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Effect of foliar application of nitrogen and zinc on the performance of soybean

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ABSTRACT

An experiment was carried out at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh during November 2021 through March 2022 to investigate the effects of foliar application of nitrogen (N) and zinc (Zn) on the performance of Binasoybean-1. The experiment comprised two factors, *viz.* (A) foliar supplementation of N, and (B) Zn fertilizer management. Factor A had two levels, *viz.* (i) no N application (control) (N0), and (ii) foliar application of 2% urea solution at pod formation stage (N1). Factor B had four levels, *viz.* (i) no Zn application (control) (Z0), (ii) basal application recommended dose (RD) of Zn (Z1), (iii) foliar application of 0.5% $ZnSO_4.7H_2O$ at pod formation stage (Z2), and (iii) basal application of 50% RD of Zn + foliar application of 0.5% $ZnSO_4.7H_2O$ at pod formation stage (Z3). All growth parameters (leaf area, branch production and plant height), yield contributing characters (total number of pods m^{-2}, number of fertile pods m^{-2}, number of seeds m^{-2}, weight of 1000-seeds), seed yield and stover yield were significantly affected by N fertilization. The highest values were recorded with foliar application of urea (2%) at pod formation stage. Zn management and the interaction of N and Zn management significantly affected the yield contributing parameters and yields of soybean. However, plant characters were affected neither by Zn nor the interaction. Basal application of 50% RD of Zn + foliar application of 0.5% $ZnSO_4.7H_2O$ at pod formation stage produced the highest values for all yield contributing characters. Interaction of these N and Zn treatments was also found to be the best combination in terms of these parameters. However, foliar N (2% urea) application coupled with a single foilar spray of 0.5% $ZnSO_4.7H_2O$ at pod formations stage was as good as the previous combination and produced the statistically similar results in all these yield contributing characters. Therefore, for higher seed yield of soybean, 2% urea solution coupled with a single foilar spray of 0.5% $ZnSO_4.7H_2O$ at pod formations stage is recommended.

Keywords: Soybean, foliar application, nitrogen, zinc, seed yield

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1 Introduction

Soybean (*Glycine max* L.) is an important legume crop which is grown and consumed mainly for oil and protein. Soybean grain is rich in nutrients such as protein (40-42%), oil (18-20%), and minerals like calcium, iron, etc (Devi et al., 2012). It is also a good source of isoflavones which is reported to help preventing heart diseases, cancer, and HIV (Fan et al., 2022; Moradi et al., 2020). Soybean oil is the leading vegetable oil in the world and it has many industrial use including biodiesel (Rani and Kumar, 2022). Soybean meal is also a primary and low-cost source of protein for animal and fish feeds (Karlsson et al., 2021; Liu et al., 2021). Though the cultivation of soybean in

Bangladesh was began in 1940s, its cultivation did not expand until 1970s. In recent years, under the Crop Diversification Program (CDP) of the Government of Bangladesh, different agriculture sectors and NGO's are trying to expand its cultivation. The acreage and production of soybean in Bangladesh are 62,870 ha and 96,921 t, respectively (BBS, 2022). Bangladesh's annual soybean production is negligible compared to its huge demand. Though the soil and climatic condition of Bangladesh is suitable for soybean production, its yield (1.8 t ha^{-1}) is not at par with world average yield of 2.5 t ha^{-1} (BBS, 2022). It is the most extensively cultivated legume on earth. Soybean's ability to associate with rhizobia bacteria in its root nodules to fix atmospheric N through symbiosis is an advantageous characteristic. (Schulte et al., 2021; Goyal et al., 2021). Therefore, legume crops require less or no nitrogen fertilization. In all legume crops, root nodules enters a senescence process characterized by a decline of N_2 fixation (Kazmierczak et al., 2020). However, in some legume crops (e.g. soybean), premature senescence might occur (Wang et al., 2023) resulting in N deficiency, especially in the late vegetative to fod formation stage. In such a case, grain yield and quality (e.g. protein content) of soybean will be compromised. Threfore, a foliar spraying of N during later growth stage can be beneficial in such cases.

