Pure Appl. Biol., 5(4): 1260-1270, December, 2016
http://dx.doi.org/10.19045/bspab.2016.50151

Research Article

Yield response of wheat cultivars to zinc application rates and methods

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Citation
Yaser Arafat, Muhammad Shafi, Mushtaq Ahmad Khan, Muhammad Adnan, Abdul Basir, Inayat-ur-Rahman, Muhammad Arshad, Abid Khan, Nouman Saleem, Muhammad Romman, Ziaur Rahman and Jawad Ali Shah. Yield response of Wheat cultivars to zinc application rates and methods. Pure and Applied Biology. Vol. 5, Issue 4, pp1260-1270. http://dx.doi.org/10.19045/bspab.2016.50151

Received: 08/09/2016 Revised: 09/11/2016 Accepted: 14/11/2016 Online First: 18/11/2016

Abstract

To examine the effects of zinc and its application methods on yield and yield components of wheat varieties, a field experiment was conducted in randomized complete block design (RCBD) with split plot arrangement at the University of Agriculture, Peshawar during Rabi season 2013-14. There were 3 wheat varieties (Atta Habib, Siran-2010 and Janbaz) which were assigned to main plots. Four zinc levels (0, 3.5, 7.00 and 10.50 kg ha^{-1}) and 3 application methods (Broad cast, side dressing and application with seed) which were allotted to sub plots making a total of 36 treatments per replication. The results revealed significantly higher number of days to anthesis (130), grain filling duration (31 days) and number of days to maturity (160) from variety Atta Habib while, maximum grains $spike^{-1}$ (49), thousand grain weight (43.36 g), grain yield (3911kg ha^{-1}), biological yield (9173 kg ha^{-1}) and harvest index (42.14 %) were recorded for Siran-2010. Application of zinc (10.50 kg ha^{-1}) produced maximum plant height (101 cm), grains $spike^{-1}$ (58), thousand grain weight (51.26 g) grain yield (4256 kg ha^{-1}), biological yield (10521 kg ha^{-1}) and harvest index (46.45 %). Similarly, significantly Higher plant height (100 cm), grains $spike^{-1}$ (48), thousand grain weight (41.11 g), grain yield (3859 kg ha^{-1}), biological yield (9457 kg ha^{-1}) and harvest index (41.72 %) were obtained from side dressing method of zinc application. It may be concluded that Siran-2010 with application of Zn at the rate of (10.50 kg ha^{-1}) as side dressing produced relatively highest yield and yield components in wheat crop under existing agro-climatic conditions.

Keywords: Wheat; Varieties; Zinc; Application methods

Introduction

Wheat *(Triticum aestivum L.)* is considered as a chief source of food of all over the world. Under optimum management practices it has the capability to provide food and feed for rapidly growing humans and animals **[1]**. The total area occupied by wheat in Pakistan was 8.6 million hectares which produced 24.2

million tones with average yield of 2796 kg ha^{-1} while In Khyber Pakhtunkhwa area occupied by wheat was 0.72 million hectares producing 1.1 million tones with average yield of 1596 kg ha^{-1} [2]. It has been investigated that grain yield production of wheat in Pakistan is less as compared to other countries like China, Russia and USA [3]. The problem of trace nutrients deficiency in both plants and soil are increasing day by day due to intensive farming and cultivation of high yielding genotypes with application of high doses of NPK fertilizer [4]. More than 48% area cultivated under cereal crops at world level has the problem of zinc deficiency [5].

