Effect of rate of Zn and B micronutrients on the yield and yield components of wheat

Maqsood Ul Hussan[1], Umer Ijaz[1**], Mazhar Ali[2], Tayyab Nawaz[1], Iqra Azam[3], Ahmad Raza[1], Muhammad Faizan Aslam[4], Hassan Saddique[1]

[1]Department of Agronomy, University of Agriculture, Faisalabad, Pakistan.
[2]Department of Agronomy, Sindh Agriculture University, Tandojam, Pakistan.
[3]Department of Botany, University of Agriculture, Faisalabad, Pakistan.
[4]Institute of Agricultural and Resource Economics, University of Agriculture, Faisalabad, Pakistan.
**Corresponding author's email: umermeelu@yahoo.com

Abstract: A field experiment was carried out to study the effect of different levels of zinc (Zn) and boron (B) fertilization on the grain yield of wheat. The experiment included four levels of Zn viz. 0, 2, 4, 6 kg ha-1 and four levels of B viz. 0, 1, 2 and 3 kg ha-1. The experiment was laid out in a randomized complete block design with three replications. All the yield and yield contributing characters except plant height and total tillers plant-1 were significantly affected due to the interaction effects of Zn and B. Among the interactions, the tallest plant (94.93 cm), maximum number of effective tillers plant-1 (4.19) and the highest grain (4.15 t ha-1) and straw yields (7.08 t ha-1) were obtained from 4 kg Zn ha-1 × 2 kg B ha-1. On the contrary, the lowest performance for all the studied crop characters was observed from the treatment combination of Zn0×B0 where Zn and B were not applied. The results showed that grain yield of wheat increased with increasing levels of both Zn and B up to 4 kg ha-1 and 2 kg ha-1, respectively. The effect of B was more prominent than with Zn on different yield components and yield of wheat.

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1. Introduction

Wheat (*Triticum aestivum* L.) ranks first among the cereal crops of the world both in acreage and production. About one- third population of the world live on wheat grain for their existence (Hanson *et al.,* 1982). The grains of wheat have high nutritive value containing 14.70% protein, 2.14% fat, 78.10% starch and 2.10% mineral matter. Fertilizers play a very important role in utilizing the soils for an efficient crop production. Without a suitable replenishment technology, the introduction of intensive agriculture in the country causes depletion of inherent nutrient reserves in the soil day by day. Such a trend has resulted in the emergence of general fertility constraints causing smaller than expected response to increased fertilizer doses. So identifying the soil related constraints to provide meaningful recommendations for successful crop production practices is important.

Grain sterility is one of the serious problems in obtaining higher yield of wheat in the country. The grain sterility of wheat as per world literature may be associated with the deficiency of some micronutrients specially Zn and B (Jahiruddin *et al.,* 1992). Among different micronutrient elements, Zn and B are considered to be the most important in order to obtain optimum production in case of wheat. As a plant nutrient the role of zinc in crop production, including wheat cultivation, has been well established (Kanwar and Randhawa, 1974). Deficiency of and response to zinc in wheat have been reported from various parts of the world. Plant root absorbs zinc in the form of Zn++. Zinc involves in a diverse range of enzymatic activities. The functional role of zinc includes auxin metabolism. Bybordi and Malakouti (2003) reported that wheat is sensitive to zinc deficiency, but less sensitive to iron and copper deficiencies. Increasing the Zn concentration of food crop plants, resulting in better crop production and improved human health, is an important global challenge (Hotz and Brown, 2004 and Welch and Graham, 2004).

Several studies have revealed that zinc fertilization not only increases yield but also increases zinc concentration in grains (Torun *et al*., 2001 and Grewal *et al*., 1997). So it should be used in correct doses for increasing soil fertility and to boost up crop production. Boron is essential for growth and yield of crops. It is relatively mobile in plants and is absorbed as BO_3^-. Vitosh *et al.* (1997) expressed that B is involved in carbohydrates metabolism and it is essentially necessary for protein synthesis, pollen germination and seed and cell wall formation. Rehem *et al.* (1998) stated that B plays a key role in water and nutrients transportation from root to shoot. They believe that boron shortage causes barren stalks and small, twisted ears and grain yield reduction through impaired development of anthers and ultimately failure of seed setting. Boron helps to develop root system, fruit setting and grain formation. Most of the amino acids increase with an increase in B supply (Iqtidar and Rehman, 1984).