Though N fertilization is uncommon in legume crops, a higher dose of phosphorus (P) is recommended (Tang et al., 2021; Allito et al., 2020). However, P and zinc (Zn) are mutually antagonistic which can cause yield reductions in many crops due to either P or Zn deficiencies (Recena et al., 2021; Suganya et al., 2020). Foliar application of different nutrients in many crops was reported to be successful in correcting periodic nutrient deficiency. But the plant cannot be fed the the total required amount of a nutrient through foliar application. Instead, a supplementary dose can be used. In case of foliar application of nutrients, the timing and concentration of foliar spray is very crucial. Though a very few works on foliar application of either N or Zn has been conducted elsewhere, there combined application has not been studied yet. Therefore, in view of the above-mentioned literature, this research was conducted (i) to assess the effect of foliar N application on growth, yield and quality of soybean, (ii) investigate effect of Zn fertilizer management on growth, yield and quality of soybean, and (iii) to find out whether there is any interaction effect between foliar urea application and Zn management on growth and yield of soybean.

2 Materials and Methods

2.1 Experimental site and soil

The experiment was conducted at the Agronomy Field Laboratory, Bangladesh agricultural University, Mymensingh. The site is located at 24°43′8.3″N, 90°25′41.2″E, in the South- West part of Old Brahmaputra river at an altitude of 18 m. The site belongs to non-calcareous dark grey floodplain soil under Old Brahmaputra Floodplain 'AEZ-9' (UNDP, 1988). The soil was silty clay loam in nature with a pH value of 7.30.

2.2 Experimental treatments and design

The experiment comprised two factors, *viz.* (A) foliar supplementation of N, and (B) Zn fertilizer management. Factor A had two levels, *viz.* (i) no N application (control) (N0), and (ii) foliar application of 2% urea solution at pod formation stage (N1). Factor B had four levels, *viz.* (i) no Zn application (control) (Z0), (ii) basal application recommended dose (RD) of Zn (Z1), (iii) foliar application of 0.5% $ZnSO_4.7H_2O$ at pod formation stage (Z2), and (iii) basal application of 50% RD of Zn + foliar application of 0.5% $ZnSO_4.7H_2O$ at pod formation stage (Z3). The recommended dose of Zn fertilizer is 10 kg $ZnSO_4.7H_2O$ ha^{-1} (BARC, 2010). The experiment was laid out in a randomized complete block design (RCBD) with four replications. The entire experimental area was divided into four blocks representing four replications to reduce soil heterogeneity and each block was sub-divided into eight plots with raised bunds as per treatment. Thus, the total numbers of unit plots were 32. The unit plot size was 2.0 m × 2.5 m; the plots were separated from each other by 1 m bunds. There were 0.75 m drains between the blocks. The treatments were randomly distributed to each block.

2.3 Plant material

The plant material used in the experiment was Binasoybean-1. Seeds of Binasoybean-1 were collected from the Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh. This variety was released by the Bangladesh Institute of Nuclear Agriculture in 2011 after regional and zonal trials and evaluation. It is recommended as a suitable variety for cultivation under Bangladesh's climatic conditions. During Rabi season insect and disease infestation is very low and it is resistant to disease and insects. The life cycle of this variety ranges from 110 to 115 days.

2.4 Crop husbandry and data collection

Land preparation was started on 15 November, 2021. The land was prepared by ploughing and cross-ploughing with a power tiller. Then the land was prepared by successive ploughing, cross-ploughing, and levelling. All kinds of weeds, stubbles, and crop residues were removed from the field before final ploughing and levelling. Triple superphosphate

(TSP), muriate of potash (MoP), and gypsum were applied at the rate of 160, 110, 95 kg ha^{-1}, respectively, during final land preparation as a basal dose. Zn fertilizer ($ZnSO_4.7H_2O$) was applied in the specified plots @ 10 kg ha^{-1} as a basal dose.

Seeds were planted on 23 November 2021 at the rate of 45 kg ha^{-1} for all Binasoybean-1 in 30 cm apart rows. In each row, plant to plant distance of 1 cm was maintained finally by thinning. Weeding and thinning were done at 20 days after planting of soybean seeds. The first weeding was done at the time of the first thinning and the second weeding and thinning were done at 35 days after planting of soybean seeds. No irrigation was applied during the experimental period as there was no symptom of moisture stress. No disease control measure was required as there was no disease incidence in the crop. The experimental plots were frequently observed and noticed any change in plant character and attack of pests and diseases on the crop. The crop was attacked by a pod borer which was controlled successfully by applying Gain @ 1.7 L ha^{-1}.

