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Original Research Article

Response of different Levels of Zinc and Iron on Seed Quality, Yield and Seed Quality Attributing Characters of Wheat (*Triticum aestivum* L.)

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A B S T R A C T

An experiment was conducted during *Rabi* 2011-12 and 2012-13 at Chandra Shekhar Azad University of Agriculture & Technology, Kanpur to find out the response of different levels of zinc and iron on seed quality, yield and seed quality attributing characters of wheat cv. K-9162 (Gangotri) in Factorial Randomized Block Design with three replications. Four doses of each zinc and iron was applied and standard procedure for experimentation was followed. Significant effect of zinc and iron was noted on seed quality, seed yield and seed quality attributing characters of wheat. The dose 10 kg Zinc and 5 kg Iron ha^{-1} either in singly or in combination of both have been found to be most appropriate in influencing seed quality, seed yield and seed quality attributing characters of wheat var. K 9162.

Keywords

Zinc, Iron, Quality parameters, Yield, Wheat

Introduction

India is the second largest producer of wheat in the world next only to China and the crop has registered fastest growth to Indian agriculture. In world, wheat is cultivated over an area of 304.18 m ha with total production and productivity of 92.29 million tonnes and 3.03 t ha^{-1}, respectively. However in India, it is cultivated an area of 30.40 m ha with total production and productivity of 94.88 mt and 3.18 t ha^{-1}, respectively. In Uttar Pradesh, the acreages, production and productivity of wheat is about 9.67 m ha, 30.01 mt and 3.11 t ha^{-1}, respectively [1]. As main staple food, wheat continues to assume greater significance in the years to come both from grain productivity as well as quality points of view. Providing required quantity of quality grains to the growing population is an everlasting challenge to the researchers. Based on the present rate of population growth of 1.5 per cent and per capita consumption of 180 g of wheat per day in the country, India will have to produce 109 mt of wheat by 2020 [2]. Zinc has been found to play an important role in physiological activities of plants. It is involved in diverse metabolic activities, influences the activities of hydrogenase and carbonic anhydrase, synthesis of cytochrome and the stabilization of ribosomal fractions and auxin metabolism.

It acts as on activator of various enzymes in the plant. Zinc plays an important role in protein synthesis and participates in chlorophyll formation. Therefore, being a constituent of chlorophyll, it helps in chlorophyll formation and encourages vegetative plant growth and seed quality. The extent of iron (Fe) deficiency in India is next to that of Zn. Iron deficiency is a widespread nutritional problem in developing countries, causing impaired physical activity and cognitive development, as well as maternal mortality. Iron is a component of many enzymes associated with nitrogen reduction, fixation, and lignin formation. It plays a role in energy transfer within the plant. Iron is momentous for photosynthesis and chlorophyll formation [3]. Iron is involved in the production of chlorophyll. Chlorophyll is the minute “sun panels” which plants use to take energy from the sun and also able to give plants their green colour. Iron is one of the most important element essential for plant growth [4]. It also plays an essential role in nucleic acid metabolism [5]. Hence, this attempt was made to study the effect of basal dose of zinc and iron application on seed quality, yield and seed quality attributing characters of wheat.

