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RESPONSE OF NITROGEN AND ZINC FERTILIZATION ON NUTRIENT UPTAKE AND SEED QUALITY OF LATE SOWN WHEAT

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Abstract

Nitrogen (N) and zinc (Zn) are two important essential plant nutrients, which have profound effect on growth, development, plant nutritional status and seed quality. The present study was conducted to observe the effects of N and Zn fertilization on N and Zn contents in seed and straw and seed quality parameters of BARI Gom-28. The study was carried out at the Regional Agricultural Research Station (RARS) in Jamalpur during December 2015 to April 2016. The experiment was replicated three times in a split plot design with four nitrogen levels (main plots) viz. (i) NF_0 = control, (ii) NF_1= 140, (iii) NF_2= 160 and (iv) NF_3= 180 kg ha^{-1} and five zinc levels (sub-plots) viz. (i) ZF_0= Control, (ii) ZF_1 = 2, (iii) ZF_2 = 4, (iv) ZF_3 = 6, and (v) ZF_4 = 8 kg ha^{-1}. The results revealed that N content of both grain and straw were the maximum (15.78% and 4.26%, respectively) in NF_2while the highest contents of Zn were 306.58 and 122.58 ppm in ZF_3. Interaction of N and Zn levels showed the highest N content of both grain and straw were 3.50% and 1.14%, respectively, with the combination of NF_2ZF_3. Similarly, the highest Zn content of grain and straw were 86.70 ppm and 32.76 ppm, respectively found in NF_2ZF_3. Seed quality study showed the highest germination percentage, vigor index, longest shoot, longest root, longest seedling and the highest dry weight of seedling in the interaction NF_2ZF_3. Thus, N and Zn fertilization @ 160 and 6 kg ha^{-1} produced correspondingly more N and Zn contents in the straw and seed and also improved seed quality of late sown wheat.

***Keywords*: **Nitrogen, zinc, seed quality, wheat.

Introduction

Wheat (*Triticum aestivum*) is the leading cereal crop in many of the developing countries and ensures more than 50% of the daily calorie intake (Cakmak, 2008). Each plant nutrient has specific function in the plant. The available amount for plant uptake influences crop yield and quality (White and Brown, 2010). Potential wheat yield can be ensured in different ways, one of them is the application of micronutrient especially with balanced and recommended N, P and K (Nadim *et al*., 2011; Malghani *et al*., 2010).

Nitrogen occupies a conspicuous place in plant growth, development and metabolism as it has many functions including promotion of rapid growth, increasing leaf sizes and chlorophyll content, enhancing fruit and seed development; formation of amino acids that act as building blocks of proteins and enzymes (Bojović and Stojanović, 2005; Jabbar *et al*., 2009; Njira and Nabwami, 2015). However, higher cropping intensity and high yielding varieties cause more N depletion from the soil and plant response positively when N is added to the soil (Ali *et al*., 2004).

Wheat is inherently low in concentrations of Zn in grain, particularly when grown on Zn deficient soils (Hussain *et al*., 2010). Monotonous consumption of wheat products lead to Zn malnutrition due to low Zn content in their grains while rich in phytate which limits bioavailability of Zn (Cakmak, 2008). In Bangladesh, dryland crops face Zn deficiency in many area of the country and causes huge yield loss of major crops like potato, maize and wheat (Alloway, 2004). About 5-15% yield reduction was reported for potato, maize, sugarcane, pulses and mustard in Zn deficient soils in farmer's fields (Ahmad *et al*., 2015). Zn deficiency in soil causes lower Zn accumulation in the cereal seed and therefore, inadequate supply Zn to human when they consume it as food (Cakmak *et al*., 2010b). N and Zn contents in the seed contribute to the seed germination and seedling establishment (Ozturk *et al*., 2006; Boonchuay *et al*., 2013). Wheat seed show faster and higher germination when grown in adequate N than lower amount of nitrogen (Naylor, 1993). Similarly, wheat seed with higher Zn content gave plants with better accumulation of dry matter in root and shoot than the low Zn content in seeds (Rengel and Graham, 1995). Besides, N nutritional status of plants have a

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positive impact on root uptake and the deposition of micronutrients especially Fe and Zn in the seed (Cakmak *et al*., 2010b).The present study was aimed at elucidating the influence of N and Zn fertilization on the deposition of N and Zn in the plants, seed and improving seed quality parameters.

