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Effect of boron and zinc application on growth, seed yield and seed quality of water spinach (*Ipomoea reptans* Poir.) under terai region of West Bengal

R. K. Sarkar*, J. C. Jana[1] and S. Datta[1]

Regional Research Sub-Station (Terai Zone), Uttar Banga Krishi Viswavidyalaya, Kharibari, Darjeeling – 734427, (West Bengal), INDIA
[1]Department of Vegetable and Spice Crops, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar – 736165, (West Bengal), INDIA
*Corresponding author. E-mail: sarkar_ram@rediffmail.com

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Abstract: The field experiment was conducted at the Instructional Farm, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal to study the effect of boron and zinc application on growth, seed yield and its quality of water spinach (*Ipomoea reptans* Poir.). The study consisted of borax @ 0 (B_0), 25 kg/ha through soil (B_1) and 1.5 g/litre twice through foliar sprays at 15 days interval (B_2) and $ZnSO_4$ @ 0 (Zn_0), 15 kg/ha through soil (Zn_1) and 1.5 g/litre twice foliar sprays at 15 days interval (Zn_2) and their nine treatment combinations (viz. B_0 Zn_0, B_1 Zn_0, B_2 Zn_0, B_0Zn_1, B_1 Zn_1, B_2 Zn_1, B_0Zn_2, B_1 Zn_2 and B_2 Zn_2. The results revealed that application of boron and zinc at all rates alone and as combinations markedly influenced all growth, seed yield and its quality parameters as compared with the control. Soil application of borax @ 25 kg/ha and $ZnSO_4$ @ 15 kg/ha alone and as combination recorded maximum number of flowers/hill (282.6, 275.1 & 311.5), number of capsules/hill (238.2, 220.7 & 257.8), seed yield (1.22 t/ha, 1.21 t/ha & 1.32 t/ha), shelling percentage (67.14%, 67.06% & 68.76%), 1000 seed weight (38.05 g, 38.25 g & 41.16 g), germination percentage (86.6%, 86.3% & 90.0%), seedling vigour index (6.20, 6.26 & 6.63) and seedling growth rate (0.123, 0.123 and 0.127 g/plant/day), respectively over control. Maximum vine length, number of nodes per plant, average internode length and chlorophyll content of leaf were found in twice foliar sprays of borax @ 1.5 g/litre (B_2) and twice foliar sprays of $ZnSO_4$ @ 1.5 g/litre (Zn_2) individually as well as their combination (B_2Zn_2). Considering the benefit : cost ratio (B: C ratio), combination of both soil application of borax @ 25 kg/ha and $ZnSO_4$ @ 15 kg/ha (B_1Zn_1) was found most economical (2.60).

Keywords: Growth, *Lpomoea reptans*, Boron, Zinc, Seed yield, Seed quality, Water spinach

INTRODUCTION

Water spinach (*Ipomoea reptans* Poir.) also named as water convolvulus, swamp cabbage, etc. is of East Indian or Chinese origin (Edie and Ho, 1969) and a member of the convolvulaceae (morning glory) family. It is an under-exploited herbaceous perennial, aquatic and semi aquatic leafy vegetable of the tropics and subtropics. The edible portion contain up to 29% crude protein on a dry matter basis (Thacker, 1990). According to Oomen and Grubben (1978) and Naren Tung *et al.* (1994), water spinach is also rich sources of minerals and vitamins, being especially rich in vitamins A (carotene 2.9 g/100 g edible portion), B_1, B_2 and C (45 mg/100 g edible portion) and in iron. Among the different minerals, it contains appreciable quantity of Zn (5.03 mg/kg), Mn (22.2 mg/kg), Cu (1.37 mg/kg) and Fe, (75.3 mg/kg) (NIAH, 1995). There are two main cultivar groups of var. *aquatica* and var. *reptans*. The first is an aquatic plant, propagated by cuttings and growing in the wild or cultivated in the fish ponds and water courses. The second is an upland vegetable, cultivated on dry or marshy land and propagated by seeds or cuttings. Both are important market vegetable in India, Malaysia, Indonesia, Pakistan, Bangladesh, Nepal and other South East Asian countries. (Palada and Crossman, 1998). A white flower is produced which matures into a four seeded pod. Flowering occurs under short day condition. The cultivation of upland water spinach (*Ipomoea reptans* Poir.) is limited due to non-availability of good quality seeds to the farmers. It has been reported that boron significantly plays a vital role in pollination, formation of fruits and seeds, movement of nitrogen, phosphorus, starches, sugar translocation, carbohydrate metabolism, indole acetic acid (IAA) metabolism, etc. (Parr and Loughman, 1983). Similarly zinc plays an essential role in plant physiology where it activates some of enzymes and related to metabolism of carbohydrates, auxins, RNA and ribosome functions. The soil application of borax (10 kg/ha) to radish crop increased the plant height (151.71 cm) and number of branches per plant (12.78) in radish compared to no boron application (142.84 cm and 10.74, respectively) (Sharma *et al.*, 1999). Yang *et*