Aqueous solution of urea (2%) and $ZnSO_4.7H_2O$ (0.5%) were applied on the foliage as per the treatments during pod formation stage of soybean. The foliar application was done by evenly spraying until the whole plants were wet and the solution just began to drip from the leaves, in the morning around 10 AM. Foliar application of Fe and Zn was done during vegetative stage of the crop. The rate of application for both solutions were 900-1000 L ha^{-1}. When 80% of the pods turned brown in colour, the crop was assessed to attain maturity. Leaf area was measured during vegetative stage while data plant height, number of branches $plant^{-1}$, number of pods $plant^{-1}$, number of filled pods $plant^{-1}$, number of seeds pod^{-1}, weight of 1000 seeds, seed yield and stover yield were recorded after harvesting.

2.5 Data analysis

The recorded data for different parameters were compiled and tabled in proper from and were subjected to statistical analysis. Statistical package 'R' (R Core Team, 2022) was used for statistical analysis. The mean difference among the treatments was adjusted by tukey's *post-hoc* test at a 5% level of significance (Gomez and Gomez, 1984).

3 Results and Discussion

3.1 Plant characters

Leaf area was significantly affected by foliar application of urea (2%) at a 1% level of significance (Table 1). The leaf area ranged between 36.06 cm^2 and 29.66 cm^2. Higher leaf area (36.06 cm^2) was recorded from the foliar application of urea at the pod formation stage (N1). The lower leaf area (29.66 cm^2) was recorded in control (N0). Zinc fertilizer management had no significant effect leaf area of soybean (Table 1). The highest leaf area (34.68 cm) was observed from the basal application of 50% RD of Zn + foliar application of 0.5% $ZnSO_4.7H_2O$ at pod formation stage (Z3). The lowest leaf area (30.84 cm) was recorded in control (Z0). The interaction effect of Zn and N did not significantly affect leaf area at a 1% level of significance (Table 1). The highest leaf area (38.01 cm) was observed from the basal application of 50% RD of Zn + foliar application of 0.5% $ZnSO_4.7H_2O$ at pod formation stage (Z3). The lowest leaf area (27.46 cm) was found in control (N0Z0). Number of branches $plant^{-1}$ and plant height were significantly affected by foliar N supplementation. In both cases, higher values were recorded in plots where foliar N was applied (Table 1). These parameters were not significantly affected by neither Zn fertilizer management nor the interaction between foliar N and Zn management (Table 1). However, the pattern of the response of branching capability and plant height to Zn application and the interaction treatments were similar to that of leaf area. Nandi et al. (2020) reported that foliar application of Zn during vegetative and flowering stages boosted the growth (leaf area, chlorophyll content and biomass accumulation) in groundnut over control (no Zn). Martins et al. (2015) found that addition of Zn in growth medium of *Brachiaria brizantha* increased it leaf area and shoot dry matter. Our results contradict with these reports as Zn fertilizer management or its interaction with foliar N application did not significant affect the growth parameters of soybean.

3.2 Yield contributing characters

Number of pods, fertile pods and seeds m^{-2}, and 1000-seed weight of soybean were significantly affected by foliar application of N, Zn fertilizer management and their interaction (Table 1). Foliar N supplement at pod formation stage gave higher values of these parameters in soybean over no N application. For Zn treatments, basal application of 50% RD of Zn + foliar application of 0.5% $ZnSO_4.7H_2O$ at pod formation stage produced the highest values for all yield contributing characters. Interaction of these N and Zn treatments (N1 × Z3) was also found to be the best combination in terms of these parameters (Table 1). However, foliar N (2% urea) application coupled with a single foliar spray of 0.5% $ZnSO_4.7H_2O$ at pod formations stage (N1 × Z2) was as good as N1 × Z3 treatment and produced the statistically similar results in all these yield contributing characters. N1 × Z2 gave 168%, 173%, 148%, and 11% higher values of number of pods m^{-2}, number of fertile pods m^{-2}, number of seeds m^{-2}, and 1000-seed weight, respectively over control. Whereas, N1 × Z3 boosted

Table 1. Effect of foliar supplementation of nitrogen (2% urea solution), zinc fertilizer management, and their interaction on plant and yield contributing characters of soybean