The soils of Pakistan in some areas are deficient in some micro elements and boron is one of them. Therefore, the present investigation aims to study the interaction effect of Zn and B on the yield and yield attributes of variety Ujala 2016.

2. Materials and methods

The study was conducted at the Agronomy field, University of Agriculture Faisalabad, Pakistan, during the period from November 2016 to April 2017 to investigate the effect of different levels of zinc and boron on the yield of wheat. Wheat (*Triticum aestivum* L.) variety Ujala 2016 was used as plant material.

A. Zinc level: Four	B. Boron level: Four
i) 0 kg ha^{-1} (Zn_0)	i) 0 kg ha^{-1} (B_0)
ii) 2 kg ha^{-1} (Zn_2)	ii) 1 kg ha^{-1} (B_1)
iii) 4 kg ha^{-1} (Zn_4)	iii) 2 kg ha^{-1} (B_2)
iv) 6 kg ha^{-1} (Zn_6)	iv) 3 kg ha^{-1} (B_3)

The experiment was laid out in a randomized complete block design with three replications; each representing a block. Each block was divided into 16 unit plots where 16 treatment combinations were allocated at random. The total number of unit plots in the experiment was (16×3) 48, each of size 4.0m×2.5m. The distance between the plot and block were 0.75m and 1.0m respectively having a provision of irrigation channel**.** The unit plots were fertilized with 180 kg N, 120 kg TSP, 60 kg MOP and Gypsum 80 kgha^{-1} respectively. Zinc and boron were applied as per experimental specification through Zinc oxide (78% Zn) and boric acid (17% B).

The whole amount of TSP, MOP, gypsum, Zinc oxide, boric acid and one third of the urea were applied at the time of final land preparation prior to sowing. The remaining two-thirds of urea was top-dressed in two equal splits on 20 and 55 days after sowing (DAS) the seed. The seeds were collected and sown on November 2016 at the rate of 120 kg ha^{-1} in 25 cm apart rows. Intercultural operations were done in order to ensure and maintain the normal growth of the crops. Manual weeding was done two times at 18 and 50 days after sowing (DAS). The plots were irrigated twice after first weeding and then at 55 DAS. The crop was harvested plot-wise at full maturity on April 2017 and carried to the threshing floor for dring, threshing and cleaning.

For collecting data on crop characters, 5 sample plants per plot were selected at random and uprooted prior to harvesting. The grain and straw yields were recorded plot-wise at 14% moisture level in t ha^{-1}. The data on the following crop parameters such as number of total tillers plant^{-1}, number of effective tillers plant^{-1}, length of spike (cm), number of spikelets spike^{-1}, number of grains spike^{-1}, number of sterile spikelets spike^{-1}, weight of 1000 grains (g), grain yield (t ha^{-1}), straw yield (t ha^{-1}), biological yield (t ha^{-1}) and harvest index (%) were recorded from each plot Plant height (cm). The recorded data were compiled, tabulated and subject to statistical analysis. Analysis of variance was done with the help of computer package programme MSTAT. The mean differences were adjudged by Ducan's New Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

3. Results and discussion

The plant height was not significantly affected by the interaction effects of Zn and B levels. The tallest plant height (94.93 cm) was found at treatment combination of 4 kg Zn ha^{-1} × 2 kg B ha^{-1} and the smallest (77.75 cm) was from control. Present results indicate that plant height increased with the increasing levels of Zn and B.

The effects of Zn and B interaction on number of total tillers plant^{-1} was not significant that results presented in Table 2. Among the treatments 4 kg Zn ha^{-1} × 2 kg B ha^{-1} was given the highest number of total tillers plant^{-1} (4.94), the lowest (3.21) was recorded in control treatment. Above results showed that the number of total tillers plant^{-1} increased with the increasing levels of Zn and B up to 4 kg Zn ha^{-1} and 2 kg B ha^{-1}.

