The Bioscan 9(4): 1479-1483, 2014
AN INTERNATIONAL QUARTERLY JOURNAL OF LIFE SCIENCES
www.thebioscan.in

EFFECT OF ZINC FERTILIZATION ON GROWTH, YIELD AND QUALITY OF WHEAT GROWN UNDER AGRO-CLIMATIC CONDITION OF KYMORE PLATEAU OF MADHYA PRADESH, INDIA

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KEYWORDS
Growth
Quality
Kymore plateau
Yield
Wheat
Zinc

Received on :
01.06.2014

Accepted on :
27.10.2014

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ABSTRACT

Field experiments was conducted under All India Co-ordinated Research Project on "Micro, secondary nutrients and pollutant elements in soils and plants" during two consecutive years 2010-11 and 2011-12 with fallow-wheat cropping sequence at the Research Farm of Department of Soil Science and Agricultural Chemistry, J.N. Krishi Vishwa Vidyalaya, Jabalpur (M.P.) to study the response of Zn application on growth, yield attributes, yield and quality of wheat in a Zn deficient soil (Vertisol). The recommended dose of N, P and K was applied @ 120 N: 60 P_2O_5: 40 K_2O kg ha^{-1} in combination with Zn @ 0, 1.25, 2.5, 5, 10 and 20 kg ha^{-1} as zinc sulphate. The results revealed that the application of increasing levels of Zn @ 5, 10 and 20 kg ha^{-1} significantly increased the growth parameters *viz.,* plant height, plant population, number of leaves per plant, dry weight per plant and leaf area index, yield attributing characters like length of earhead, number of grains per ear head, number of effective tillers per meter and 1000-grain weight, grain and straw yields as well as harvest index with the increasing levels of Zn at different growth stages as compared to NPK fertilization alone. Further, the quality parameters like protein (crude and true) in wheat grain were markedly increased by the application of increasing levels of Zn as compared to NPK alone. Thus, the present studies indicated that the application of 10 kg Zn ha^{-1} with 100 % NPK on wheat crop enhanced the productivity as well as maintained the quality of wheat grain.

INTRODUCTION

In India, wheat (*Triticum aestivum*) is the most important cereal crop after rice, grown under diverse agro-climatic conditions. India ranks second in the world in production (93.90 million tonnes) of wheat, from an area of 29.90 million ha with the productivity of 3.14 tonnes ha^{-1} and contributes almost one-third to total food grain of India (Anonymous, 2013). Madhya Pradesh contributes 16.35 and 11.27 per cent to the total area and production of wheat in the country. However, the productivity is still very low (2.16 tonnes ha^{-1}). Stagnation in wheat production, lower productivity and inferior quality of the produce is due to various constraints including inadequate and imbalanced nutrient application (Prasad, 2012). Hence, it is of utmost importance to increase the productivity of wheat in the state by way of better plant nutrition and other suitable agronomical practices.

Micronutrient plays many important roles in plant nutrition and crop production. Zinc is one of the eight essential trace elements or micronutrients for the normal healthy growth and reproduction of crop plants. Crops are likely to respond to application of Zn if soils are deficient in Zn because the same plays a significant role in various enzymatic and physiological activities in plant body. It also helps in formation of chlorophyll and auxins. Zinc is the most common deficient micronutrient element in soil in the world and about 50 per cent soils of India are deficient in Zn (Gibbson, 2006). The Zn deficiency in soils of Kymore Plateau and Satpura hills zone is about 70.3 per cent. In Kymore plateau, rice-wheat and soybean-wheat are the two most dominant cropping's in which 70.3 and 73.2 per cent soils, respectively, are Zn deficient (Khamparia *et al.,* 2010). Zinc as a plant nutrient which has received considerable attention because of its occurrence in small quantities in the soil and criticality for plant growth. Keeping this in view, the present investigation was carried out to study the influence of Zn application on growth parameters, yield attributing components, yield and quality of wheat in a Zn deficient medium black (Vertisol) soil.