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al. (2009) studied on the effects of boron (B), molybdenum (Mo), zinc (Zn) and their interactions on seed yield and yield formation of rapeseed (*Brassica napus* L. var. Huashuang 4). Results showed that application of B fertilizer to a sandy soil increased the seed yield by 46.1% compared to the control. The effect of single or combined foliar application of 0.1% and 0.2% boron and 0.2% and 0.4% zinc on the yield and yield components of fennel were determined by Sharangi *et al.* (2002) in a field experiment conducted in Nadia, West Bengal, India during winter season of 2000-02. Spraying with 0.2% Zn resulted in highest values for plant height and number of umbels per plant, whereas spraying with 0.1% B resulted in the highest number of umbellets and seeds per umbel, 1000 seed weight, seed yield and essential oil content. However, information regarding the role of boron and zinc on growth, seed yield and seed quality of water spinach (*Ipomoea reptans* Poir.) is quite scanty. Hence, the recent investigation aims to study the effect of boron and zinc application as well as their combinations on growth, seed yield and its quality of water spinach.

MATERIALS AND METHODS

The present experiment was conducted during *kharif* seasons of 2007-08 and 2008-09 at the Instructional Farm of Uttar Banga Krishi Viswavidyalaya in terai region of West Bengal. The experimental field was medium low, sandy loam in texture, acidic in nature and low fertility status with a soil pH of 5.95. The climate is sub-tropical humid in nature with distinctive characteristics of high rainfall, high humidity and a prolonged winter. The sowing of seed was done directly in the field in 1^{st} week of June and plot size was 4.5 m^2 with spacing of 30 cm x 15 cm. Well rotten farmyard manure @ 20 tonnes per ha was applied as basal at the time of land preparation. Inorganic fertilizers were applied @ 100 : 60 : 80 @ N : P_2O_5 : K_2O kg/ha. Full dose of P_2O_5 as single super phosphate and full dose of K_2O as muriate of potash were given as basal at time of land preparation. Nitrogen fertilizer as urea was given in four equal splits. One-fourth nitrogen (¼th) was applied as basal at the time of land preparation and another $^3/_4{}^{th}$ of nitrogen in three equal splits as top dressing at one month interval. Borax as a source of boron and $ZnSO_4$ as a source of zinc were applied accordingly with the treatment combinations. The experiment was conducted with upland water spinach (*Ipomoea reptans* Poir.) with its locally collected genotype named as *Danga Kalmi Sag*.

The experiment was comprised of three levels of boron (B_0, no application of borax; B_1, soil application of borax @ 25 kg/ha and B_2, foliar sprays of borax @1.5 g/litre twice at 15 days interval) and three zinc levels (Zn_0, no application of $ZnSO_4$; Zn_1, soil application of $ZnSO_4$ @ 15 kg/ha and Zn_2, foliar sprays of $ZnSO_4$ @1.5 g/litre twice at 15 days interval) and their nine combinations (viz. B_0Zn_0, B_1Zn_0, B_2Zn_0, B_0Zn_1, B_1Zn_1, B_2Zn_1, B_0Zn_2, B_1Zn_2 and B_2Zn_2. The experiment was conducted in factorial randomized block design with three replications. Different growth, seed yield and seed quality parameters were recorded from 10 randomly selected plants from each plot.