It was also found that the interaction of different levels of Zn and B showed significant effects on the number of effective tillers plant^{-1} (Table 1). The maximum number of effective tillers plant^{-1} (4.19) was produced by 4 kg Zn ha^{-1} × 2 kg B ha^{-1}. Zn_4 B_1 produced the second highest which was statistically similar to Zn_4B_3, Zn_2B_2 treatment combinations, while the lowest number of effective tillers plant^{-1} (2.27) was observed from control treatment combination (Zn_0B_0). However, it was recorded that the best performance in respect of number of effective tillers plant^{-1} was observed due to the interaction of 4 kg Zn ha^{-1} × 2 kg B ha^{-1} fertilizer applications.

The combined effects of Zn and B influence spike length significantly (Table 2). However, the longest spike length (11.98 cm) was observed with the combination of 4 kg Zn ha^{-1} × 2 kg B ha^{-1} and the shortest value (9.46 cm) in control treatments combination. From the above findings, it is concluded that the spike length was enhanced by Zn and B interaction.

Number of spikelets spike^{-1} of wheat showed significant effect due to interaction of Zn and B (Table 1). The highest number of spikelets spike^{-1} (22.47) was produced by 4 kg Zn ha^{-1} × 2 kg B ha^{-1}

and control treatment combination (Zn_0B_0) produced the lowest number of spikelets spike^{-1} (16.12). Therefore, it was observed that best performance in respect of number of spikelets spike^{-1} was 4 kg Zn ha^{-1} with combination of 2 kg B ha^{-1}. The above results indicate that the number of spikelets spike^{-1} was enhanced by Zn and B interaction. This is in conformity with that of Ziaeyan and Rajaie (2009).

Interaction effects of Zn and B showed significant variation on the number of grains spike^{-1} (Table 2). The number of grains spike^{-1} varied from 35.31 to 51.44 depending on the various treatments used. The treatment Zn_4 B_2 produced the highest number of grains spike^{-1} (51.44) and the lowest (35.31) was obtained from control treatment. The positive effect of Zn and B interaction on number of grains spike^{-1} of wheat was reported by Ali *et al.* (2009).

Interaction effects of Zn and B represented in Table 1. Significant variation in respect of number of sterile spikelets spike^{-1} was found. Fertilization with 0 kg Zn in combination with 0 kg B ha^{-1} showed the highest number of sterile spikelets spike^{-1} (6.13). The second highest was obtained from Zn_2B_0 treatment and the lowest number of sterile spikelets spike^{-1} (2.22) was observed when the crop fertilized with 4 kg Zn and 2 kg B ha^{-1} which was statistically identical with Zn_4 B_3 and Zn_4 B_1 treatments combination (Table 2).

The analysis of variance showed that the interaction effects of Zn and B were significant for 1000-grain weight (Table 1). The maximum 1000-grain weight (58.18 g) was obtained from 4 kg Zn ha^{-1} × 2 kg B ha^{-1}, while the lowest 1000grain weight (39.70 g) was found from control treatment. The above results indicate that the 1000-grain weight was enhanced by Zn and B interaction. This positive effect of Zn and B interaction on 1000-grain weight of wheat was also reported by Ali *et al.* (2009).

The interaction effect of different levels of Zn and B fertilizers was significant regarding grain yield. The highest grain yield (4.15 t ha^{-1}) was recorded at a combination of 4 kg Zn × 2 kg B ha^{-1} and the lowest (1.71 t ha^{-1}) was recorded from control. Zn in conjunction with B produced higher grain yield which is cleared from the trial. Similar results were also published by Arif *et al.* (2006).

The interaction effects of Zn and B in relation to straw yield showed significant effect (Table 2). From the interaction treatments, it is clear that 4 kg Zn ha^{-1} × 2 kg B ha^{-1} produced the highest straw yield. The lowest performance in respect of straw yield found in control (Zn_0 B_o) treatment.

Biological yield of wheat showed significant effect due to interaction of Zn and B (Table 2). The highest biological yield (11.23 t ha^{-1}) was produced by 4 kg Zn ha^{-1} × 2 kg B ha^{-1} and lowest biological yield (5.15 t ha^{-1}) was achieved by control treatment. The result obtained in this regard is in accordance with the findings of Torun *et al.* (2001) and Grewal *et al.* (1997) who have reported increased dry matter production for application of zinc and boron over control.

Interaction effect of different levels of Zn and B was significantly influenced in respect of harvest index (Table 2). The result exhibits that 4 kg Zn ha^{-1} × 2 kg B ha^{-1} produced the highest harvest index (36.91%) as compared to control treatments (33.20%). It might be due to the combination of Zn and B and more biological yield and grain yield.