MATERIALS AND METHODS

Soils and its characteristics

The present investigation is a part of an ongoing All India Co-ordinated Research Project on "Micro, secondary nutrients and pollutant elements in soils and plants", with fallow-wheat cropping sequence during the two consecutive years 2010-11 and 2011-12, at two different Zn deficient sites, at the Research Farm of the Department of Soil Science and Agricultural Chemistry, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh, India. Both the experimental sites (23°10'' N latitude and 79°57'' E longitude) have a semi-arid and sub-tropical climate with a characteristic feature of dry summer and cold winter. In winter season *i.e.* from November to February months, the temperature ranges from 4 to 33ºC and the relative humidity varies from 70 to 90 per cent. Dry and warm weather usually prevails during the months of March to June. The temperature in the month of May attains a value as high as 46ºC. Monsoon season extends from mid-June to mid-September. The temperature during this period varies from 25 to 35ºC and the relative humidity ranges from 70 to 80 per cent. The total annual rainfall varies from 1000 to 1500 mm with the mean value of around 1350 mm. The length of growing period ranges from 150 to 180 days. The soil of the experimental sites falls under Vertisol and belongs to Kheri-series of fine montmorillonite, Hyperthermic family of *Typic Haplusterts* popularly known as "medium black soil". The textural class of soil is clayey, neutral in reaction, non-saline, non-calcareous, medium in organic carbon content, low in available N, medium in available P and K and deficient in DTPA-extractable Zn. The key soil properties (0-15 cm soil depth) are presented in Table 1.

Experimental details

The experiment was designed and conducted with different Zn levels (0, 1.25, 2.5, 5, 10 and 20 kg Zn ha^{-1}) having four replications arranged in the randomized block design. Two blocks were separated with a gap of 1.50 m, whereas individual plots (5m × 8 m) were separated with a distance of 1.25 m. The 100 % NPK was commonly applied in all the treatments (Zn levels) and he recommended dose of nutrients was 120 N: 60 P_2O_5: 40 K_2O kg ha^{-1}. A basal dose of 60:60:40 N, P_2O_5, and K_2O was applied before sowing of wheat, through urea, super phosphate and muriate of potash fertilizers. Remaining 60 kg N was applied to wheat crop in two splits first half at 21–25 days (after the first irrigation) and the rest at 51-55 days after sowing. The doses of Zn @ 0, 1.25, 2.50, 5, 10 and 20 kg ha^{-1} were given through zinc sulphate fertilizer before sowing of wheat. Wheat (GW-273) was sown during 2-3rd week of Dec. 2010-11 and 2011-12 of *rabi* season with hand drill using seed rate 120 kg ha^{-1}. It is irrigated at critical phases of crop growth and as when needed. All crop management and protection measures were followed. Weed control practices were included hoeing along with appropriate weedicides spray. Insects and diseases were kept under check by following suitable control measures. Wheat crop were harvested at maturity (120 days after sowing) and yield data were recorded after threshing. The crude protein content was determined by multiplying the nitrogen content value of grain with 5.73, which also includes non-protein nitrogen. To get true protein content, deduce the non-protein nitrogen from crude protein content and then multiplying with the factor (A.O.A.C., 1965).

Statistical analysis

The data were analyzed statistically as per standard ANOVA technique outlined by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

The results obtained from the present investigations as well as relevant discussion based on the data pooled over two consecutive years (2010-11 and 2011-12) have been presented under following heads.

Effect of Zn application on growth parameters, yield attributes, yield, harvest index and quality of wheat

Growth characters

Plant height

The plant height increased with the increasing levels of Zn at 15, 30, 60, 90 and 120 days after sowing (DAS) as compared to NPK fertilization alone (Table 2). The application of 10 kg Zn ha^{-1} significantly increased plant height by 19.80, 18.68, 14.89 and 19.11 per cent at 15, 60, 90 and 120 DAS, respectively over control, while higher level of Zn *i.e.* 20 kg Zn ha^{-1} was statistically at par with that of 10 kg Zn ha^{-1}. However, the plant height at 30 DAS increased significantly with the application of 20 kg Zn ha^{-1} only as compared to control, while the other levels of Zn *viz.,* 1.25, 2.5 and 5 kg Zn ha^{-1} were increased plant height non-significantly. The rate of growth was most rapid in vegetative phase up to 90 days after sowing and slowed at reproductive phase. Maurya *et al.*, 2010 also observed that the plant height of wheat was found to be significantly affected and increased with the soil application of 12 and 16 kg Zn ha^{-1} up to 90 days after sowing and slow in reproductive phase. This might be due to more availability and absorption of Zn from soil solution which caused more seed respiration rate, oxygen carrier, auxin metabolism, synthesis of cytochrome and stabilization of ribosomal fractions, faster cell division and cell elongation and root and shoot development ultimately increased plant height of wheat. However, increasing the rates of photosynthesis and chlorophyll formation due to the Zn, accelerated the meristem activity of plant that led to progressive increase in internode length Mehandi *et al.* (2012). These results are in conformity with those of Singh *et al.* (2012).