Flowering generally starts when the day become shorter and average temperature gradually goes down from October (average max. temperature 28.9^{0}C and min. 14.1^{0}C) and seed sets in December (average max. 25.1^{0}C & min. 11.4^{0}C). Harvesting of fruits was done in the month of middle of February when fruits started showing signs of turning yellow colour. The harvested fruits were kept plot wise on threshing floor for few days for complete drying. Then threshing was done by rubbing the fruits with wooden stick on the floor. Seeds were cleaned and dried in well ventilated shady room for few days to reduce the moisture. The grains from each plot in all the cases were sun dried, cleaned thoroughly and weighted in kilogram per plot. Seed yield per plot was converted to tonnes per hectare. Chlorophyll content of green leaves was recorded at time flowering by Chlorophyll Meter (SPAD-502). Different seed testing parameters like shelling percentage, test weight, germination percentage, seedling vigour index (SVI) and seedling growth rate were calculated. The statistical analysis of data was done as per method suggested by Gomez and Gomez (1984). The cost of production and gross return was estimated on the basis of price fixed by Government of West Bengal to work out the economics of water spinach cultivation in terai region of West Bengal.

RESULTS AND DISCUSSION

Growth and physiological parameters: There was positive effects of boron and zinc application with different doses recorded on growth parameters i.e. vine length, number of nodes per plant, average internode length, days to 50 percent flower induction and days to fruit harvest of upland water spinach. Data presented in Table 1 revealed that maximum vine length (47.53 cm), number of nodes/plant (22.95) and average internode length (2.11 cm) were recorded in B_2 (foliar sprays of borax @ 1.5 g/litre twice at 15 days interval) which was statistically *at par* with B_1 (soil application of borax @ 25 kg/ha). Highest vine length (47.67 cm), no. of nodes/plant (23.22) and average internode length (2.12 cm) were recorded in Zn_2 (foliar sprays of $ZnSO_4$ @ 1.5 g/litre twice at 15 days interval), which was statistically *at par* with Zn_1 (soil application of $ZnSO_4$ @ 15 kg/ha). The interactions between boron with zinc were also noticed significant in increasing in these characters. Significantly maximum vine length (49.19 cm), no. of nodes/plant (23.89) and average internode length (2.18 cm) were obtained in combination of B_2Zn_2 (foliar sprays of borax @ 1.5 g/litre twice at 15 days interval and foliar sprays of $ZnSO_4$ @ 1.5 g/

litre twice at 15 days interval) which was statistically *at par* with B_1Zn_2 (soil application of borax @ 25 kg/ha along with foliar sprays of $ZnSO_4$ @ 1.5 g/litre twice at 15 days interval) and B_2Zn_1 (foliar sprays of borax @ 1.5 g/litre twice at 15 days interval along with soil application of $ZnSO_4$ @ 15 kg/ha). Plants under control plots (B_0Zn_0) recorded minimum value in all these attributes. Sharangi *et al.* (2002) in a field experiment in Nadia, West Bengal, India with single or combined foliar application of 0.1 and 0.2% boron and 0.2 and 0.4% zinc on the yield and yield components of fennel reported that spraying with 0.2% Zn resulted in highest values for plant height and number of umbels per plant, whereas spraying with 0.1% B resulted in the highest number of umbellets and seeds per umbel. The soil application of borax (10 kg/ha) to radish crop increased the plant height (151.71 cm) and number of branches per plant (12.78) in radish compared to no boron application (142.84 cm and 10.74, respectively) (Sharma *et al.*, 1999). These findings were in good connection with the results of present findings.

Days to 50% flower flowering and days to fruit harvest were increased significantly due to application of boron and zinc over control. It is therefore, earliest 50% flowering (113.5 days) was recorded in control treatments, whereas, highest period for 50% flowering (126.3 days) and fruit harvest (244.4 days) were recorded by foliar sprays of borax @ 1.5 g/litre twice at 15 days interval (B_2). In case of zinc treatment, highest period for 50% flowering (125.7 days) and fruit harvest (242.9 days) were recorded by foliar sprays of $ZnSO_4$ @ 1.5 g/litre twice at 15 days interval (Zn_2). This increase in both flowering and fruit harvest might be due to enhancement in vegetative growth phase by foliar application of both micronutrients. The period for 50% flowering increased with the application of B_2 (foliar sprays of borax @ 1.5 g/litre twice at 15 days interval) and Zn_2 (foliar sprays of $ZnSO_4$ @ 1.5 g/litre twice at 15 days interval) were 12.8 and 11.3 days, respectively over control. Among interactions between boron and zinc, B_2Zn_2 (foliar sprays of borax @ 1.5 g/litre twice at 15 days interval and foliar sprays of $ZnSO_4$ @ 1.5 g/litre twice at 15 days interval) significantly increased the period for 50% flowering as well as fruit harvest.