Soils of Pakistan are generally alkaline in reaction and calcareous in nature. These types of soils usually contain low amount of available micronutrients, particularly zinc deficiency is widespread in cereals that are grown on calcareous soil [6, 7]. The main soil factors affecting the availability of Zn to plants are low in total Zn contents, high pH, high calcite and organic matter contents and high concentrations of Na, Ca, Mg, bicarbonate and phosphate in the soil solution or in labile forms [8]. Wheat grown on calcareous soils and lowland rice on flooded soils are also highly prone to Zn deficiency. Zinc efficiency traits for sandy and clayey soils appear to be genetically different. Zinc efficient genotypes absorb more Zn from deficient soil; produce more dry matter and more grain yield [9]. Zinc deficiency in Pakistan soils has been recognized [10]. [11] Also reported the Zn deficiency in Khyber Pakhtunkhwa. Studies of [12] revealed the merits of Zn application to cereal crop. [13] Reported that zinc ranged between deficiency (<0.5 mg kg^{-1}) and adequate limits (>1.0 mg kg^{-1}) in Pakistan. Zinc is responsible for protein synthesis, metabolic process of plants, enhance N metabolism and un-adequate supply of Zn adversely affects protein synthesis [14]. Zinc deficiency negatively affects root growth, physiological functions and uptake of nutrients, which may lead to reduction in yield and yield components [15]. Zinc deficiency in plants adversely affects flowering and fruiting formation [16]. Trace nutrient including zinc reduce crop productivity may be due to their low contents in the soil. [17].

Application of trace nutrients including zinc may be applied through side dressing, foliar or broadcast enhanced yield and quality of wheat crop [18]. Placement of fertilizer within rows is more efficient and accessible to roots and gives best result compared to other methods of fertilization [19]. [20] Concluded that fertilization of nutrients including zinc and its application through different methods improved yield and yield components. Wheat crop growth, yield and yield attributes had positively affected with application of micro nutrients and their application methods [21]. The effects of different micro nutrients including zinc as well as its application methods had positively affected on crop growth, grains yield and yield parameters [22].

Keeping in view the importance of zinc and its application methods, the present experiment was conducted to investigate its impacts on yield and yield components of wheat varieties.

Materials and methods

Field experiment was conducted at Agricultural Research Farms of The University of Agriculture Peshawar-Pakistan during Rabi season 2013-14. Experimental site is located at 350 m above sea level. Mean annual rainfall ranged from 380-550mm. The experiment was conducted in randomized complete block design (RCBD) with split plot arrangement. Treatments were replicated three times. Wheat varieties (Siran-2010, Atta Habib and janbaz) were assigned to main plots While different levels of Zn (0, 3.50, 7.00 and 10.50 Zn kg ha^{-1}) and its application methods (Broadcast, Side dressed and application with seed) was assigned to sub plots. A sub plot size of 4 × 5 m^2 was used. zinc sulphate ($ZnSo_4$) was used as a source of zinc (Zn^+). Recommended seed rate of 120 kg ha^{-1} was used uniformly for all wheat varieties. A Basal dose of nitrogen (120 kg ha^{-1}) was applied in the form of urea in two splits (½ N before sowing and ½ N after 2nd irrigation) to all plots. All other agronomic and cultural practices were carried out uniformly. Data collected included number of days to anthesis, grain filling duration, days to physiological maturity, plant height, grains $spike^{-1}$, 1000 grain weight, grain yield, biological yield and harvest index. Data were analyzed using the statistical package MSTAT-C **[23]** means were compared using least significant differences (LSD) test at $P \leq 0.05$ upon significant F-test.

Results and discussion

Days to anthesis

Data regarding days to anthesis of wheat as affected by wheat varieties, zinc levels and its application methods are presented in (Table 1). Analysis of the data showed that wheat varieties have significant effect ($p \leq 0.05$) on number of days to anthesis. Maximum number of days to anthesis (130) was recorded for wheat variety Atta Habib followed by Siran-2010 (126) while minimum number of days to anthesis (122) was recorded for Janbaz. Our results are similar with the finding of **[24-26]** reported that possible reason for variation in number of days to anthesis might be due to genetic variable characters of wheat varieties. The data further revealed that similar value for numbers of days to anthesis (126) was counted for all Zn levels i.e. (0, 3.50, 7.00 and 10.50 kg ha^{-1}) and its application methods (Broadcast, Side dressing and application with seed). Similar results are obtained by **[27]** Revealed that uniform growth and development depends upon the genetic makeup of varieties and environmental interaction.