The degree of Statistical relationship between grain yield and number of effective tillers plant^{-1}, grain yield and number of sterile spikelets spike^{-1}, grain yield and number of grains spike^{-1}, grain yield and straw yield of wheat has been found out significant relationship at 1% level of probability. The positive slopes exhibited positive relationship. The correlation matrix and regression lines of these parameters have been shown in Table 3 and Figures 1-4.

Table 1 Analysis of variance of the studied crop characters of Ujala 2016.

Sources of variation	Degrees of freedom	Plant height (cm)	Total tillers plant-1 (no.)	Effective tillers plant-1 (no.)	Spike length (cm)	No. of spikelets spike-1	No. of grains spike-1	No. of sterile spikelets spike-1	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Replication	2	37.41	0.272	0.220	0.010	0.413	1.61	0.269	1.41	0.012	0.121	0.156	0.805
Zn level	3	93.90*	1.910**	1.566**	2.673**	13.886**	60.02**	5.833**	61.39**	1.197**	4.257 **	9.677**	7.494**
B level	3	93.14*	0.609*	1.181**	2.258**	14.492**	84.33**	5.012**	113.27**	1.916**	4.372 **	11.819**	9.984**
Zn x B level	9	18.01NS	0.281NS	0.106*	0.472*	2.939**	18.23**	0.651**	28.22**	0.309**	0.892 **	2.212**	1.273*
Error	30	31.73	0.197	0.048	0.213	0.491	3.38	0.145	3.52	0.015	0.054	0.066	0.564

** = Significant at 1% level of probability.
* = Significant at 5% level of probability.
NS = Not significant

3.1 Grain yield and number of effective tillers plant^{-1}

The degree of relationship between grain yield and number of effective tillers plant^{-1} of wheat was studied (Fig. 1). The result revealed that grain yield and number of effective tillers plant^{-1} have a direct significant positive relationship at 1% level of significance which has been confirmed with correlation co-efficient r = 0.902** (Fig. 1). The relationship was more evident by the equation Y=1.0352x - 0.1413 and sowing gradual increase in grain yield with the increase of number of effective tiller plant^{-1}.

3.2 Grain yield and number of sterile spikelets spike^{-1}

A correlation matrix was done (Table 3) in order to observe the degree of interrelationship between grain yield and number of sterile spikelets spike^{-1}. The result showed that the grain yield and number of sterile spikelets spike^{-1} have a significant negative relationship at 1% level of significance. The correlation coefficient r = 0.861** (Fig. 2) and the regression line of Y (grain yield) on X (number of sterile spikelets spike^{-1}) have the equation Y = -0.4838x + 4.985. The negative slope indicates negative relationship, which means that an increase in the sterile spikelets spike^{-1} will lead to a decrease in grain yield of wheat.

3.3 Grain yield and number of grains spike^{-1}

The degree of relationship between grain yield and number of grains spike^{-1} of wheat was studied (Fig. 4). It is shown from the result that there was a direct significant and positive relationship at 1% level of significance between grain yield and number of grains spike^{-1}. The correlation co-efficient r = 0.940** and the regression line of y (grain yield) on number of grains spike^{-1} having Y = 0.134x - 3.0575 (Table 3). The positive slope indicates that grain yield and number of grains spike^{-1} are directly correlated, i.e. increase in number of grains spike^{-1} will lead to an increase in grain yield.

3.4 Grain yield and straw yield

From the results of experiment, it is observed that grain yield showed significantly positive correlation with its straw yield (r = 0.946**). The regression equation of Y (grain yield) Vs X (straw yield) was found to be Y = 0.5653x - 0.1593 (Fig. 3 and Table 3). It means that an increase in straw yield will lead to an increase in grain yield.

The overall results demonstrated that the application of Zn and B played a significant role in efficient wheat production. The definite information from above discussion will be useful for national policy making to achieve optimum yield production of wheat in Bangladesh.