Treatments	LA (cm^2)	NBP	PH (cm)	TNP	NFP	NS	WTS (g)
Nitrogen							
N0	29.66 b	1.09 b	36.96 b	474 b	449 b	726 b	98.84 b
N1	36.06 a	2.00 a	41.21 a	935 a	894 a	1387 a	106.76 a
CV (%)	7.25	19.21	4.62	30.72	29.41	28.06	4.85
Sig. level	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zn fertilization							
Z0	30.84	1.20	37.50	509 c	481 d	794 c	99.94 c
Z1	32.32	1.38	38.50	581 c	551 c	885 c	100.91 c
Z2	33.6	1.70	39.58	790 b	751 b	1171 b	103.28 b
Z3	34.68	1.90	40.77	941 a	902 a	1378 a	107.08 a
CV (%)	7.25	19.21	4.62	30.72	29.41	28.06	4.85
Sig. level	NS	NS	NS	<0.05	<0.05	<0.05	<0.05
Interaction							
N0 × Z0	27.46	0.75	35.40	406 c	382 c	641 c	96.40 b
N0 × Z1	29.25	0.85	36.40	461 c	433 c	700 c	97.13 b
N0 × Z2	30.56	1.30	37.70	489 c	459 c	752 c	99.75 b
N0 × Z3	31.35	1.45	38.30	542 c	522 c	814 c	102.08 ab
N1 × Z0	34.21	1.65	39.60	613 bc	580 c	947 bc	103.48 ab
N1 × Z1	35.4	1.90	40.60	699 bc	670 bc	1070 bc	104.70 ab
N1 × Z2	36.64	2.10	41.40	1090 ab	1043 ab	1590 ab	106.80 ab
N1 × Z3	38.01	2.35	43.20	1339 a	1283 a	1942 a	112.08 a
CV (%)	7.25	19.21	4.62	30.72	29.41	28.06	4.85
Sig. level	NS	NS	NS	<0.01	<0.01	<0.01	<0.01

LA: leaf area, NBP: number of branches plant^{-1}, PH: plant height, TNP: total number of pods m^{-2}, NFP: number of fertile pods m^{-2}, NS: number of seeds m^{-2}, and WTS: weight of 1000 seeds;
N0: no N application, N1: foliar application of 2% urea solution at pod formation stage, Z0: no Zn application, Z1: basal application recommended dose (RD) of Zn, Z2: foliar application of 0.5% $ZnSO_4.7H_2O$ at pod formation stage, and Z3: basal application of 50% RD of Zn + foliar application of 0.5% $ZnSO_4.7H_2O$ at pod formation stage

230%, 236%, 203%, and 16% values of these parameters over control. Ullah et al. (2020) reported that Zn fertilization contributes to higher 1000-seed weight and Rehman et al. (2020) reported bold size grain in Zn fertilized legumes.

3.3 Seed and stover yields

Seed yield was significantly affected by foliar supplementation of N at a 1% level of significance (Table 2). Higher seed weight of soybean (38.38 g m^{-2}) was recorded from the foliar application of urea (2%) at pod formation stage (N1). Seed yield was also significantly affected by Zn fertilizer management (Table 2). The highest seed yield (39.75 g m^{-2}) was recorded in plots where 50% basal and foliar Zn was applied (Z3). It is noticeable that application of full RD of Zn as basal (Z1) and only foliar application of 0.5% $ZnSO_4.7H_2O$ at pod formations stage (Z2) had statistically similar effect of on soybean seed yield (Table 2). Again, Z2 and Z3 treatments had the similar effect. The combined effect of N and Zn fertilization management (interaction) followed the similar results as found for sole effect of N and Zn (Fig. 1a). The interaction effect of N and Zn significantly affected soybean seed yield at a 1% level of significance. Seed yield ranged between 46.75 g m^{-2} and 23.25 g m^{-2}. The highest seed yield was recorded with N1 × Z3 treatment. However, N1 × Z2 gave statistically similar yield. Our results are in consistent with previous works. For example, Haider et al. (2018) and Manzeke et al. (2017) have reported that higher doses of Zn has resulted in higher values of yield contributing characters as well seed yield of grain legumes in comparison to lower dose or no Zn treatments. Manzeke et al. (2020) found co-application of N and Zn fertilizer more effective at increasing Zn uptake in maize and cowpea grains than Zn fertilizer alone. Li et al. (2015) stated that compared with foliar Zn alone, combined with N increases Zn uptake in wheat.