Grain fill duration

Data regarding grain fill duration of wheat as affected by wheat varieties, zinc levels and its application methods are presented in (Table 1). Analysis of the data showed that wheat varieties had significantly ($p \leq 0.05$) affected grain fill duration of wheat crop. Maximum days (31) to grain filling duration were recorded for wheat variety Atta Habib followed by Siran-2010 (29 days) while minimum days (27) to grain fill duration was counted for Janbaz variety. **[28, 29]** reported that alteration in grain filling duration occurred due to genetic variability among wheat varieties. Equal days (29) to grain fill duration was recorded for all the applied different Zn levels (0, 3.50, 7.00 and 10.50 kg ha^{-1}). The equal day (29) to grain filling duration was recorded in case of all Zn application methods (Broadcast, Side dressing and application with seed). Our results are in conformity with **[27]** who reported that grains fill duration depends upon exposure of crop to sun light (photoperiod) and temperature which were experienced by all the plots uniformly.

Days to physiological maturity

Data regarding days to physiological maturity of wheat as affected by wheat varieties, zinc levels and its application method are presented in (Table 1). Analysis of the data revealed that varieties, zinc levels and its application methods showed significant effect ($p \leq 0.05$) on number of days to physiological maturity of wheat. Highest number of days (160) to maturity was recorded for wheat variety Atta Habib followed by siran-2010 (157 days) which was at par with Janbaz with mean value of (157 days). Similar result is also obtained by **[24, 25]** concluded that heritable characteristics among wheat cultivars are the ultimate reason of variable number of days to physiological maturity. The data further revealed that maximum numbers of days (158) to physiological maturity was counted for zinc levels applied at the rate of7.00 and 10.50kg h^{-1}compared with minimum numbers of days (157) to physiological maturity with application of 3.50 Zn kg ha^{-1} and from control respectively. In case of application methods maximum number of days (158) to maturity was counted in Zn application as side dressing and application with seed. Minimum number of days (157) to physiological maturity was observed in broadcast method of Zn application. [27] Reported that rate of development in reproductive stage reflects the maturity of crops which mostly depend upon environmental factors.

Table 1. Days to anthesis, grain filling duration and days to maturity of wheat as affected by wheat varieties, Zinc levels and its application methods

Treatments	Days to anthesis	Grain fill duration	Days to maturity
Varieties (V)			
Siran-10	126b	29b	157b
Atta Habib	130a	31a	160a
Janbaz	122c	27c	157b
LSD(0.05)	2.56	0.98	1.50
Zinc levels (Zn)			
0	126	29	157
3.50	126	29	157
7.00	126	29	158
10.50	126	29	158
LSD(0.05)	ns	ns	ns
Application Methods (AM)			
Broadcast	126	29	157
Side dressed	126	29	158
Application with Seed	126	29	158
LSD(0.05)	ns	ns	ns
Interactions	**Significance level**		
AM × Zn	ns	ns	ns
Zn × V	ns	ns	ns
AM × V	ns	ns	ns
AM × V × Zn	ns	ns	ns

ns represents non-significant difference at $p \leq 0.05$. Means with different letters in each column are significantly different at $p \leq 0.05$ using LSD test

Plant height (cm)