Materials and Methods

This research work was carried out for two consecutive years 2011-12 and 2012-13 at Chandra Shekhar Azad University of Agriculture & Technology, Kanpur. Geographically, Kanpur is situated in sub tropical zone at $25^0 26'$ and $26^0 58'$ N latitude and $79^0 32'$ and $80^0 34'$ E longitude with an altitude of 125.90 m above Mean Sea Level. The mean annual rainfall is about 816 mm. Soil texture of experimental site was sandy loam having fine sand 62.50 and 62.20 %, silt 23.80 and 24.00 %, clay 13.70 and 13.80 %, pH 8.52 and 8.54, organic carbon 0.44 (Low) and 0.47 % (Low), EC 0.42 and 0.41 ds m^{-1}, available N 221 (Low) and 225 kg ha^{-1} (Low), available P 19 (Medium) and 20 kg ha^{-1} (Medium), available K 245 (Medium) and 249 kg ha^{-1} (Medium), available zinc 0.9 (Low) and 1.0 kg ha^{-1} (Low) and available iron 9.2 (Normal) and 9.4 kg ha^{-1} (Normal) during 2011-12 and 2012-13, respectively. The experiment was conducted on wheat var. K-9162 (Gangotri). Four doses of zinc (0, 5, 10, 15 Kg ha^{-1}) and iron (0, 2.5, 5.0, 7.5 Kg ha^{-1}) were applied as basal dose and experiment was laid out in Factorial RBD with three replications. Fertilizers applied below the seeds for maximum uptake [6]. The feeder dose of NPK @ of 150:75:60 Kg ha^{-1} was also applied. The sources of nutrients were urea, diammonium phosphate, muriate of potash, zinc sulphate monohydrate (33%) and ferrous sulphate (19%). Standard procedure for experimentation was followed. Observations were recorded on seed quality characters viz. Protein content in seed (%), Test weight of seed (g), Seed length (mm), Seed breadth (mm), Germination (%), Seedling length (cm), Seedling dry weight (g), Seedling Vigour Index-I, Seedling Vigour Index-II and Seed yield (q ha^{-1}). Data were statistically analysed following the procedure laid down by [7].

Protein content was analyzed by “Infratec (Grain analyser)” in the Quality testing laboratory, Directorate of Wheat Research, Karnal, Haryana (India) with the help of Principal Scientist Dr. Seva Ram. For test weight of seed 1000 seeds in three replications were counted manually from seed lot of each treatment and weight in (g) up to two decimal places with the help of the digital balance. Ten seeds in three replications of each treatment were taken out randomly from seed lot. These seeds were put on scale neck to neck and side to side length and breadth were measured in mm, respectively, and averaged. Germination test was carried out by following the procedure out lined by ISTA rules [8]. Three replications of 100 seeds each for every treatment were uniformly placed on moist germination paper and rolled with wax paper to prevent moisture evaporation during test period. Samples were placed in plastic tray in stand upright position and these trays were shifted to seed germinator maintained at 20±2°C temperature and 90±3 per cent relative humidity. The sample was allowed to germinate for the prescribed period. Germination percentage was recorded on 8^{th} days by counting normal seedlings. On 8^{th} day of germination, ten seedlings were selected randomly from each replication and seedling length was measured in cm and averaged. Randomly taken ten normal seedlings which were used for recording the seedling measurement were kept in beakers and dried for 48 hours in a hot air oven maintained at 60-80^{0}C temperature. These dried seedlings were removal and cooled in a desicator for 30 minutes. Then the weight was recorded and express in grams. The seedling vigour index-I was calculated by multiplying the per cent seed germination and total seedling length (cm) of all treatments separately. The seedling vigour index was determined by using the formula suggested by [9] as below.

Seedling Vigour Index-I = Germination Percentage x Seedling Length (cm)

Seedling vigour index-II = Germination Percentage x Seedling dry weight (g)

Results and Discussion

Seed quality parameters

It is evident from the Table 1 that application of various doses of zinc (Zn) influenced the protein content during both year and in pooled. It was evident from the findings that the applied levels of Zinc (5, 10 and 15 kg ha^{-1}) were significant superior on control (0 kg Zn ha^{-1}). Enhancing trends of protein content was observed as the level of zinc (Zn) increased. The maximum protein content (%) was exhibited by application of Zn_3 i.e. 11.93, 12.42 and 12.17 % but it showed at par performance to Zn_2 i.e. 11.89, 12.38 and 12.14 % during I year II year and pooled mean, respectively. It is apparent from the Table 1 that the various dose of iron (Fe) significantly influenced the protein content (%) during I year and in pooled but iron doses did not show significant effect with respect to protein content (%) during 2012-13. However, numerically maximum protein content (12.13 %) was observed in treatment Fe_2 and lowest was recorded in Fe_0 (11.94 %) in II year analysis. Table 1 indicates that in 2011-12 and in pooled analysis the treatment Fe_2 showed significantly maximum (11.63 and 11.88 %) protein content which was at par to Fe_3 (11.61 and 11.84 %) and Fe_1, (11.54 and 11.79 %) treatment while significantly minimum protein content (11.42 and 11.68 %) was found in control. The interaction of zinc and iron did not show significant effect with respect to protein content (%) during both the year and in pooled. Whereas, numerically highest protein content i.e. 12.10, 12.63 and 12.37 % were observed in the treatment combination $Zn_2 \times Fe_2$ and lowest were recorded in $Zn_0 \times Fe_0$ viz. 10.83, 11.50 and 11.17 % in I year, II year and in pooled data, respectively. Similar result was report by [10], [11].