Materials and Methods

Experimental site, weather and soil condition

To quantify the nutrient content and seed quality of wheat under different N and Zn fertilization doses, a field experiment was conducted at the Regional Agricultural Research Station, Jamalpur of Bangladesh Agricultural Research Institute (BARI) in rabi season of 2015-2016. The geographic location of the experimental site was between $24^0 34'$ and $25^0 26'$ N latitude and between $89^0 40'$ and $90^0 12'$ E longitude at a height of15 m above the mean sea level (AEZ 9). The soil fertility status is given in Table 1. The test crop was BARI Gom-28.

Table 1. Chemical properties of soil before planting

Soil characteristics	0-15 cm	15-30 cm	Critical level
Soil p^H	6.39	7.00	
Organic matter (%)	3.31	0.81	
Total nitrogen (%)	0.191	0.047	0.12
Exchangeable K (milimol $100g^{-1}$ soil)	0.13	0.08	0.12
Available P (µg g^{-1} soil)	14.21	5.46	7.0
Available S (µg g^{-1} soil)	18.42	10.86	10.0
Available B (µg g^{-1} soil)	0.37	0.34	0.2
Available Zn (µg g^{-1} soil)	1.98	0.98	0.6

Source: Regional office of SRDI (Soil Resource Development Institute), Sylhet, Bangladesh

Setup and design

The experiment was laid out in a two factors (N and Zn) split-plot design with three replications. Four levels of nitrogen viz. NF_0: Control; NF_1: 140 kg ha^{-1}; NF_2: 160 kg ha^{-1} and NF_3: 180 kg $ha^{-1}$and five levels of zinc viz., ZF_0: Control; ZF_1: 2 kg ha^{-1}; ZF_2: 4 kg ha^{-1}; ZF_3: 6 kg ha^{-1} and ZF_4: 8 kg ha^{-1} were assigned in the main plots and sub-plots, respectively.

Fertilizer application

Recommended doses of P, K, S and B (40,120,20,1.5 kg ha^{-1},respectively) for wheat was applied (FRG, 2012). The sources of N, Zn, P, K, S and B were urea, zinc sulphate, triple super phosphate, muriate of potash, gypsum and boric acid, respectively. N and Zn were applied as per treatment. The whole amount of Zn, P, K, S, B and half of N were incorporated in the soil at the time of final land preparation in each plot. The remaining amount of N was top dressed at 20 days after emergence of seedlings. In case of Zn, all doses were applied plot-wise as basal.

Seed sowing, intercultural operations and harvesting

Seeds were sown continuously in rows @ 125 kg ha^{-1} with row to row distance 20 cm. Weeding was done two times in the early stage of plant development. Irrigation was given two times at crown root initiation and tillering stages. Harvesting was done when 100% of the spike become straw in color.

Seed quality and plant nutrient content analysis

The seed quality parameters like germination percentage, vigor index, shoot length, root length, seedling length and dry weight $seedling^{-1}$ were studied in Agronomy Lab,Sylhet Agricultural University. Germination test was conducted after one month of harvesting. During the test, 25 seeds were randomly selected from each plot and placed on wetted filter paper in each Petridis (20 mm) at 26˚C room temperature for 7 days. The Petridis were monitored daily and distilled water was applied when needed. After 7 days the required data were recorded. Seed vigor index was calculated by multiplying germination (%) and seedling length (mm). The seed lot showing the higher seed vigour index is considered to be more vigorous. Germination percentage and vigor index were calculated by the following formula-

$$Germination\ percentage(\%) = \frac{Number\ of\ seeds\ germinated}{Total\ number\ of\ seeds\ set} \times 100$$

$$Vigor\ index = Germinatination\ percentage \times seedling\ length\ (mm)$$

Again shoot and root length of 10 seedlings were recorded in cm after 7 days of germination. Seedling length was calculated by the sum total of shoot length and root length of seedling which is expressed by mm. The seedlings obtained after standard germination test were used for dry weight test. The shoot and root were detached from coleoptiles and were placed in paper bags, dried in oven at 72ºC for 34 hours. After drying the samples were weighed using a digital electric balance. On the other hand, N and Zn content of seed and straw were analyzed by using kjeldahl and DTPA extraction method at BARI, Gazipur.