Table 2 Interaction effect of Zn and B levels on the yield and yield contributing characters of Ujala-2016

Interaction (Zn x B) (kg ha^{-1})	Total tillers plant-1 (no.)	Effective tillers plant-1 (no.)	Spike length (cm)	No. of spikelets spike-1	No. of grains spike-1	No. of sterile spikelets spike-1	1000-grain weight (g)	Biological yield (t ha^{-1})	Harvest index (%)
Zn 0×B0	3.21	2.27 g	9.46 f	16.12f	35.31e	6.13a	39.70f	5.15j	33.20g
Zn 0×B1	3.40	2.82f	10.26def	20.60bcd	46.78cd	4.08bcd	52.54de	9.52ef	33.30g
Zn 0×B2	3.57	3.33 de	11.49ab	21.71ab	48.64abc	3.60cdefg	55.51abcd	9.78de	35.81abcd
Zn 0×B3	3.42	3.08 ef	10.84bcde	20.87bc	46.64cd	3.79bcdef	53.83cde	9.08fgh	36.22abc
Zn 2×B0	3.43	2.88f	10.69bcde	20.66bcd	44.64d	4.48b	51.79e	8.93gh	33.84fg
Zn 2×B1	3.63	3.12 ef	10.88bcde	21.23abc	47.34bcd	4.14bc	53.46cde	9.71de	32.94g
Zn 2×B2	4.15	3.68 bcd	11.15abc	21.81ab	48.87abc	3.32efgh	56.37abc	10.72b	34.90cdef
Zn 2×B3	3.81	3.41 cde	10.99bcd	20.68bcd	47.65bcd	3.38defgh	55.93abcd	10.29bc	34.33efg
Zn 4×B0	3.70	3.22 ef	10.70bcde	20.51bcd	46.31cd	3.97bcde	52.35de	9.19fg	34.79cdef
Zn 4×B1	4.72	3.83b	11.57ab	21.87ab	50.65ab	2.77hij	54.57bcde	10.10cd	34.75def
Zn 4×B2	4.94	4.19 a	11.98a	22.47a	51.44a	2.22j	58.18a	11.23a	36.91a
Zn 4×B3	4.10	3.78 bc	10.74bcde	21.57ab	50.77ab	2.42ij	57.64ab	10.45bc	35.69abcde
Zn 6×B0	4.09	3.18 ef	9.99ef	18.34e	47.00cd	3.32efgh	52.45de	8.32i	35.50abcde
Zn 6×B1	3.79	3.30 de	10.16def	19.40de	47.97abcd	3.14fgh	53.31cde	8.84gh	35.14bcdef
Zn 6×B2	3.85	3.37de	10.44cde	20.01cd	48.30abc	3.04ghi	54.62bcde	9.09fgh	35.64abcde
Zn 6×B3	3.58	3.17 ef	10.09def	19.44de	46.73cd	3.10fghi	51.72e	8.71hi	36.45ab
LSD0.05	0.740	0.365	0.769	1.160	3.060	0.635	3.120	0.428	1.250
S$\bar{x}$	0.256	0.126	0.265	0.404	1.060	0.219	1.080	0.148	0.433
Level of significance	NS	*	*	**	**	**	**	**	*
CV (%)	11.57	6.65	4.31	3.42	3.90	10.70	3.52	2.76	2.15

In a column, figures with same letter (s) or without letter do not differ significantly as per DMRT

** = Significant at 1% level of probability.

* = Significant at 5% level of probability.

NS = Non significant

Zn0 = 0 kg Zn ha^{-1}, Zn2 = 2 kg Zn ha^{-1}, Zn4 = 4 kg Zn ha^{-1} and Zn6 = 6 kg Zn ha^{-1}, B0 = 0 kg B ha^{-1}, B1 = 1 kg B ha^{-1}, B2 = 2 kg B ha^{-1} and B3 = 3kg B ha^{-1}

Table 3. Correlation matrix of different selected characters of Ujala-2016

Correlation characters	Correlation coefficient (r)	R2	Regression equation Y = mx +C
Grain yield Vs No. of effective tilllers plant-1	r = 0.902**	R^2 = 0.813	Y = 1.0352x - 0.1413
Grain yield Vs sterile spikelets spike^{-1}	r = 0.861**	R^2 = 0.742	Y = -0.4838x + 4.985
Straw yield Vs No. of grains spike^{-1}	r = 0.940**	R^2 = 0.884	Y = 0.134x - 3.0575
Grain yield Vs straw yield	r = 0.946**	R^2 = 0.895	Y = 0.5653x - 0.1593