The influence of various doses of zinc (Zn) was found significantly effective for increasing test weight during both years and in pooled. During 2012-13 and in pooled analysis Zn_2 showed significantly maximum (48.12 and 47.06 g) test weight of wheat but was at par to Zn_3 (47.99 and 47.01 g) and significantly lowest was found in control i.e. 45.95 and 44.77 g. While during I year Zn_3 (46.09 g) showed significantly maximum test weight of wheat seed (Table 1) but it was at par to Zn_2 (45.99 g) and significantly lowest test weight was found in control (43.59 g). During pooled analysis Fe_3 treatment showed maximum (46.46 g) test weight of wheat seed but was at par to Fe_2 (46.30 g) and Fe_1 (45.95 g) and significantly minimum was found in control (45.54 g).

During I and II year iron (Fe) dose did not show significant effect on test weight of seed. However, numerically maximum test weight of wheat (Table 1) was found in treatment Fe_3 (45.31 and 47.60 g) and lowest was recorded in treatment Fe_0 (44.51 and 46.57 g). The interaction of zinc and iron expressed non significant effect with respect to test weight of seed. These results are in conformity with the findings of [12].

Application of different level of zinc (Zn) was significantly influenced the seed length during both year and in pooled. Table 1 disclosed that level of zinc Zn_3 to Zn_1, and Zn_1 to Zn_0 showed at par performance in I year, II year and in pooled. Significantly maximum seed length i.e. 7.66, 8.70 and 8.18 mm was observed in Zn_2 treatment while significantly minimum seed length i.e. 7.41, 8.43 and 7.92 mm of wheat was found in control during I year, II year and in pooled data. Application of different level of iron (Fe) influenced non significantly to seed length during both year and in pooled. Numerically highest seed length i.e. 7.58, 8.58, and 8.08 mm was observed in Fe_2 treatment while minimum seed length i.e. 7.46, 8.50 and 7.98 mm (Table 1) was recorded in control during I year, II year and in pooled analysis. The interaction effect between zinc (Zn) and iron (Fe) were also found to be non significant on seed length. This study was supported by [13].

During I year and II year Zn_2 and Zn_3 treatment showed at par performance to each other with respect to seed breadth with significantly higher values i.e. 3.47, 3.99 and 3.43, 3.95 mm, respectively. In pooled analysis Zn_2 showed significantly maximum seed breadth i.e. 3.73 mm which was at par to Zn_3 i.e. 3.69 mm (Table 1). Numerically, minimum i.e. 3.35, 3.85 and 3.60 mm was found in Zn_0 in I year, II year and pooled analysis, respectively. However, Zn_1 was at par to Zn_1 and Zn_2 in I year and Zn_1 in II year. Application of Fe_2 produced maximum seed breadth (3.69 mm) which was at par to Fe_3 (3.67 mm), Fe (3.67) and Fe_0 (3.65). During I year and II year iron doses showed non significant effect on seed breadth (Table 1). However, numerically maximum seed breadth (3.43 and 3.94 mm) was found in Fe_2 and minimum (3.38 and 3.91 mm) was recorded in Fe_0 (control). The interaction of zinc and iron expressed non significant effect with respect to seed breadth during both year and in pooled. Similar type result observed [14].

The application of zinc showed significant effect on germination percentage of wheat during both year and in pooled. The treatment Zn_2 showed significantly highest (95.39, 95.86 and 95.71 %) germination percentage while minimum in Zn_0 (94.33, 95.23, and 94.79 %).