Data regarding this plant character of wheat as affected by wheat varieties, zinc levels and its application methods is presented in Table 2. Statistical analysis of the data showed that varieties, different levels of zinc and its methods of application have significantly ($p \leq 0.05$) affected plant height of wheat crop. Taller plants (100 cm) were observed for variety Janbaz followed by Atta Habib (97cm) while shortest plants (96 cm) for variety Siran-2010. Similar result is also obtained by [30-32] reported that genetic variability is the major cause for difference in plant height. Among different levels of zinc taller plants (101cm) was produced by zinc level at the rate of 10.50kg ha^{-1} statistically similar value for plant height (99 cm) was also obtained for zinc level at the rate of 7.00 kg ha^{-1} followed by plant height (97 cm) for 3.50 Zn kg ha^{-1} while shorter plant height (93 cm) was calculated for control plot. [33, 34] concluded that application of zinc at the rate of 10 kg ha^{-1} produced taller plants compared with control. Among Zn application methods maximum plant height of (100 cm) was calculated for side dressing method while statistically similar value of plant height (96 cm) was calculated for both Zn application methods broadcasting and application with seed. [35] Reported maximum plant height with application of Zn at 5.00 kg ha^{-1} as side dressed application method.

Table 2. Plant height (cm), grains spike^{-1}and 1000 grain weight (g) of wheat as affected by wheat varieties, Zn levels and its application methods

Treatments	Plant height (cm)	Grains spike^{-1}	1000 grain weight (g)
Varieties (V)			
Siran-10	96bc	49a	43.36a
Atta Habib	97b	46b	39.00b
Janbaz	100a	45b	39.25b
LSD(0.05)	2.94	1.34	1.64
Zinc levels (Zn)			
0	93c	33d	31.00d
3.50	97ab	45c	36.30c
7.00	99a	51b	43.59b
10.50	101a	58a	51.26a
LSD(0.05)	2.98	1.69	1.19
Application Methods (AM)			
Broadcast	96b	46b	39.64c
Side dressed	100a	48a	41.11a
Application with Seed	96b	45b	40.86a
LSD(0.05)	2.58	1.46	1.03
Interactions	**Significance level**		
AM × Zn	ns	ns	ns
Zn × V	ns	ns	s
AM × V	ns	ns	ns
AM × V × Zn	ns	ns	ns

ns represent non-significant difference at p≤0.05. Means with different letters in each column are significantly different at p≤0.05 using LSD test

Grain spike^{-1}

Data regarding grain spike^{-1} of wheat as affected by wheat varieties, zinc levels and its application methods is presented in Table 2. Statistical analysis of the data showed significant effect ($p \leq 0.05$) of wheat varieties, Zinc and its application methods on grains spike^{-1}. Among wheat varieties Siran-2010 produced more numbers of grains spike^{-1} (49) while statistically similar grain spike^{-1} was counted for varieties Atta Habib (46) and Janbaz (45). Our results are in agreement with findings of [36, 37] who reported that variation in numbers of grains spike^{-1} occurred due to variable genetic potential of varieties for the trait. Among various Zn levels more number of grain spike^{-1} (58) was counted for Zn applied at the rate of 10.50 kg ha^{-1} followed by grain spike^{-1} (51, 45) at the rate of 7.00 and 3.50 Zn kg ha^{-1} respectively. While control plot give minimum number of grain spike^{-1} (33). Our results are similar with the findings of **[38, 34, 39]** who revealed that zinc is responsible for improved flowering induction, fruit formation and finally enhanced number of grains. Data regarding Zn application methods showed that Zn applied as a side dressing counted for maximum grains spike^{-1} (48) followed by broadcast method (46) which was statistically at par to Zn applied with seed method (45). Our findings are fruitful with finding of **[19]** who reported that application of zinc as side dressed method performed better in term of grains spike^{1}.

Thousand grain weight (g)