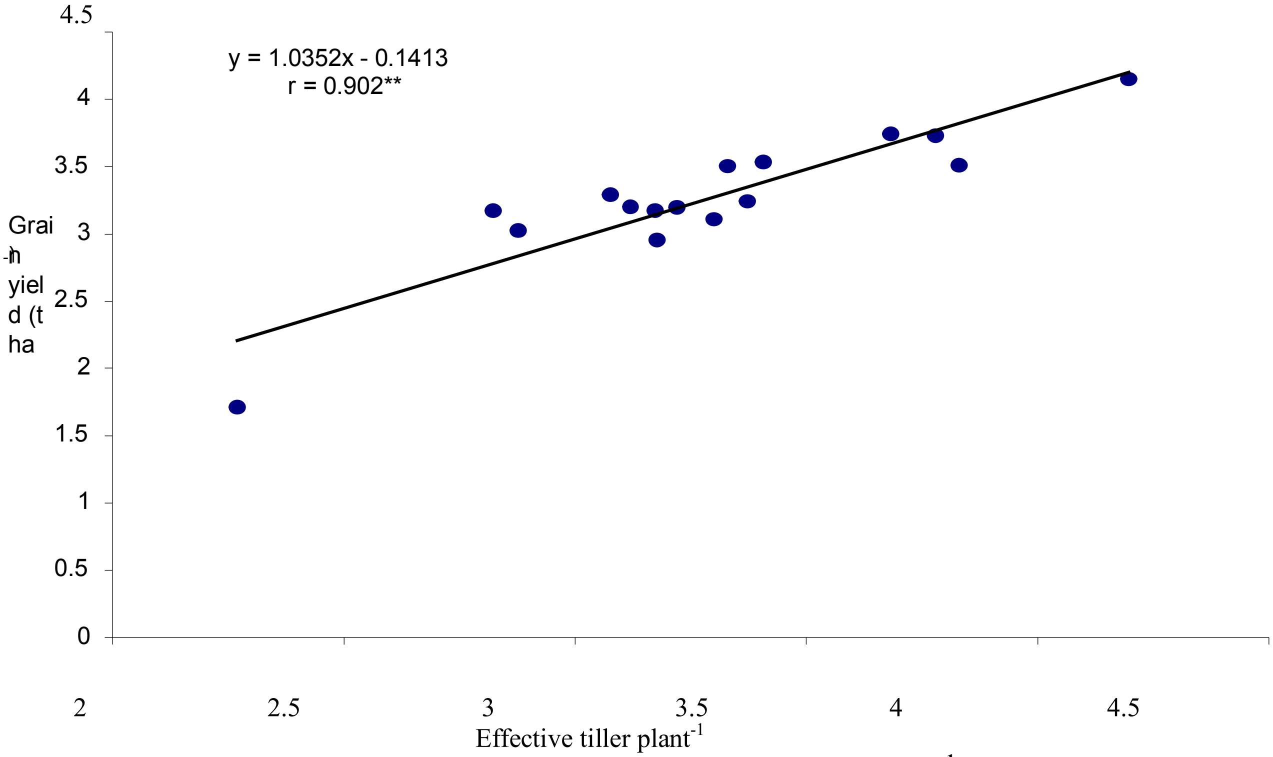

Fig. 1 Relationship between grain yield and no. of effective tillers plant^{-1} of Ujala-2016