During I and II year analysis the treatment Zn_1 and Zn_3 were at par to each other while in pooled analysis treatment Zn_2 (95.71 %) was at par to Zn_1 (95.34 %). During I year Table 4.21 showed that Fe_2

treatment expressed significant highest (95.26 %) germination but was at par to Fe_1 (95.09 %). The treatment Fe_3 (94.79 %) also showed at par performance to Fe_0 (94.61 %). During II year treatment Fe_3 showed significantly highest (95.91 %) germination but treatment Fe_0, Fe_1 and Fe_2 was at par to each other.

Similarly in pooled analysis highest (95.43 %) germination was found in Fe_2 but was at par to Fe_3 and Fe_1 treatments (Table 1). In case of interaction during I year, II year and pooled analysis the application of Zn_2 x Fe_2 produced significantly higher germination (96.08, 96.30 and 96.19 %) which was at par to Zn_2 x Fe_1 in I year, Zn_3 x Fe_3, Zn_2 x Fe_1, Zn_2 x Fe_3 and Zn_1 x Fe_3, in II year (Table 3). The treatment Zn_0 x Fe_0 showed significantly minimum germination (93.70, 95.00 and 94.37 %) during I year, II year and in pooled data. These results are in conformity with findings of [15].

Table 2 disclosed that various level of Zinc expressed significant difference among them on seedling length (cm). During I year, II year and pooled, treatment Zn_2 produced highest seedling length (24.56, 26.58 and 25.57 cm) while minimum seedling length (23.31, 25.32 and 24.32 cm) was obtained in control. Effect of various doses of iron viz. 2.5, 5.0 and 7.5 kg ha^{-1} were found significantly effective on seedling length (cm) during both years and pooled.

Treatment Fe_2 produced highest seedling length i.e. 24.09, 26.14 and 25.12 cm while minimum seedling length i.e. 23.67, 25.70 and 24.68 cm of wheat was recorded in without iron (Fe_0) applied plots. But during I year treatment Fe_2 (24.09 cm) showed at par performance to Fe_3 (24.09) and in II year Fe_3 (25.98 cm) was at par to Fe_1 (25.88 cm) with respect of seedling length. In case of interaction during I year, II year and in pooled analysis application of Zn_2 x Fe_2 produced maximum seedling length (24.92, 26.97 and 25.95 cm) followed by Zn_2 x Fe_3 (Table 4).

The minimum seedling length was observed in combination of Zn_0 x Fe_0 (22.96, 25.08 and 24.02 cm). But during 2011-12 treatment Zn_2 (24.92 cm) showed at par performance to Zn_3 (24.77 cm) in respect of seedling length. Similar result was observed [16].

Regarding seedling dry weight, Zn_2 (0.334, 0.435 and 0.385 g) was significantly superior over other in both years and pooled, but it was at par to Zn_3 (0.327, 0.428 and 0.378 g) for producing higher seedling dry weight.

The mean value of both year and pooled have showed that the iron doses significantly influenced the seedling dry weight (g). Treatment Fe_2 (0.327, 0.428 and 0.378 g) was statistically at par with Fe_3 (0.324, 0.425 and 0.375 g) in both years and pooled (Table 2).

The interaction of zinc and iron had shown significant effect on seedling dry weight (g) for 2011-12, 2012-13 and pooled (Table 5). Application of Zn_2 x Fe_2 produced maximum seedling dry weight i.e. 0.345, 0.449 and 0.397 g followed by Zn_2 x Fe_1 (0.335, 0.435 and 0.385 g) and the minimum seedling dry weight was observed in the combination of Zn_0 x Fe_0 during both year and pooled [17].

All zinc level showed significant difference to each other on SVI-I, but Zn_3 treatment was at par to Zn_1 in I and II year.