Results obtained on leaf chlorophyll of water spinach varied significantly due to application of both boron and zinc. Significantly highest values (44.54 SPAD-502) of leaf chlorophyll was observed in foliar sprays of borax @ 1.5 g/litre twice at 15 days interval (B_2) which was statistically *at par* with soil application of borax @ 25 kg/ha (B_1). In case of zinc, significantly maximum leaf chlorophyll content (44.41 SPAD-502) was recorded in foliar sprays of $ZnSO_4$ @ 1.5 g/litre twice at 15 days interval (Zn_2) which was statistically *at par* with soil application of $ZnSO_4$ @ 15 kg/ha (Zn_1). The increase in leaf chlorophyll might be due to the involvement of boron and zinc in protein synthesis which resulted more chlorophyll synthesis in water spinach leaf. Among interactions, maximum leaf chlorophyll (46.16 SPAD-502) was found in B_2Zn_2 (foliar sprays of borax @ 1.5 g/litre twice at 15 days interval and foliar sprays of $ZnSO_4$ @ 1.5 g/litre twice at 15 days interval).

The seed yield parameters including number of flowers and number of capsules per hill responded linearly under different doses of boron and zinc (Table 2). Both micronutrient applications significantly increased seed yield traits over control. The results indicated that number of flowers per hill varied between 200.2 to 282.6 for boron and 215.4 to 275.1 for zinc application. Significantly highest number of flowers/hill (282.6) and number of capsules/hill (238.2) were produced in B_1 (soil application of borax @ 25 kg/ha), while, least number of flowers/hill (200.2) and number of capsules/hill (163.1) in control (B_0). The highest number of flowers/hill (275.1) and number of capsules/hill (220.7) were produced in Zn_1 (soil application of $ZnSO_4$ @ 15 kg/ha) and lowest number of flowers/hill (215.4) and number of capsules/hill (189.3) in control (Zn_0). The percent increase due to B_1 (soil application of borax @ 25 kg/ha) and Zn_1 (soil application of $ZnSO_4$ @ 15 kg/ha) were 41.16% & 27.72% in number of flowers/hill and 46.05% & 16.59% in number of capsules/hill, respectively over control treatments. The interaction between boron and zinc also had the positive influence on these yield attributes. These were found to be maximum (311.5 & 257.8) in combination of soil application of borax @ 25 kg/ha with $ZnSO_4$ @ 15 kg/ha (B_1Zn_1). It was followed by B_1Zn_2, B_2Zn_1 and B_2Zn_2 treatment combinations. The best treatment combination B_1Zn_1 was recorded 91.93% and 79.90% higher number of flowers/hill and number of capsules/hill, respectively over control (B_0Zn_0). Higher number of flowers per hill was recorded by boron and zinc application might be due to the fact that these micronutrients had direct activities in pollen formation, pollen tube development as well as in protein synthesis which resulted more flower production. The effect of single or combined foliar application of 0.1 and 0.2% boron and 0.2 and 0.4% zinc on the yield and yield components of fennel were studied by Sharangi *et al.* (2002) in a field experiment recorded that spraying with 0.2% Zn resulted in highest values number of umbels per plant, whereas spraying with 0.1% B resulted in the highest number of umbellets and seeds per umbel. Chatterjee and Bandyopadhyay (2015) reported that combined use of seed treatment with molybdenum (0.5 g/kg seed) and biofertilizers along with foliar spray of boron at 4 weeks of planting significantly enhanced the growth and yield attributes of cowpea and registered 42% and 54% improvement in number of pod and pod yield/plant respectively over control.