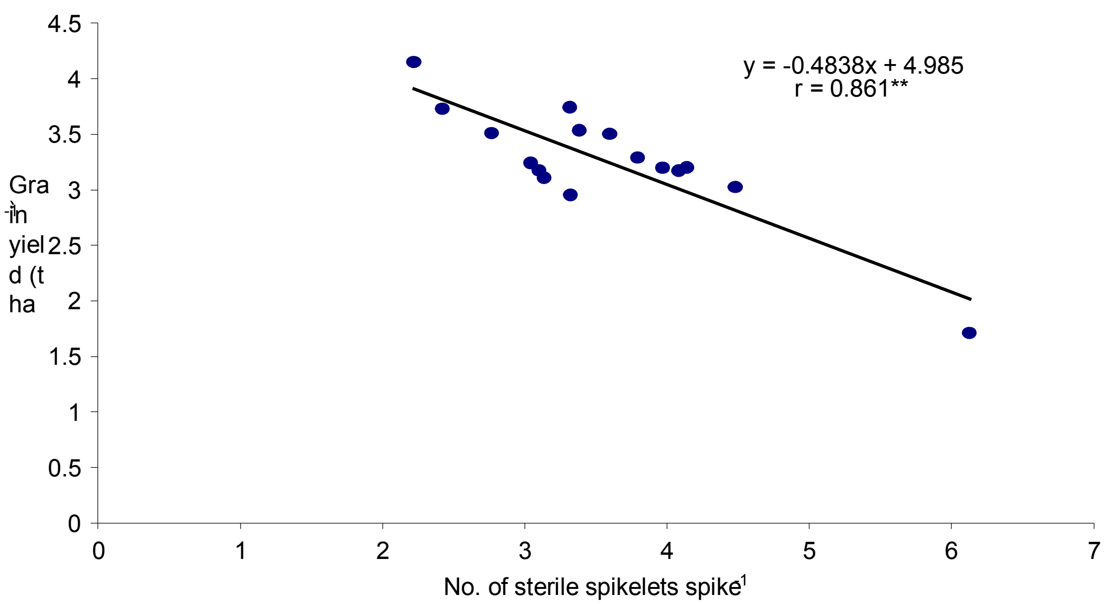

Fig. 2 Relationship between grain yield and no. of sterile spikelets spike^{-1} of Ujala-2016

