chemical composition of wheat. The 18th World Congress of Soil Science. Philadelphia, Pennsylvania, USA, 104-107.

Hossen M., Ali, M.S., Begum, M., Khatton, A. and Halim, A. (2008). Study on high yield of quality jute seed production for diversified uses. J Innov Dev Strategy 2:71-73.

Islam, M. (2009). Jute Seed Technology. Bangladesh Jute Research Institute. Pp. 01

Islam. M.F., Islam, M.R., Jahiruddin, M. and Sarmin, T. (2017). Cropping pattern based micronutrient application for wheat-mungbean-T. aman crop sequence under Tista Meander floodplain soil at Rangpur. J Bangladesh Agri Uni 15(2):140–147. doi: 10.3329/jbau.v15i2.35055.

Jenik P.D. and Barton, M.K. (2005). Surge and destroy: The role of auxin in plant embryogenesis. Development 132:3577-3585. doi: 10.1242/dev.01952

Ju, X. and Christie, P. (2011). Calculation of theoretical nitrogen rate for simple nitrogen recommendations in intensive cropping systems: A case study on the North China Plain. Field Crops Res 124:450–458. doi:10.1016/j.fcr.2011.08.002.

Kaya, C. and Higgs, D. (2002). Response of tomato (*Lycopersicon esculentum* L.) cultivars to foliar application of zinc when grown in sand culture at low zinc. Sci Hortic 93: 53–64. doi: 10.1016/S0304-4238(01)00310-7.

Kenbaev B. and B. Sade. (2002). Response of field-grown barley cultivars grown on zincdeficient soil to zinc application. Commun Soil Sci Plant Anal 33(3-4): 533–5544. doi: 10.1081/CSS-120002762.

Li, X., Lu, J., Wu, L. and Chen, F. (2009). The difference of potassium dynamics between yellowish red soil and yellow cinnamon soil under rapeseed (Brassica napus L.)–rice (Oryza sativa L.) rotation. Plant Soil 320: 141–151. doi: 10.1007/s11104-008-9879-7.

Liu, H., Gan, W., Rengel, Z. and Zhao, P. (2016). Effects of zinc fertilizer rate and application method on photosynthetic characteristics and grain yield of summer maize. J Soil Sci Plant Nutr 16 (2):550-562. doi: 10.4067/S0718-95162016005000045.

Mamun, M., Saha, C.K., Mostofa, M.G., Miah, A. and Hossain. M.Z. (2017). Identification of suitable varieties for seed production of jute in non-traditional areas of Bangladesh. Bangladesh J Plant Breed Genet 30(1):33-37.

Mir, R.R., Rustgi, S., Sharma, S., Singh, R., Goyal, A., Kumar, J., Gaur, A., Tyagi, A.K., Khan, H., Sinha, M. K., Balyan, H.S., and Gupta, P.K. (2008). A preliminary genetic analysis of fiber traits and the use of new genomic SSRs for genetic diversity in jute. Euphytica, 161:413-42. doi: 10.1007/s10681-007-9597-x.

Munirah, N., Khairi, M., Nozulaidi, M. and Jahan, S. (2015). The Effects of zinc application on physiology and production of corn plants. Aust J Basic & App Sci 9(2):362-367.

Nasiri, Y., Zehtab-Salmasi, S., Nasrullahzadeh, S., Najafi, N. and Ghassemi-Golezani, K. (2010). Effects of foliar application of micronutrients (Fe and Zn) on flower yield and essential oil of chamomile (*Matricaria chamomilla* L.). J Med Plants Res 4:1733-1737. doi: 10.5897/JMPR10.083.

Pandey S.N. and Gautam, S. (2009). Effects of zinc supply on its uptake, growth and biochemical constituents in lentil. Indian J Plant Physio 14(1): 67-70.

Pandey, N., Pathak, G.C. and Sharma, C.P. (2006). Zinc is critically required for pollen function and fertilisation in lentil. J Trace Elem Med Bio 20: 89–96. doi: 10.1016/j.jtemb.2005.09.006.

Rahman, M.T., Jahiruddin, M., Humauan, M.R., Alam M.J. and Khan. A.A. (2008). Effect of sulphur and zinc on growth, yield and nutrient uptake of boro rice (Cv. Brridhan 29). J Soil Nat 2:10-15.

Reid, D.E., Ferguson, B.J., Hayashi, S., Lin, Y.H. and Gresshoff, P.M. (2011). Molecular mechanisms controlling legume autoregulation of nodulation. Ann Bot 108(5):789-795. doi: 10.1093/aob/mcr205.

Salehin, F. and Rahman, S. (2012). Effects of zinc and nitrogen fertilizer and their application method on yield and yield components of *Phaseolus vulgaris* L. Agric Sci 3(1):9-13. doi: 10.4236/as.2012.31003.

Sawan. Z.M., Ashraf, H., Fahmy and Yousef, S.E. (2011). Effect of potassium, zinc and phosphorus on seed yield, seed viability and seedling vigor of cotton (*Gossypium barbadense* L.), Arc Agron Soil Sci 57:1, 75-90, doi: 10.1080/03650340903222328.

Shah, M.A., Manaf, A., Hussain, M., Farooq S. and Hye. M.Z.U. (2013). Sulphur fertilization improves the sesame productivity and economic returns under rain-fed conditions. Int J Agric Biol 15:1301–1306.

Shah, S. T., Ullah, S., Khan, N., Sajid, M., Rab, A., Amin, N.U., Iqbal, A., Naeem, A., Iqbal, M., Haq, S.U., Rahman, S., Shah F.A. and Rawan. S. (2016). Effect of zinc as a foliar spray on growth and flower production of Marigold (*Tagetes erecta L.*). Pure Appl Biol 5(4):738-743. doi:10.19045/bspab.2016.50092.

Singh, A.K. and Bhatt, B.P. (2013). Effects of foliar application of zinc on growth and seed yield of late-sown lentil (*Lens culinaris).* Indian J Agric Sci 86(6):622–626.

Singh, A. K., M. K. Meena and R. C. Bharati. (2011). Sulphur and zinc nutrient management in rice-lentil cropping system. International Conference on "Life Science Research for Rural and Agricultural Development" (pp: 66-67). 27-29 December, 2011, CPRS Patna (Bihar).

Somani, L. L. (2008). Micronutrients for soil and plant health Agrotech Publishing Academy 74 pp.

Umer, S., Bansal, S.K., Imas P. and Magen, H. (1999). Effect of foliar fertilization of potassium on yield, quality and nutrient uptake of groundnut. J Plant Nutr 22:1785-1795. doi: 10.1080/01904169909365754.

Vasconcelos, A.C.F., Nascimento, C.W.A. and Filho, F.C. (2011). Distribution of zinc in maize plants as a function of soil and foliar Zn supply. Int Res J Agri Sci Soil Sci 1(1).1–5.

Yadavi, A., Aboueshaghi, R.S., Dehnavi, M.M. and Balouchi, H. (2014). Effect of micronutrıents foliar application on grain qualitative characteristics and some physiological traits of bean (*Phaseolus vulgaris* L.) under drought stress. Indian J. Fund. Appl. Life Sci., 4:124-131.