Data regarding thousand grain weight of wheat as affected by varieties, zinc levels and its application methods are presented in Table 2. Statistical analysis of the data showed that significant ($p \leq 0.05$) influence of varieties, Zn levels and its application methods was observed for 1000 grains weight of wheat crop. In case of wheat varieties Siran-2010 produced highest 1000 grains weight (43.36 g) followed by Atta Habib (39.00 g) which was statistically at par with Janbaz (39.25 g). Our results are in agreement with the finding of **[36, 30, 37]** who reported that variation in 1000 grains weight (g) occurred due to variable water and nutrients use efficiency of varieties. In case of various Zn levels, Zn applied at the rate of 10.50 Zn kg ha^{-1} resulted in maximum thousand grain weight (51.26 g) followed by Zn level at the rate of 7.00 kg ha^{-1} and 3.50 kg ha^{-1}with 1000 grains weight of (43.59 and 36.30 g) respectively while minimum thousand grain weight (30.00 g) was recorded from control plot. Our result is in agreement with the finding of **[40-42]** who also find out that zinc has improved water and nutrients availability to roots and consequently increased 1000 grains weight (g). Zn application as a ide dressing resulted in higher 1000 grains weight (41.11 g) which was statistically similar with Zn application with seed method with mean value of (40.86 g) and lowest thousand grain weight (39.64 g) was recorded in broadcast method of Zn application. Similar result was observed by **[35]** who obtained highest thousand grain weight in side dressing application of zinc.

Grain yield (kg ha^{-1})

Data regarding grain yield of wheat as affected by wheat varieties, zinc levels and its application methods are presented in Table 3. Statistical analysis of the data revealed that wheat Varieties, zinc levels and its application methods have significantly affected ($p \leq 0.05$) grain yield of wheat crop. In case of Wheat varieties Siran-2010 produced highest grains yield (3911) which was at par with variety Atta Habib (3778kg ha^{-1}) While minimum grains yield (3581) was produced by Janbaz. Our result is similar with the finding of **[36, 43]** who reported that genetic variability among varieties might be responsible for variable grain yield. In case of zinc levels, Zn applied at the rate of 10.50 kg ha^{-1} produced maximum grain yield (4256 kg ha^{-1}) followed by Zn used at the rate of 7.00 and 3.50 kg ha^{-1} with grains yield of (3886 and 3664 kg ha^{-1}). Similar result is also obtained by **[44, 40, 34, 45]** who concluded that application of adequate amount of zinc has improved water and nutrients availability, enhanced cell physiology which may lead to improved grains yield. Among zinc application methods side dressing produced maximum grains yield (3859 kg ha^{-1}) followed by application of Zn with seed (3716 kg ha^{-1}) while minimum grain yield (3695 kg ha^{-1}) obtained in case of broadcast method of Zn application. Similar result is also obtained by **[35]** who reported that side dressing application of zinc improved grain yield compared with other methods of Zn application.

Table 3. Grain yield (kg ha^{-1}), biological yield (kg ha^{-1}), and harvest index (%) of wheat as affected by wheat varieties, Zinc levels and its application methods

Treatments	Grain yield(kg ha^{-1})	By (kg ha^{-1})	Harvest index (%)
Varieties (V)			
Siran-10	3911a	9173a	42.14a
Atta Habib	3778a	8845b	41.03b
Jan-baz	3581b	8820ab	39.42c
LSD(0.05)	169.59	226.16	1.07
Zinc (Zn)			
0	3221d	6898d	34.89d
3.50	3664c	8924c	38.56c
7.00	3886b	9440b	43.56b
10.50	4256a	10521a	46.45a
LSD(0.05)	131.24	229.91	0.95
Application Methods (AM)			
Broadcast	3695c	8693b	39.95b
Side dressed	3859a	9457a	41.72a
Application with Seed	3716b	8688ab	40.92a
LSD(0.05)	113.66	199.11	0.83
Interactions	**Significance level**		
AM × Zn	ns	ns	ns
Zn × V	ns	ns	ns
AM × V	ns	ns	ns
AM × V × Zn	ns	ns	ns

ns represent the significant and non-significant difference at $p \leq 0.05$. Means with different letters in each column are significantly different at $p \leq 0.05$ using LSD test

Biological yield (kg ha^{-1})