Table.1 Effect of Zinc and Iron on seed yield and seed quality parameters of wheat variety Gangotri (K-9162)

Levels of Zinc & Iron (kg ha[-1])	Seed quality parameters														
	Protein content in seed (%)			Test weight of seed (g)			Seed length (mm)			Seed breadth (mm)			Germination (%)		
	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled
0.0 (Zn_0)	11.02	11.59	11.30	43.59	45.95	44.77	7.41	8.43	7.92	3.35	3.85	3.60	76.23 (94.33)	77.38 (95.23)	76.81 (94.79)
5.0 (Zn_1)	11.36	11.79	11.57	44.41	46.41	45.41	7.49	8.49	7.99	3.40	3.92	3.66	77.18 (95.08)	77.90 (95.61)	77.54 (95.34)
10.0 (Zn_2)	11.89	12.38	12.14	45.99	48.12	47.06	7.66	8.70	8.18	3.47	3.99	3.73	77.60 (95.39)	78.50 (95.86)	78.05 (95.71)
15.0 (Zn_3)	11.93	12.42	12.17	46.09	47.99	47.01	7.53	8.49	8.01	3.43	3.95	3.69	77.01 (94.95)	78.07 (95.73)	77.54 (95.34)
SE (d)	**0.05**	**0.08**	**0.05**	**0.35**	**0.54**	**0.32**	**0.06**	**0.06**	**0.04**	**0.04**	**0.05**	**0.02**	**0.15**	**0.18**	**0.12**
CD (p=0.05)	**0.11**	**0.17**	**0.10**	**0.72**	**1.11**	**0.65**	**0.12**	**0.13**	**0.09**	**0.09**	**0.10**	**0.05**	**0.31**	**0.37**	**0.23**
0.0 (Fe_0)	11.42	11.94	11.68	44.51	46.57	45.54	7.46	8.50	7.98	3.38	3.91	3.65	76.58 (94.61)	77.90 (95.61)	77.24 (95.12)
2.5 (Fe_1)	11.54	12.04	11.79	44.93	46.97	45.95	7.53	8.51	8.02	3.42	3.93	3.67	77.20 (95.09)	77.73 (95.48)	77.46 (95.29)
5.0 (Fe_2)	11.63	12.13	11.88	45.27	47.32	46.30	7.58	8.58	8.08	3.43	3.94	3.69	77.43 (95.26)	77.90 (95.61)	77.66 (95.43)
7.5 (Fe_3)	11.61	12.07	11.84	45.31	47.60	46.46	7.53	8.51	8.02	3.41	3.93	3.67	76.81 (94.79)	78.33 (95.91)	77.57 (95.37)
SE (d)	**0.05**	**0.08**	**0.05**	**0.35**	**0.54**	**0.32**	**0.06**	**0.06**	**0.04**	**0.04**	**0.05**	**0.02**	**0.15**	**0.18**	**0.12**
CD (p=0.05)	**0.11**	**NS**	**0.10**	**NS**	**NS**	**0.65**	**NS**	**NS**	**NS**	**NS**	**NS**	**0.05**	**0.31**	**0.37**	**0.23**

NS- non-significant, Back values are presented in parenthesis.

Table.2 Effect of Zinc and Iron on seed yield and seed quality attributing characters of wheat variety Gangotri (K-9162)