Seed yield: The seed yield ranged between 0.83 to 1.32 t/ha (Table 2). With regard to seed yield is concerned, significantly maximum seed yield of 1.22 t/ ha and 1.21 t/ha were recorded under soil application of borax 25 kg/ha (B_1) and soil application of $ZnSO_4$ @ 15 kg/ha (Zn_1), respectively. The combined application of B_1 and Zn_1 recorded maximum seed yield (1.32 t/ha) which was statistically *at par* with B_2Zn_1 (1.27 t/ha) and B_1Zn_1 (1.25 t/ha). The percent increase in seed yield of water spinach was 27.08 and 26.04 in B_1 and Zn_1 treatments, respectively over control. Furthermore, the superior combination (B_1Zn_1) produced about 59.04% higher seed yield over control (B_0Zn_0). A field experiment was carried out by Halder *et al.* (2007) to evaluate the effect of boron on the yield of mustard with four varieties viz., BARI Sharisha-6, 7, 8 and 9 and four levels each of boron (0, 1.0, 1.5 and 2.0 kg ha^{-1}). Results revealed that BARI Sharisha-6 integrated with 1.5 kg B ha^{-1} was found to be superior to all other treatments combinations. The highest mean seed yield (1.96 t ha^{-1}) was recorded with the said treatment by 25.64% yield increase. On the other hand, boron @ 1.5 kg $^{-1}$ individually increased the highest seed yield by 58.83% over control (B_0). However, from regression analysis, a positive but quadratic relationship was observed between seed yield and boron levels. Sharangi *et al.* (2002) in a field experiment conducted on fennel showed that spraying with 0.2% Zn resulted in highest values for plant height and number of umbels per plant, whereas spraying with 0.1% B resulted in the highest seeds per umbel, 1000 seed weight, seed yield. A field experiment was conducted by Sharma *et al.* (1999) with four levels of boron (0, 10 and 20 kg borax per hectare in soil and a foliar spray of 0.1% boric acid) and three levels of zinc (0 and 10 kg $ZnSO_4$ per hectare in soil and a foliar application of 0.1% $ZnSO_4$) to study the growth, yield and seed quality of radish cv. Japanese White. The foliar spray of 0.1% boric acid and an application of 10 kg $ZnSO_4$ per hectare in soil application were found most effective for increasing pods per plant, diameter of the main shoot and seed yield. Wen *et al.* (2009) reported boron increased seed yield by 22-35%, the number of pods per raceme by 100%, the number of seeds per pod by 41-52% in alfalfa. Zeidan *et al.* (2010) also reported that application of Zn, Fe and Mn significantly increased grain yield and yield components of wheat.

Seed quality parameters: The depicted data in Table 2 revealed that all seed quality parameters of water spinach were significantly affected by all the experimental treatments. It was found that all seed quality attributes were linearly increased with application of both the micronutrients individually and also due to their interactions over control treatments. Soil application of borax @ 25 kg/ha and $ZnSO_4$ @ 15 kg/ha alone recorded maximum shelling percentage (67.14% and 67.06%, respectively), 1000 seed weight (38.05 g and 38.25 g, respectively), germination percentage (86.6% & 86.3%, respectively), seedling vigour index (SVI) (6.20 and 6.26, respectively) and seedling growth rate (0.123 and 0.123 g/plant/day, respectively) over control. Boron is essential for development and growth of new cells in the plant meristem and it plays a vital role in pollination, formation of fruit and seeds, movement of nitrogen, phosphorus, starches, etc in different crops (Lewis, 1980). Application of zinc helped for the development of plant height and number of umbels per plant in fennel. Similarly in this experiment, application of boron and zinc enhanced vegetative and seed quality characters. Among the interactions, soil application of borax @ 25 kg/ha with $ZnSO_4$ @ 15 kg/ha (B_1Zn_1) recorded maximum shelling percentage (68.76%), 1000 seed weight (41.16 g), germination percentage (90.0%), seedling vigour index (6.63) and seedling growth rate (0.127 g/plant/day). The values in all seed quality attributes recorded due to B_1Zn_1 treatment combination was statistically *at par* with B_1Zn_2, B_2Zn_1 and B_2Zn_2 treatment combinations, whereas, control treatment recorded minimum values of all these quality parameters of water spinach. Improvement in seed quality due to B_1Zn_1 combination was 9.98% in shelling, 57.94% in 1000 seed weight, 21.46% in germination, 24.62% in SVI and 17.59% in seedling growth rate, higher over control (B_0Zn_0). Superiority in all seed quality parameters due to application of these two micronutrients might be due to the fact that they helped in more protein synthesis, boldness of seeds etc. The increase in seed weight might be due to better mineral utilization of plants accompanied with enhancement of photosynthesis, other metabolic activity and greater diversion of food material to seed (Naga Sivaiah *et al.* 2013). Christos (2006) reported that foliar application with B improved seed germination percentage and increased seed vigor in alfalfa which was increased by 27% in 2003 and up to 19% in 2004 compared with the untreated control. Sharangi *et al.* (2002) in a field experiment conducted on fennel showed that spraying with 0.2% Zn resulted in highest values for plant height and number of umbels per plant, whereas spraying with 0.1% B resulted in the highest seeds per umbel, 1000 seed weight, seed yield and essential oil content. Sharma *et al.* (1999) conducted a field experiment with four levels of boron (0, 10 and 20 kg borax per hectare in soil and a foliar spray of 0.1% boric acid) and three levels of zinc (0 and 10 kg $ZnSO_4$ per hectare in soil and a foliar application of 0.1% $ZnSO_4$) to study the growth, yield and seed quality of radish cv. Japanese White. The foliar spray of 0.1% boric acid and an application of 10 kg $ZnSO_4$ per hectare in soil application were found most effective for increasing