Data regarding biological yield of wheat as affected by wheat varieties, zinc levels and its application methods are presented in Table 3. Statistical analysis of the data showed that wheat varieties, Zn levels and its application methods have significantly affected ($p \leq 0.05$) biological yield of wheat. Among varieties Siran-2010 produced highest biological yield (9173 kg ha^{-1}) followed by Atta Habib (8845 kg ha^{-1}) which was at par with Janbaz (8820 kg ha^{-1}). Similar result was also obtained by [46, 37] who reported that difference in biological yield of wheat varieties might be due to their variable plant height characteristics and growth habit. In case of zinc Levels, Zn applied at the rate of 10.50 kg ha^{-1} produced maximum biological yield (10521 kg ha^{-1}) followed by application of Zn at the rate of 7.00 and 3.50 kg ha^{-1} produce biological yield of (9440 and 8924 kg ha^{-1}) while control plot give lower biological yield (6898 kg ha^{-1}) Similar result was also obtained by [40]. Who find out that application of zinc in adequate amount has improved water and nutrients availability and photosynthetic activities which may lead to improved biological yield. Application of zinc as a side dressed method produced maximum biological yield (9457 kg ha^{-1}) followed by broadcast (8693 kg ha^{-1}) which was at par with application of Zn with seed (8688 kg ha^{-1}) . same result was also obtained by [22] concluded that application of Zn as side dressed application method has improved mobility of Zn to roots and enhanced plants growth that resulted highest biological yield.

Harvest index (%)

Data regarding harvest index of wheat as affected by wheat varieties, zinc levels and its application methods are presented in Table 3. Statistical analysis of the data showed that wheat varieties, Zn levels and its application methods have significantly affected ($p \leq 0.05$) harvest index of wheat. Among wheat varieties maximum harvest index (42.14%) was calculated for Siran-2010 followed by Atta Habib (41.03%) while minimum harvest index was calculated for Janbaz (39.42%). Our results are similar with finding of [47, 37] reported that difference in harvest index might be due to genetic variability of varieties. Among zinc levels, Application of Zn at the rate of 10.50 kg ha^{-1} produced highest harvest index (46.45%) followed by harvest index (43.56 and 38.56 %) at levels of (7.00 and 3.50 kg Zn ha^{-1}) respectively. Lower harvest index (34.89 %) was calculated for control plot. Similar result is also obtained by [48] Revealed that application of zinc has positively changed harvest index of wheat. Among application methods, Zn applied as a side dressing results in highest harvest index (41.72%) which was statistically at par with application method with seed with mean value of (40.92%) and lowest harvest index (39.95%) was recorded in broadcast method of Zn application. Our results are similar with finding of [19] Reported that application of Zn as side dressing has led to maximum harvest index.

Conclusions and recommendations

Highest grain yield of (3911 kg ha^{-1}) was produced by Siran-2010 followed by Atta Habib (3778 kg h^{-1}) as compared with lowest grain yield (3581 kg ha^{-1}) produced by Janbaz. Application of zinc at the rate of 10.5 kg ha^{-1} produced maximum grain yield (4256 kg h^{-1}) followed by zinc levels of (7.00 and 3.50 Kg ha^{-1}) with grain yield of (3886 and 3664 kg ha^{-1}) respectively while control produced lower grain yield of (3221 kg ha^{-1}). Among application methods of Zinc, side dressing method ranked 1st with production of grain yield (3859 kg ha^{-1}) followed by application of Zn with seed method (3221 kg ha^{-1}) while broadcast method of Zn application ranked 3rd with production of (3695 kg ha^{-1}). It is suggested that, cultivation of Siran-2010 with application of 10.50 kg Zn ha^{-1} as side dressing is relatively best combination for obtaining good yield and yield components of wheat crop under existing agro-climatic conditions.

Authors' contributions

Designed the experiment: M Shafi & M Adnan, Performed the experiments: MA Khan, Y Arafat & A Basir, Analyzed the data: IU Rahman & M Arshad, Contributed the materials: N Saleem & A Khan, Wrote the paper: JA Shah, M Romman & Z Rahman.

Acknowledgement

The authors are thankful to the University of Agriculture Peshawar for conducting this experiment on their resources.

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