Plant population

It is obvious from the data presented in table 2 that the plant population did not change significantly with the increasing levels of Zn at 15, 30, 60 and 90 DAS and same to that of application of NPK alone, but it was slightly declined at 120 DAS, however, the differences did not touch to the level of significance at all the stages and both the years of experimentation. Inadequate and imbalanced plant nutrients interfered with normal seed germination and growth function, which ultimately resulted in lower plant population. Plant population increased with the increasing levels of Zn which might be due to continuous supply of major (NPK) and micro-nutrients specially Zn at the time of seed germination and critical phases of crop growth. A minute decline in plant population occurred at 120 DAS due to the intra-specific competition between crop plant for growth resources like macro and micro-nutrients, space, moisture and light. Moreover, some dead tissues due to pathogenic infection, injury and damage done by insect-pest and high wind velocity during dough and maturity stages were responsible factors for declining the plant population (Kibe and Singh, 2003). These results confirm the finding of Ananda and Patil (2007).

Leaf area index

A perusal of the data (Table 2) reveals that the leaf area index was increased with increasing levels of Zn at different DAS. The leaf area index significantly increased with the application of 10 kg Zn ha^{-1} by 15.58, 18.20 and 16.16 at 30, 60 and 90

DAS, respectively. However, the application of 20 kg Zn ha^{-1} was statistically at par with 10 kg Zn ha^{-1} at different DAS. The application of 5 kg Zn ha^{-1} also seems to be significant in increasing the leaf area index by 8.97 only at 90 DAS. These findings may be attributed to the fact that Zn causes cell elongation, act as principal component and catalyst of N metabolism, various enzymatic and hormonal activities, increasing the rates of chlorophyll formation, protein synthesis and photosynthetic area and activities and thereby increased leaf area index at different days after sowing Nawab *et al.* (2006). Moreover, Zn accumulates dry matter at a faster rate per unit leaf area per unit time by reducing death of tillers and senescence of leaf at different days after sowing Ram *et al.* (2012). The above results are in agreement with the evidence presented by Mehandi *et al.* (2012) who observed an increased leaf area index at different DAS with the application of Zn to soil.

Number of leaves per plant and dry weight per plant (g)

The number of leaves per plant increased with the increasing Zn levels at different successive growth stages over control, but slightly reduced at dough stage as compared to milking stage (Table 3). The application of 10 kg Zn ha^{-1} significantly increased the number of leaves per plant at tillering, earhead milk and dough stages by 19.94, 16.51, 17.50 and 16.62 per cent, respectively, as compared to control. However, the application of 20 kg Zn ha^{-1} was statistically at par with 10 kg Zn ha^{-1} at all the growth stages. The application of 5 kg Zn ha^{-1} was also found to be significant in increasing number of leaves by 13.24 per cent and statistically at par with 10 and 20 kg Zn ha^{-1} only at tillering stage.

Similarly, the increasing levels of Zn enhanced dry weight per plant at different growth stages over control, but slightly reduced at dough stage as compared to milk stage (Table 3). The application of 10 kg Zn ha^{-1} significantly increased the dry weight per plant at tillering, earhead milk and dough stages by 19.71, 15.45, 14.87 and 19.50 per cent, respectively, as compared to control. However, the application of 20 kg Zn ha^{-1} was statistically at par with 10 kg Zn ha^{-1} at all the growth stages.

The increase in number of plant leaves might be due to the faster cell division and cell elongation within the plant. Zinc acts as a functional, structural or regulatory co-factor and is involved in many enzymatic activities. However, it is required for synthesis of tryptophan and production of growth hormones such as indole acetic acid. It is a constituent of enzymes like carbonic anhydrase, superoxide dismutase, alcoholic dehydrogenase, transfer of photosynthates from source to sink and also involved in nitrogen metabolism. However, the number of leaves per plant and dry weight per plant slightly reduces at dough stage over milk stage that may due to the reduction of all the functional activities like physiological and metabolic within the plant and leaf shedding effects at maturity Gosawmi (2007). These findings are also corroborated with the findings reported by Soleymani and Shahrajabian (2012).

Length of earhead

It is evident from table 3 that the length of earhead increased significantly with the application of 10 kg Zn ha^{-1} by 17.08 and 20.67 per cent at milking and dough stages, respectively, as compared to NPK fertilization alone. However, the application of 20 kg Zn ha^{-1} also significantly increased the length of earhead over control but statistically at par with 10 kg Zn ha^{-1} while, the length of earhead was slightly decreased at dough stage as compared to milking stage in all Zn levels. This may be due to increasing rates of photosynthesis and chlorophyll formation which accelerates the meristem activity of plant that led to progressive increase in internode length. Similar results have been reported by Abbas *et al.,* (2010).