Table 2. Effect of foliar supplementation of nitrogen (2% urea solution) and zinc fertilizer management on seed and stover yields of soybean

Treatments	Seed yield (g m^{-2})	Stover yeid (g m^{-2})
Nitrogen		
N0	28.88 b	135.69 b
N1	38.38 a	192.88 a
CV (%)	17.37	18.8
Sig. level	<0.01	<0.01
Zn fertilzation		
Z0	28.62 c	139.3 c
Z1	31.75 b	152.3 b
Z2	34.38 ab	165.3 ab
Z3	39.75 a	200 a
CV (%)	17.37	18.8
Sig. level	<0.01	<0.01

N0: no N application, N1: foliar application of 2% urea solution at pod formation stage, Z0: no Zn application, Z1: basal application recommended dose (RD) of Zn, Z2: foliar application of 0.5% $ZnSO_4.7H_2O$ at pod formation stage, and Z3: basal application of 50% RD of Zn + foliar application of 0.5% $ZnSO_4.7H_2O$ at pod formation stage

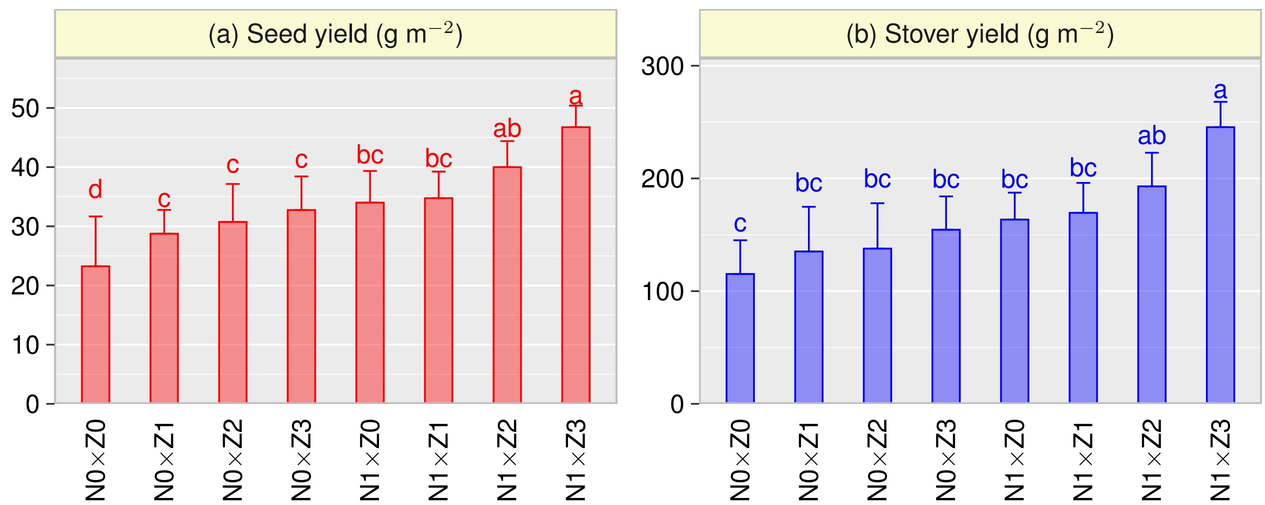

Figure 1. Effect of interaction of foliar supplementation of nitrogen (2% urea solution) and zinc fertilizer management on seed and stover yields of soybean. N0: no N application, N1: foliar application of 2% urea solution at pod formation stage, Z0: no Zn application, Z1: basal application recommended dose (RD) of Zn, Z2: foliar application of 0.5% $ZnSO_4.7H_2O$ at pod formation stage, and Z3: basal application of 50% RD of Zn + foliar application of 0.5% $ZnSO_4.7H_2O$ at pod formation stage

Stover yield of soybean was significantly affected by the sole effects of N, Zn and their combination. The response of stover yield to the treatments and treatment combinations followed the similar pattern as observed in seed yield (Table 2 and Fig. 1b). Stover yield of soybean for interaction effect ranged between 245.5 g m^{-2} and 115.25 g m^{-2}. The highest stover production was recorded from plots treated with N1 × Z3 treatment, though N1 × Z2 gave the similar value.

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Conflict of Interest

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

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