1000 seed weight and germination percentage. The increase in seed quality parameters may be due to the participation of micronutrients (Zn, Fe, Cu and Mn) in catalytic activity and breakdown of complex substances into simple forms like glucose, amino acids and fatty acids. These in turn were reflected on enhanced germination, elongation of root and shoot of coriander seedlings (Santosh, 2012). Sinta *et al.* (2015) in a study reported the need for application of micronutrients (Zn, Fe, Cu and Mn) in maximum realization of yield and quality of coriander seed crops in calcareous soils.

Economic evaluation: The economics of water spinach seed production with varied boron and zinc application doses showed variations among treatment combinations on gross return, net return and benefit cost ratio (BCR) (Table 3). The treatment combination B_1Zn_1 recorded maximum gross return (Rs. 1,45,200.00), net return (Rs. 89,305.00) and B:C ratio of 2.60 with a cost of cultivation of Rs. 55,895.00 followed by combination B_2Zn_1 and B_1Zn_2 combination with B:C ratio of 2.58 (cost of cultivation of Rs. 54,110.00) and 2.54 (cost of cultivation of Rs. 54,239.00), respectively, while, combination B_0Zn_0 (control) recorded lowest gross return (Rs. 91,300.00) and net return (Rs. 39,080.00) and B:C ratio of 1.75.

Conclusion

From the above discussion considering all the parameters (growth, yield and quality) including economics of production it may be concluded that the combination of soil application of borax @ 25 kg/ha along with soil application of $ZnSO_4$ @ 15 kg/ha was noticed to be superior amongst all other remaining treatment combinations and that may be adopted for its commercial cultivation in medium to upland situation

Table 1. Effect of boron and zinc application on growth parameter and physiological parameters of water spinach (pooled).

Treatment	Vine length (cm)	No. of nodes / plant	Avg. internode length (cm)	Days to 50% flowering	Days to fruit harvest	Chlorophyll content (SPAD 502)
Boron application						
B_0	45.55	21.60	2.00	113.5	230.7	40.79
B_1	47.15	22.31	2.06	122.5	240.9	43.71
B_2	47.53	22.95	2.11	126.3	244.4	44.54
S. Em±	0.30	0.32	0.02	0.51	0.45	0.42
C.D. at 5%	0.87	0.93	0.05	1.45	1.27	1.20
Zinc application						
Zn_0	45.47	21.37	1.97	114.4	233.9	40.78
Zn_1	47.09	22.27	2.08	122.2	239.1	43.86
Zn_2	47.67	23.22	2.12	125.7	242.9	44.41
S. Em±	0.30	0.32	0.02	0.51	0.45	0.42
C.D. at 5%	0.87	0.93	0.05	1.45	1.27	1.20
Interaction (B x Zn)						
$B_0 Zn_0$	44.92	20.78	1.91	108.80	226.10	28.53
$B_1 Zn_0$	45.93	21.52	1.97	114.90	235.90	41.73
$B_2 Zn_0$	45.56	21.80	2.03	119.40	239.70	42.07
B_0Zn_1	45.85	21.62	2.04	113.00	231.30	42.03
$B_1 Zn_1$	47.58	22.04	2.09	125.10	241.80	44.15
$B_2 Zn_1$	47.85	23.16	2.11	128.60	244.30	45.40
B_0Zn_2	45.87	22.40	2.05	118.60	234.60	41.82
$B_1 Zn_2$	47.95	23.38	2.13	127.60	245.00	45.25
$B_2 Zn_2$	49.19	23.89	2.18	131.00	249.20	46.16
S. Em±	0.53	0.56	0.03	0.88	0.77	0.73
C.D. at 5%	1.50	1.60	0.09	2.52	2.20	2.08

S. Em-Standard Error of the Mean; CD-Critical Difference, Treatments: B_0, no boron application; B_1, soil application of borax @ 25 kg/ha; B_2, foliar sprays of borax @ 1.5 g/litre twice at 15 days interval and Zn_0, no zinc application; Zn_1, soil application of $ZnSO_4$ @ 15 kg/ha, Zn_2, foliar sprays of $ZnSO_4$ @ 1.5 g/litre twice at 15 days interval.