Data analysis

The analysis of variance (ANOVA) was performed by using R program for seed quality parameters. The difference among the treatment means was estimated by LSD (Least Significance Difference) test at 5% level of probability wherever F values were found significant. Due to have one replication data no statistical analysis was done in case of nutrient content

Results and Discussion

Effect of N fertilization on N content of wheat seed and straw

The nitrogen doses exhibited a variation in terms of seed nutrient content of wheat (Table 2). In both wheat seed and straw, there were 38.66 % and 54.91% higher N was recorded in treatment NF_2 over control. Increasing N rates from 60 to 120 kg ha^{-1} resulted in the increase in grain nitrogen concentration from 1.52 to 2.28% in bread wheat (Arduini et al., 2006). The increase in straw N concentration was observed with increasing N input (Worku e*t al.,* 2007). Similarly, straw nitrogen of bread wheat varieties exhibited a progressive increase in response of N levels from 0 to 120 kg ha^{-1} (Alemu *et al.,* 2012). The highest grain and straw nitrogen concentration (2.7 and 0.35%, respectively) were produced when N was applied @ 360 kg ha^{-1} (Belete *et al*., 2018) which was contradictory tothe present study. The reason behind it might be due to high initial N content in the experimental soil. The increase in grain nitrogen concentration of the varieties at highest N rate might be due to the sufficient availability of nitrogen that increased N mobilization to the grain at grain filling stage. However, considerably lower N contents, 11.38% in seed and 2.75% in straw, were recorded in NF_0 where no N was applied. The results also showed an upward trend of N contents in both straw and seed and decreased beyond NF_2. Wen *et al.* (2018) also reported that the increment of N content in seed with increasing N fertilization.

Table 2. N and Zn content of late sown wheat seed and straw as influenced by N and Zn levels

	N%				Zn (ppm)				
	NF_0	NF_1	NF_2	NF_3	ZF0	ZF_1	ZF_2	ZF_3	ZF_4
Seeds	**11.38**	11.76	**15.78**	11.62	**218.42**	252.27	265.42	**306.58**	285.08
Straw	**2.75**	3.13	**4.26**	3.65	**59.16**	75.16	91.45	**122.58**	104.61

Legends: NF_0 = 0 kg ha^{-1}, NF_1 = 140 kg ha^{-1}, NF_2 = 160 kg ha^{-1}, NF_3 = 180 kg ha^{-1}; ZF_0= 0 kg ha^{-1}, ZF_1 = 2 kg ha^{-1}, ZF_2 = 4 kg ha^{-1}, ZF_3 = 6 kg ha^{-1}, ZF_4 = 8 kg ha^{-1}

Effect of Zn fertilization in Zn content in seed and straw

The different Zn fertilization rates exhibited greater variations in Zn content in straw and seed (Table 2). In both straw and seed, the concentration of Zn was increased with increasing Zn application rate (Torun *et al.,* 2001). The higher Zn concentration 306.58 ppm and 122.58 ppm were recorded in both seed and straw, respectively in the treatment ZF_3 which were 40.36% and 107.20% higher over control. On the contrary, the presence of minimum Zn was recorded in treatment ZF_0 for both seed and straw. Similar result also reported in many studies that higher Zn deposition in wheat grain happen when Zn fertilization was done @ 6 kg ha^{-1} (Talukder *et al.,* 2011; Yang *et al.,* 2011). However, in another study it was reported that Zn deposition was increased up to 16 kg ha^{-1} which is far away from the present findings (Ghulam *et al*., 2009). It may be due to the different soil type and very low initial Zn content of that soil.

Interaction effect of N and Zn levels on the N and Zn content of seed and straw

The plant uptake of both N and Zn were increased with increased combined application of N and Zn in both straw and seed (Table 3). However, N content in seed decreased beyond the combination of treatment NF_2 and ZF_3 compared to their previous highest combination. The N deposition in seed was 104.67% higher in the treatment $NF_2 \times ZF_3$ than control ($NF_0 \times ZF_0$). Overall, a similar trend of N content % in straw was recorded in terms of combined effect of N and Zn fertilization (Table 3). The N deposition in straw was 137.50% higher inthe treatment $NF_2 \times ZF_3$ over control ($NF_0 \times ZF_0$).

Zn content in seed decreased beyond the combination of treatment NF_2 and ZF_3 compared to their previous highest combination (Table 3). The highest Zn content (86.70 ppm) in seed was recorded in the treatment $NF_2 \times ZF_3$which was 71.41% higher than control. Overall, similar trend of Zn content in straw was recorded in terms of combine effect of N and Zn fertilization. The Zn contentin straw was 153.95% higher in the treatment $NF_2 \times ZF_3$ over control ($NF_0 \times ZF_0$). Depending on the N supply, Zn remobilization occurs and higher N supply favored the contribution of Zn uptake to plant body and grain Zn accumulation (Cakmak *et al*., 2010a; Kutman *et al*., 2012).