Levels of Zinc & Iron (kg ha^{-1})	Seed yield and seed quality attributing characters														
	Seedling length (cm)			Seedling dry weight (g)			Seedling Vigour Index-I			Seedling Vigour Index-II			Seed yield (q ha^{-1})		
	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled
0.0 (Zn_0)	23.31	25.32	24.32	0.298	0.403	0.350	2199.23	2413.96	2306.59	28.19	38.43	33.31	33.65	33.97	33.79
5.0 (Zn_1)	23.86	25.86	24.86	0.319	0.420	0.369	2268.45	2472.15	2370.30	30.33	40.12	35.22	35.39	35.77	35.58
10.0 (Zn_2)	24.56	26.58	25.57	0.334	0.435	0.385	2349.84	2558.81	2454.33	31.94	41.87	36.91	38.27	39.53	38.90
15.0 (Zn_3)	24.01	25.94	24.98	0.327	0.428	0.378	2279.28	2483.68	2381.48	31.05	40.96	36.00	37.95	38.51	38.23
SE (d)	**0.05**	**0.06**	**0.04**	**0.004**	**0.004**	**0.003**	**7.38**	**7.74**	**5.35**	**0.23**	**0.24**	**0.17**	**0.46**	**0.44**	**0.35**
CD (p=0.05)	**0.10**	**0.13**	**0.08**	**0.008**	**0.008**	**0.006**	**15.07**	**15.81**	**10.69**	**0.47**	**0.49**	**0.33**	**0.93**	**0.91**	**0.71**
0.0 (Fe_0)	23.67	25.70	24.68	0.309	0.412	0.361	2242.63	2452.74	2347.69	29.39	39.27	34.33	35.48	36.07	35.78
2.5 (Fe_1)	23.90	25.88	24.89	0.318	0.420	0.369	2272.35	2476.50	2374.43	30.22	40.22	35.22	36.08	36.71	36.40
5.0 (Fe_2)	24.09	26.14	25.12	0.327	0.428	0.378	2299.05	2514.04	2406.55	31.15	41.21	36.18	36.84	37.50	37.17
7.5 (Fe_3)	24.09	25.98	25.04	0.324	0.425	0.375	2282.76	2485.32	2384.04	30.74	40.69	35.71	36.86	37.50	37.18
SE (d)	**0.05**	**0.06**	**0.04**	**0.004**	**0.004**	**0.003**	**7.38**	**7.74**	**5.35**	**0.23**	**0.24**	**0.17**	**0.46**	**0.44**	**0.35**
CD (p=0.05)	**0.10**	**0.13**	**0.08**	**0.008**	**0.008**	**0.006**	**15.07**	**15.81**	**10.69**	**0.47**	**0.49**	**0.33**	**0.93**	**0.91**	**0.71**

NS- non-significant

Table.3 Interaction Effect of Zinc and Iron on Germination (%) in Wheat variety Gangotri (K-9162)

Iron / Zinc	2011-12				2012-13				Pooled			
	Fe_0	Fe_1	Fe_2	Fe_3	Fe_0	Fe_1	Fe_2	Fe_3	Fe_0	Fe_1	Fe_2	Fe_3
Zn_0	75.46 (93.70)	76.19 (94.30)	76.19 (94.30)	77.08 (95.00)	77.08 (95.00)	77.48 (95.30)	77.48 (95.30)	77.48 (95.30)	76.27 (94.37)	76.84 (94.82)	76.84 (94.82)	77.28 (95.15)
Zn_1	77.08 (95.00)	77.48 (95.30)	77.48 (95.30)	76.69 (94.70)	78.17 (95.80)	77.48 (95.30)	77.48 (95.30)	78.46 (96.01)	77.63 (95.41)	77.48 (95.30)	77.48 (95.30)	77.58 (95.37)
Zn_2	77.14 (95.05)	78.03 (95.70)	78.58 (96.08)	76.64 (94.66)	78.17 (95.80)	78.49 (95.31)	78.91 (96.30)	78.46 (96.01)	77.65 (95.43)	78.26 (95.86)	78.75 (96.19)	77.55 (95.35)
Zn_3	76.64 (94.66)	77.08 (95.00)	77.48 (95.30)	76.82 (94.80)	78.17 (95.80)	77.48 (95.30)	77.71 (95.47)	78.91 (96.30)	77.41 (95.25)	77.28 (95.15)	77.60 (95.39)	77.87 (95.58)
SE (d)	**0.30**				**0.36**				**0.23**			
CD (p=0.05)	**0.62**				**0.73**				**0.47**			

NS- non-significant, Back values are presented in parenthesis.