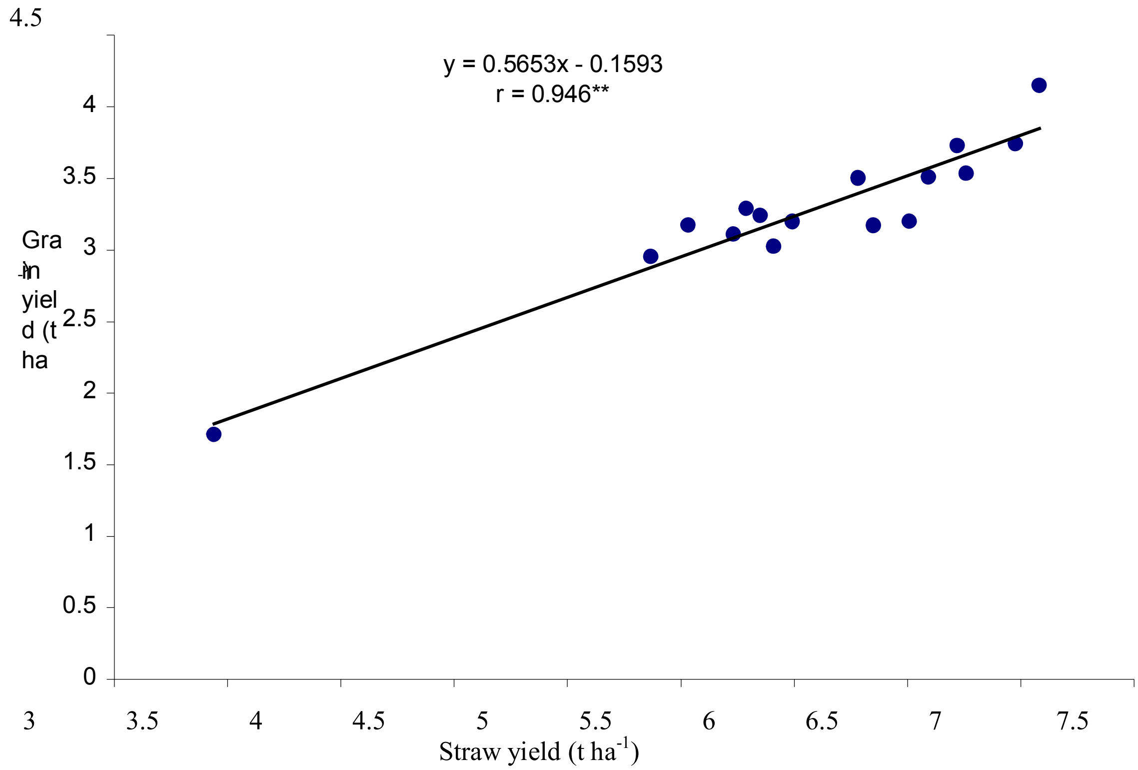

Fig. 3 Relationship between grain yield and straw yield of Ujala-2016

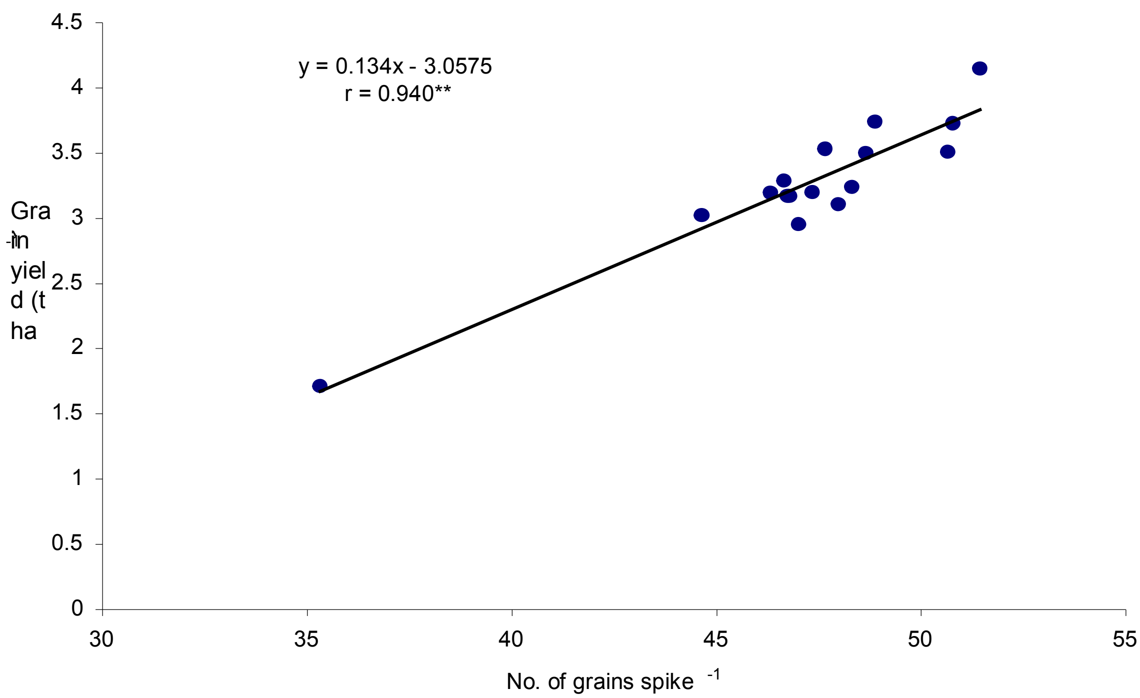

Fig. 4 Relationship between grain yield and no. of grains spike^{-1} of Ujala-2016

Significant effects on the most of the yield and yield attributing characters were observed in the interaction effects of levels of Zn and B. Plant height and total tillers plant^{-1} were found to be non-significant. The tallest plant (94.93 cm), greatest number of total tillers plant (4.94), number effective tillers plant^{-1} (4.19), longest spike length (11.98 cm), maximum number of spikelets spike^{-1} (22.47), number of grains spike^{-1} (51.44), highest 1000-grain weight (58.18 g), highest grain yield (4.15 t ha^{-1}), straw yield (7.08 t ha^{-1}), biological yield (11.23) and harvest index (36.91%) were achieved from the treatment combination of 4 kg Zn ha^{-1}× 2 kg B ha^{-1}. In contrast, the highest number of sterile spikelets spike^{-1} (6.13) was found in control treatment. Finally, except the number of sterile spikelets spike^{-1}, all the yield and yield attributing characters were found lowest in control treatment.

4. Conclusion

The overall results of the present study demonstrated that wheat may be grown successfully for obtaining maximum yield with the application of 4 kg Zn ha^{-1} and 2 kg B ha^{-1}. However, before making conclusion concerning the appropriate dose of Zn and B, the study needs further investigation in other Agro-Ecological Zones (AEZs) of Pakistan for country-wide recommendation which will be useful.

[**]Corresponding Author:
Umer Ijaz
Department of Agronomy,
University of Agriculture, Faisalabad, Pakistan.
E-mail: umermeelu@yahoo.com

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