Yield attributing components

Effective tillers, Number of grains per earhead and 1000-

Table 1: Physico-chemical properties of soil of two experimental sites

Properties	Content Site-I (2010-11)	Site-II (2011-12)
Sand (%)	25.3	25.1
Silt (%)	17.9	17.9
Clay (%)	56.7	56.8
Soil pH (1:2.5)	7.2	7.0
Electrical conductivity (dS m^{-1})	0.30	0.24
Organic carbon (%)	0.63	0.68
Calcium carbonate (%)	2.40	3.00
Available Nitrogen (kg ha^{-1})	219.0	216.6
Available Phosphorus (kg ha^{-1})	18.9	18.2
Available Potassium (kg ha^{-1})	330.3	329.7
DTPA extractable-Zn (mg kg^{-1})	0.53	0.56

Table 2: Effect of Zn application on growth characters of wheat grown in a Vertisol (data pooled over 2 year)

Levels of Zn(kg ha^{-1})	Various growth parameters at different days after sowing (DAS)											
	Plant height (cm)					Plant population (m^{-2})					Leaf area index	
	15 DAS	30 DAS	60 DAS	90 DAS	120 DAS	15 DAS	30 DAS	60 DAS	90 DAS	120 DAS	30 DAS	60DAS	90 DAS
0 (Control)	5.48	20.66	57.28	73.33	83.39	236.50	236.75	237.25	237.38	231.88	1.66	3.24	4.02
1.25	5.53	20.73	57.72	73.90	84.30	237.88	239.13	240.63	240.25	236.00	1.67	3.26	4.05
2.5	5.64	21.39	61.38	75.37	88.09	240.13	240.63	239.75	241.00	236.63	1.72	3.38	4.10
5	5.93	22.50	63.63	78.25	93.02	242.13	242.63	242.75	243.50	239.50	1.82	3.50	4.38
10	6.57	23.13	67.98	84.25	99.32	244.38	245.00	245.38	246.13	242.13	1.92	3.83	4.66
20	6.62	23.69	68.69	87.59	99.87	247.00	247.88	249.25	248.50	245.75	1.99	3.88	4.74
SEm (±)	0.22	0.89	2.39	3.02	3.50	1.01	2.50	3.22	3.66	5.84	0.07	0.13	9.24
C.D. (P = 0.05)	0.64	2.56	6.92	8.73	10.10	NS	NS	NS	NS	NS	0.20	0.38	0.17

DAS - Days after sowing; SEm - Standard error of mean; C.D. - Critical difference; NS – Non-significant

Table 3: Effect of Zn application on growth characters of wheat grown in a Vertisol (data pooled over 2 year)

Levels of Zn(kg ha^{-1})	Various growth parameters at different growth stages									
	Number of leaves per plant				Dry weight per plant (g)				Length of earhead (cm)	
	Tillering	Earhead	Milk	Dough	Tillering	Earhead	Milk	Dough	Milk	Dough
0 (Control)	5.90	7.50	10.06	9.88	1.45	18.89	21.93	21.68	9.99	8.95
1.25	5.99	7.56	10.14	9.96	1.46	19.03	22.07	21.88	10.16	8.99
2.5	6.20	7.77	10.31	10.19	1.49	19.40	22.76	22.49	10.34	9.33
5	6.68	8.32	11.15	10.77	1.59	20.53	24.08	24.17	10.91	9.69
10	7.08	8.74	11.82	11.55	1.73	21.81	25.20	25.90	11.69	10.80
20	7.09	8.98	11.98	11.62	1.74	22.48	26.03	25.98	11.94	10.86
SEm (±)	0.24	0.31	0.42	0.40	0.06	0.76	0.91	0.90	0.40	0.38
C.D. (P=0.05)	0.70	0.90	1.20	1.17	0.17	2.20	2.64	2.59	1.15	1.08

Table 4: Effect of Zn application on yield attributing components and yield of wheat grown in a Vertisol (data pooled over 2 year)