Table.4 Interaction Effect of Zinc and Iron on Seedling length (cm) in Wheat Variety Gangotri (K-9162)

Iron / Zinc	2011-12				2012-13				Pooled			
	Fe_0	Fe_1	Fe_2	Fe_3	Fe_0	Fe_1	Fe_2	Fe_3	Fe_0	Fe_1	Fe_2	Fe_3
Zn_0	22.96	23.31	23.44	23.54	25.08	25.26	25.44	25.49	24.02	24.29	24.44	24.52
Zn_1	23.52	23.82	24.01	24.09	25.50	25.81	26.03	26.09	25.51	24.82	25.02	25.09
Zn_2	24.15	24.40	24.92	24.77	26.24	26.46	26.97	26.67	25.20	25.43	25.95	25.72
Zn_3	24.03	24.05	24.01	23.97	25.97	26.01	26.12	25.66	25.01	25.03	25.06	24.82
SE (d)	**0.10**				**0.13**				**0.08**			
CD (p=0.05)	**0.20**				**0.26**				**0.16**			

NS- non-significant

Table.5 Interaction Effect of Zinc and Iron on Seedling dry weight (g) in Wheat Variety Gangotri (K-9162)

Iron / Zinc	2011-12				2012-13				Pooled			
	Fe_0	Fe_1	Fe_2	Fe_3	Fe_0	Fe_1	Fe_2	Fe_3	Fe_0	Fe_1	Fe_2	Fe_3
Zn_0	0.288	0.295	0.302	0.307	0.393	0.401	0.407	0.411	0.340	0.348	0.354	0.359
Zn_1	0.304	0.314	0.328	0.330	0.407	0.415	0.427	0.429	0.355	0.364	0.378	0.380
Zn_2	0.324	0.335	0.345	0.333	0.425	0.435	0.449	0.432	0.374	0.385	0.397	0.383
Zn_3	0.322	0.327	0.332	0.327	0.423	0.431	0.430	0.429	0.373	0.379	0.381	0.378
SE (d)	**0.008**				**0.008**				**0.006**			
CD (p=0.05)	**NS**				**NS**				**0.012**			

NS- non-significant

Table.6 Interaction Effect of Zinc and Iron on Seedling Vigour Index-I in Wheat Variety Gangotri (K-9162)

Iron / Zinc	2011-12				2012-13				Pooled			
	Fe_0	Fe_1	Fe_2	Fe_3	Fe_0	Fe_1	Fe_2	Fe_3	Fe_0	Fe_1	Fe_2	Fe_3
Zn_0	2150.91	2198.96	2210.85	2236.19	2382.92	2408.44	2425.60	2438.87	2266.91	2303.70	2318.22	2337.53
Zn_1	2234.08	2271.16	2288.34	2288.20	2433.53	2460.27	2498.56	2496.26	2333.81	2365.71	2393.45	2388.23
Zn_2	2310.68	2334.23	2409.26	2345.21	2510.04	2549.01	2615.77	2551.43	2414.86	2441.61	2512.52	2443.32
Zn_3	2274.84	2285.07	2287.77	2269.44	2475.49	2488.30	2516.24	2454.70	2375.17	2386.69	2402.01	2362.07
SE (d)	**14.75**				**15.48**				**10.68**			
CD (p=0.05)	**30.13**				**31.62**				**21.38**			

NS- non-significant

Table.7 Interaction Effect of Zinc and Iron on Seedling Vigour Index-II in Wheat Variety Gangotri (K-9162)

Iron / Zinc	2011-12				2012-13				Pooled			
	Fe_0	Fe_1	Fe_2	Fe_3	Fe_0	Fe_1	Fe_2	Fe_3	Fe_0	Fe_1	Fe_2	Fe_3
Zn_0	27.27	27.86	28.45	29.17	37.34	38.23	38.83	39.32	32.31	33.05	33.64	34.24
Zn_1	28.85	29.91	31.30	31.24	38.81	39.57	41.03	41.07	33.83	34.74	36.17	36.16
Zn_2	30.93	32.05	33.22	31.56	40.77	41.87	43.55	41.30	35.85	36.96	38.39	36.43
Zn_3	30.52	31.07	31.62	30.99	40.16	41.20	41.42	41.05	35.34	36.14	36.52	36.02
SE (d)	**0.46**				**0.48**				**0.33**			
CD (p=0.05)	**0.95**				**0.97**				**0.67**			