Table 3. Interaction effect of N and Zn levels on N content of seed and straw of late sown wheat

N-levels	N content (%) of seed					N content (%) of straw				
	ZF_0	ZF_1	ZF_2	ZF_3	ZF_4	ZF0	ZF_1	ZF_2	ZF_3	ZF_4
NF_0	**1.71**	2.13	2.36	2.80	2.38	**0.48**	0.50	0.54	0.67	0.56
NF_1	2.13	2.60	2.24	2.63	2.16	0.50	0.56	00.59	0.76	0.72
NF_2	2.91	3.02	3.05	**3.50**	3.30	0.75	0.78	0.78	**1.14**	.81
NF_3	2.16	2.24	2.38	2.52	2.32	0.56	0.64	0.73	0.72	1.00
	Zn content of seed (ppm)					Zn content of straw (ppm)				
NF_0	**50.58**	59.74	63.12	69.82	56.84	**12.90**	17.76	21.64	27.62	24.24
NF_1	54.00	62.98	63.50	81.18	74.88	14.16	18.84	22.52	30.34	24.56
NF_2	57.86	69.71	74.28	**86.70**	75.52	16.02	19.64	23.65	**32.76**	27.76
NF_3	55.98	59.84	64.52	68.88	77.84	16.08	19.04	23.64	31.86	28.46

NF_0 =0 kg ha^{-1}, NF_1 = 140 kg ha^{-1}, NF_2 = 160 kg ha^{-1}, NF_3 = 180 kg ha^{-1}; ZF_0= 0 kg ha^{-1}, ZF_1 = 2 kg ha^{-1}, ZF_2 = 4 kg ha^{-1}, ZF_3 = 6 kg ha^{-1}, ZF_4 = 8 kg ha^{-1}

Effect of N on seed quality parameters

All the parameters of seed quality were significant at various doses of nitrogen applied in that experiment except germination percentage and dry weight seedling^{-1}(Table 4). The germination percentage increased with increasing the N rate and that result was in line with (Samiram and Dhillon, 1993; Satyanarayana, 2012). The highest vigor index (9006.35), longest shoot (4.90 cm), longest root (6.23 cm) and longest seedling (111.37 mm) were noted in NF_2. The minimum vigor index (4982.67), shoot length (2.90 cm), root length (3.84 cm) and seedling length (67.67 mm) were recorded from NF_0 with no application of nitrogen except lowest dry weight (0.077 g) recorded in NF_1. Studies on sunflowers showed that high germination in sunflower is gained by using 120 kgha^{-1} nitrogen fertilizer (Maheswarappa *et al*., 1985; Sawan *et al.,* 1985). Some reports also are remarkable that application of 0,200,400 and 600 kgha^{-1} nitrogen fertilizer has no effect on seed vigor and germination percentage (Osechas *et al.,* 2002). It was reported that wheat and other cereals experimented hydroponically or in pot and field experiments by increasing nitrogen supply, enhanced both shoot and root growth, but usually shoot growth more than root growth, leading to increased shoot/root dry weight ratio with increase N supply (Marschner, 1986; Lucas *et al*., 2000). The result of the present experiment showed that the seed quality parameters progressively increased with increasing the N levels up to NF_2.

Table 4. Germination, vigor index and seedling vigor of late sown wheat seeds as influenced by N levels

N levels	Germination (%)	Seed Vigor index	Seedling vigor			
			Shoot length (cm)	Root length (cm)	Seedling length (mm)	Dry Weight of seedling^{-1} (g)
NF_0	70.67	4982.67	2.90	3.84	67.67	0.079
NF_1	74.40	6246.61	3.70	4.51	82.09	0.077
NF_2	79.73	9006.35	4.90	6.23	111.37	0.095
NF_3	76.00	7263.39	4.21	5.19	94.13	0.088
$LSD_{0.05}$	6.37	410.87	0.11	0.20	1.20	0.017
LS	NS	**	**	**	**	NS

LS = Level of Significance; ** = Significant at 1 % level of probability; NS= Not-Significant

Effect of zinc on seed quality parameters

The zinc levels showed a significant variation in terms of seed quality parameters of wheat (Table 5). The highest germination percentage (89.00%), vigor index (9859.13), shoot length (4.77 cm), root length (6.26 cm), seedling length (110.35 mm) and highest dry weight of seedling (0.108 g) were noted in ZF_3. The lowest germination percentage (58.00%), vigor index (4169.07), shoot length (3.37 cm), root length (3.60 cm), seedling length (69.70 mm) and dry weight of seedling (0.068 g) were recorded in ZF_0. The result showed that there was a progressive increased seed quality parameter with increasing the Zn levels.