Levels of Zn(kg ha^{-1})	Different yield attributing characters yield and quality parameters at harvest							
	Number of effective tillers (m^{-1} row length)	Number of grain per earhead	1000-grain weight(g)	Yield(t ha^{-1})		Harvest index (%)	Protein (%)	
				Grain	Straw		Crude	True
0 (Control)	355.48	44.75	36.61	3.88	4.76	44.97	10.02	9.12
1.25	358.84	45.10	37.09	3.93	4.81	44.98	10.42	9.41
2.5	367.49	46.46	37.89	4.04	4.88	45.15	11.09	9.86
5	383.08	49.16	40.49	4.24	5.09	45.37	11.86	10.36
10	411.73	53.31	43.45	4.62	5.42	46.19	12.22	11.00
20	421.31	53.41	43.58	4.66	5.44	46.07	12.33	11.21
SEm (±)	14.17	1.78	1.46	0.16	0.19	0.59	0.25	0.27
C.D. (P=0.05)	40.94	5.15	4.21	0.45	0.56	NS	0.72	0.78

grain weight

At harvest, the application of 10 kg Zn ha^{-1} significantly increased yield attributing characters *viz.,* the number of grains per ear head, number of effective tillers (m^{-1}) and 1000-grain weight (g) by 19.11, 15.82 and 18.62 per cent, respectively, over control (Table 4). However, the application of 20 kg Zn ha^{-1} also increased all the yield attributing characters significantly but statistically at par with 10 kg Zn ha^{-1}. The increase in yield attributing characters like length of earhead, number of grain per ear head, number of effective tillers (m^{-1}) and 1000-grain weight (g) etc. with the application of Zn has been reported by Bameri *et al.,* (2012). Such effects of Zn application might be due to pivotal role of Zn in crop growth, involving in photosynthesis processes, respiration and nitrogen metabolism-protein synthesis. Zn plays an important key role in biosynthesis of IAA, regulating the auxin concentration in plant and other biochemical and physiological activates and initiation of primordia for reproductive parts and thus ascribed the beneficial effect of to better translocation of desired metabolites to the yield-contributing parts of plant.

Yield and harvest index

The grain and straw yields as well as harvest index increased with the increasing levels of Zn as compared to NPK alone (Table 4). Zn fertilization @ 10 kg ha^{-1} enhanced both grain and straw yields significantly by 19.19 and 14.26 per cent, respectively, as compared to control. However, the application of 20 kg Zn ha^{-1} was also significant in increasing grain and straw yields by 20.15 and 14.26 per cent, respectively, over control but statistically at par with 10 kg Zn ha^{-1}. The harvest index was also increased, though non-significantly with the increasing levels of Zn as compare to control. This was perhaps due to abundant supply of Zn nutrition and balanced NPK, which increased the protoplasmic constituents, accelerates the process of cell division and elongation, photosynthesis processes, respiration, nitrogen metabolism-protein synthesis, other biochemical and physiological activates. This in turn increased the values of all growth and yield attributing parameters, which finally reflected in increased both grain and straw yields as well as harvest index. Our results are in line with Mukherjee (2012) and Sharma *et al.* (2013) which showed that the soil application of Zn had economical and long-term effects on enhanced crop production on Zn deficient soils.

Effect of Zn application on quality parameters of wheat grain

The quality of wheat depends on their inherent chemical compositions, which have a response function in various enzymatic activities in grain. The results of the present study on the effect of various Zn levels on quality of wheat *viz.,* crude and true protein content in wheat grain are presented in table 4.

Crude protein content

It is observed from the data presented in table 4 that the crude protein in wheat grain was markedly increased by the application of increasing Zn levels. The application of Zn @ 2.5, 5, 10 and 20 kg ha^{-1} significantly increased crude protein content in wheat grains by 10.59, 18.34, 21.89 and 23.03 per cent over control. This might be due to that application of Zn increased N-metabolism, which enhanced accumulation of amino acids and drastically increased the rate of protein synthesis and consequently, protein content in grain. Zn application in soil enhanced the Zn concentration in the plant which associated with RNA and ribosome induction the result of which accelerates protein synthesis (Sonune *et al.,* 2001).

The results are in consonance with the findings of Mishra (2012).

True protein content

The data presented in table 4 revealed that the true protein (deduced non-protein nitrogen from crude protein) in wheat grain increased with the increasing Zn levels. The application of Zn @ 2.5, 5, 10 and 20 kg ha^{-1} significantly increased true protein content in wheat grains by 8.17, 13.63, 20.71 and 22.98 per cent as compared to control plot. This could be due to increased conversion of N to protein compounds and the build-up of free amino acids and amides in the plant with Zn application (Kharub and Gupta, 2003). These conditions are an evidence for the importance of Zn in protein synthesis and its production in grain. The present results are in conformity with those reported by Pable *et al.,* (2010).

ACKNOWLEDGMENTS

This research was supported by the Department of Soil Science and Agricultural Chemistry, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P.), India and Indian Institute of Soil Science, Bhopal (M.P.), India.

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