NS- non-significant

Treatment Zn_2 recorded highest seedling vigour index-I 2349.84, 2558.81 and 2454.33 while minimum SVI-I viz. 2199.23, 2413.96 and 2306.59 was obtained in without zinc applied plot during I year, II year and pooled, respectively. Treatment Fe_2 produced significantly highest SVI-I viz. 2299.05, 2514.04 and 2406.55 of wheat as compared to rest doses of Iron (Fe). The minimum SVI-I viz. 2242.63, 2452.74 and 2347.69 was reported in control, but treatment Fe_3 was at par to Fe_1 during I year, II year and pooled data, respectively (Table 2). In interaction during I year, II year and pooled analysis (Table 6) application of Zn_2 x Fe_2 produced significantly highest SVI-I (2409.26, 2615.77 and 2512.52) and minimum SVI-I was observed in treatment combination of Zn_0 x Fe_0 (2150.91, 2382.92 and 2266.91), Similar type result observed [18].

It is visualised from the mean value (Table 2) of both years and pooled that zinc doses significantly influenced the SVI-II. The significantly maximum SVI-II were recorded with Zn_2 (31.94, 41.87 and 36.91) and followed by Zn_3, Zn_1 and Zn_0 in both year and pooled. The mean value of both years and pooled showed that the iron (Fe) doses were significantly influenced the SVI-II. The significantly maximum SVI-II was exhibited by Fe_2 i.e. 31.15, 41.21 and 36.18 during I year, II year and pooled analysis, respectively but during I year Fe_2 (31.15) was at par to Fe_3 (30.74). The interaction of zinc and iron showed significant effect on SVI-II during both year and pooled (Table 7). During I year, II year and in pooled analysis application of Zn_2 x Fe_2 produced significantly highest SVI-II (33.22, 43.55 and 38.39) and minimum SVI-II was fond in treatment combination of Zn_0 x Fe_0 (27.27, 37.34 and 32.31) [19].

Seed Yield

During I year and pooled analysis Zn_2 showed significantly maximum (38.27 and 38.90 q ha^{-1}) seed yield but at par to Zn_3 (37.95 and 38.23 q ha^{-1}). Whereas during II year Zn_2 showed significantly higher seed yield (39.53 q ha^{-1}) of wheat followed by Zn_3 (38.51 q ha^{-1}). During both year and pooled analysis minimum seed yield of wheat i.e. 33.65, 33.97 and 33.79 q ha^{-1} was obtained in control. It is apparent from the Table 2 that application of Fe_2 showed significantly maximum (36.84 q ha^{-1}) seed yield which was at par to Fe_3 (36.86 q ha^{-1}) and Fe_1 (36.08 q ha^{-1}) and minimum was found in control (35.48 q ha^{-1}) during I year analysis. During II year Fe_3 dose of iron showed maximum seed yield i.e. 37.50 q ha^{-1} which was at par to Fe_2 (37.50 q ha^{-1}) and Fe_1 (36.07 q ha^{-1}) treatments. Similarly during pooled analysis Fe_3 treatment of iron showed maximum seed yield i.e. 37.18 q ha^{-1} which was at par to Fe_2 i.e. 37.17 q ha^{-1} and significantly lower seed yield was found in control (Fe_0) and Fe_1 i.e. 35.78 and 36.40 q ha^{-1}, respectively. Interaction of zinc (Zn) and iron (Fe) did not show significant influence on seed yield (q ha^{-1}) however, numerically maximum seed yield viz. 39.02, 40.32 and 39.67 q ha^{-1} in Zn_2 x Fe_2 and minimum viz. 32.86, 33.22 and 33.04 q ha^{-1} in Zn_0 x Fe_0 during I year, II year and pooled analysis, respectively [20], [21].

Thus, it is concluded that application of 10 kg zinc and 5.0 kg iron ha^{-1} either singly or in combination of both have been found most appropriate and economical for achieving the maximum seed quality, seed yield and seed quality attributing characters of wheat cv. K-9162 (Gangotri).

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