Table 2. Effect of boron and zinc application on seed yield and seed quality parameters of water spinach (pooled).

Treatment	No. of flowers / hill	No. of cap-sules /hill	Seed yield (t/ha)	Shelling percentage (%)	1000 seed weight (g)	Germination percentage (%)	Seedling vigour index	Seedling growth rate
Boron								
B_0	200.2	163.1	0.96	63.76	30.85	78.1 (8.84)	5.55	0.113
B_1	282.6	238.2	1.22	67.14	38.05	86.6 (9.31)	6.20	0.123
B_2	268.2	218.6	1.16	66.08	37.23	84.0 (9.17)	5.95	0.121
S. Em±	0.65	0.77	0.01	0.42	0.46	0.58	0.06	0.001
C.D. at 5%	1.86	2.20	0.04	1.20	1.30	2.67	0.17	0.002
Zinc								
Zn_0	215.4	189.3	0.96	63.93	30.56	78.4 (8.85)	5.53	0.114
Zn_1	275.1	220.7	1.21	67.06	38.25	86.3 (9.29)	6.26	0.123
Zn_2	260.5	209.9	1.15	65.98	37.32	83.9 (9.16)	5.91	0.121
S. Em±	0.65	0.77	0.01	0.42	0.46	0.58	0.06	0.001
C.D. at 5%	1.86	2.20	0.04	1.20	1.30	2.67	0.17	0.002
Interaction (B x Zn)								
$B_0 Zn_0$	162.30	143.30	0.83	62.52	26.06	74.10	5.32	0.108
$B_1 Zn_0$	247.90	221.70	1.05	64.85	33.03	52.20	5.67	0.117
$B_2 Zn_0$	235.90	202.90	1.00	64.43	32.60	78.80	5.59	0.116
B_0Zn_1	227.90	177.20	1.04	64.80	34.02	80.60	5.76	0.116
$B_1 Zn_1$	311.50	257.80	1.32	68.76	41.16	90.00	6.63	0.127
$B_2 Zn_1$	286.00	227.20	1.27	67.62	39.58	88.50	6.40	0.125
B_0Zn_2	210.30	168.70	1.01	63.96	32.47	79.60	5.56	0.114
$B_1 Zn_2$	288.40	235.20	1.25	67.81	39.97	87.50	6.29	0.125
$B_2 Zn_2$	282.80	225.70	1.20	66.18	39.52	84.70	5.87	0.123
S. Em±	1.12	1.34	0.02	0.73	0.79	1.01	0.10	0.001
C.D. at 5%	3.21	3.82	0.07	2.61	2.26	3.89	0.34	0.004

S. Em-Standard Error of the Mean; CD-Critical Difference, Treatments: B_0, no boron application; B_1, soil application of borax @ 25 kg/ha; B_2, foliar sprays of borax @ 1.5 g/litre twice at 15 days interval and Zn_0, no zinc application; Zn_1, soil application of $ZnSO_4$ @ 15 kg/ha, Zn_2, foliar sprays of $ZnSO_4$ @ 1.5 g/litre twice at 15 days interval. *-Figures in the parenthesis indicate square root transformed values.

Table 3. Economics of water spinach seed production for boron and zinc application.

Treatment combination	Total seed yield (t/ha)	Total input (Rs.)	Gross return (Rs.)	Net return (Rs.)	BCR
B_0Zn_0	0.83	52220	91300	39080	1.75
B_0Zn_1	1.04	54020	114400	60380	2.12
B_0Zn_2	1.01	52364	111100	58736	2.12
B_1Zn_0	1.05	54095	115500	61405	2.14
B_1Zn_1	1.32	55895	145200	89305	2.60
B_1Zn_2	1.25	54239	137500	83261	2.54
B_2Zn_0	1.00	52310	110000	57690	2.10
B_2Zn_1	1.27	54110	139700	85590	2.58
B_2Zn_2	1.20	52454	132000	79546	2.52

Sale price of seed, Rs. 11.00 per 100 g.

under terai region of West Bengal.

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