Table 5. Germination, vigor index and seedling vigor of late sown wheat seeds as influenced by Zn levels

Zn levels	Germination %	Seed vigor index	Seedling vigor			
			Shoot length (cm)	Root length (cm)	Seedling length (mm)	Dry weight of seedling^{-1}
ZF_0	58.00	4169.07	3.37	3.60	69.70	0.068
ZF_1	69.00	5478.28	3.59	4.28	78.78	0.075
ZF_2	78.33	7022.26	3.86	5.05	89.43	0.083
ZF_3	89.00	9859.13	4.77	6.26	110.35	0.108
ZF_4	81.67	7845.03	4.06	5.52	95.82	0.088
$LSD_{0.05}$	3.62	261.03	0.11	0.23	2.09	0.005
LS	**	**	**	**	**	**

LS = Level of Significance; ** = Significant at 1 % level of probability; NS= Not-Significant

High seed-Zn has very important physiological roles during seed germination and early seedling growth. Besides, seedlings from seeds containing high Zn have better ability to withstand adverse environmental conditions (Cakmak, 2008). An increase in wheat seed Zn has been associated with an increase in the vigor of wheat seedlings, which leads to secondary benefits for the seedling (Haslett *et al.*, 2001). Rehman *et al.* (2015) reported that an increase in seed Zn improved the rate at which seeds germinate as well as stand density. These experiments proof that Zn has a positive influence on the vigor of wheat. On the contrary, plants emerging from seeds with low Zn have poor seedling vigor and field establishment on Zn-deficient soils (Yilmaz *et al*., 1998). Rengel and Graham (1995) showed in pot experiments that increasing seed-Zn contents from 0.25 µg per seed to 0.70 µg per seed significantly improved root and shoot growth of wheat plants under Zn deficiency and concluded that high seed-Zn acts similarly to a starter-fertilizer effect.

Table 6. Interaction effect of N and Zn on germination, vigor index and seedling vigor of late sown wheat seed

Treatment combinations (N x Zn)	Germination (%)	Seed Vigor index	Seedling vigor			
			Shoot length (cm)	Root length (cm)	Seedling length (mm)	Dry weight of seedling^{-1} (g)
NF_0ZF_0	45.33	2173.20	2.09	2.68	47.70	0.063
NF_0ZF_1	64.00	3621.07	2.47	3.20	56.73	0.070
NF_0ZF_2	78.67	5291.60	2.83	3.79	67.27	0.080
NF_0ZF_3	85.33	8073.20	4.01	5.45	94.63	0.097
NF_0ZF_4	80.00	5754.26	3.09	4.11	72.03	0.083
$NF_1 ZF_0$	56.00	3670.67	3.25	3.28	65.33	0.063
$NF_1 ZF_1$	69.33	5097.07	3.45	3.90	73.50	0.070
NF_1ZF_2	76.00	6166.13	3.71	4.41	81.13	0.073
NF_1ZF_3	89.33	9031.86	4.27	5.83	101.10	0.097
NF_1ZF_4	81.33	7267.33	3.82	5.11	89.37	0.080
$NF_2 ZF_0$	66.67	6017.60	3.41d	4.62	90.37	0.77
NF_2ZF_1	72.00	7386.40	4.58	5.68	102.70	0.087
NF_2ZF_2	81.33	9239.33	4.82	6.56	113.87	0.090
NF_2ZF_3	94.67	12385.60	5.65	7.43	130.87	0.123
NF_2ZF_4	84.00	10002.80	5.03b	6.87	119.07	0.097
NF_3ZF_0	64.00	4814.800	3.71	3.82	75.40	0.070
NF_3ZF_1	70.66	5808.57f	3.87	4.35	82.20	0.073
NF_3ZF_2	77.33	7392.00	4.08	5.45	95.43	0.087
NF_3ZF_3	86.67	9945.86	5.14	6.33	114.80	0.117
NF_3ZF_4	81.33	8355.72	4.27	6.01	102.80	0.093
$LSD_{0.05}$	7.25	522.07	0.22	0.46	4.17	0.011
LS	*	NS	**	NS	**	NS

LS = Level of Significance; * = Significant at 5 % level of probability; ** = Significant at 1 % level of probability; NS= Not-Significant

Interaction effect of nitrogen and zinc on seed quality parameters

The results presented that there was significant variations among the seed quality parameters affected by different doses of N and Zn except seed vigor index, root length, dry weight seedling^{-1} (Table 6). The highest germination percentage (94.67%), shoot length (5.65 cm) and seedling length (130.87 mm) were noted in $NF_2 \times ZF_3$ which was statistically different from other treatment combinations while sequentially lowest 45.33%, 2.09 cm and 47.70 mm were recorded from the combination NF_0ZF_0. Overall, the seed quality increased up to NF_2ZF_3 and after that decreased.

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