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Influence of phasing and different levels of zinc application on growth parameter and yield attributing characters of cotton and soybean in Vertisol

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Abstract
The field experiment was conducted to study effect of phasing and levels of Zinc application on yield of cotton and Soybean and soil fertility status during *kharif* season 2017-18 and 2018-19 at Research Farm, All India Co-ordinated Research Project on Micro and Secondary Nutrients and Pollutant Elements in Soils and Plants, Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The experiment was laid in a Factorial randomized block design with two factors *viz*, Factor A as phasing of zinc application and factor B as levels of Zinc application. The significantly highest Growth parameter recorded with Alternate year application of zinc followed by zinc application in every year and first year.

Keywords: Zinc phasing, levels, growth parameter, vertisols, alternate year

1. Introduction

Cotton is one of the important cash as well as fibre crop and play vital role in the history and civilization of mankind, with enormous potential in textile industries and is a means of livelihood for millions of farmers and those concerned with its trade, processing, manufacturing and other allied industries. No agricultural commodity in the world exercised a profound influence on economy as cotton had done from the time immemorial. Therefore, it is popularly known as white gold. Cotton seed contains about 15-20 percent oil and is used as vegetable oil and in soap industries. After extraction of oil, the left over cake is proteinous which is used as cattle feed. It is the king among the fibre crops, taking into consideration the economic impact it generates.

Soybean is one of the important oilseed as well as leguminous crop. It is the cheapest and richest source of high quality protein (40%). It supply most of the nutritional constituents essential for human health. Soybean occupies an intermediate position between legumes and oilseed. Soybean helps to builds up the soil fertility by fixing atmospheric nitrogen through nodules. Symbiotically soybean fixes nitrogen and leaves about 25 percent for succeeding crop. All these qualities have made it an ideal crop in rotation. In India, the area under this crop increased due to its high yielding potential and multifarious industrial uses. Soybean is called as boon of malnourished world because of its high nutritive value mainly due to its high protein (40%), oil (20%) and carbohydrate (35%). Soybean is triple beneficial crop and is now making headway in Indian Agriculture (Pable *et al.*, 2010) [8]. In India it is mainly grown as ‘oilseed crop’. Hence, soybean is called as “Wonder bean” or “Miracle bean”. Soybean occupies an intermediate position between legumes and oilseed.

Zinc is essential micronutrient for the normal healthy growth and reproduction of the crop plants. The translocation of Zn from root to shoot meristems helps in regulation of auxin concentration in plant which promotes flower setting and helps in proper development of fruits/grains and carbohydrate translocation. Zinc is a metal component of a series of enzymes and chlorophyll formation. The main function of zinc in plant is largely as activator of enzymes *viz.*, carbonic anhydrase, alcohol dehydrogenase, glutamic dehydrogenase etc. Zinc content of plants also plays an important role in plant reproduction. Its deficiency inhibits at different stages of plant reproductive development such as initiation of flowering, floral development, male and female gametogenesis, fertilization and seed development. The physiological effects of Zn deficiency in pollen function, fertilization and reproductive development of plants was reported by Pandey *et al.* (2006) [9].

Micronutrient deficiency has become a limiting factor for crop productivity in many parts of the world. Zn is the most widespread productivity constraint in rainfed production (Srinivasarao *et al.* 2009) [14]. The deficiency of micronutrient may emerge when the supply of micronutrients to the soil is less compared to removal through crop harvest which in turn limits crop productivity (Shukla *et al.* 2009) [12]. In severe deficiency conditions, the yield loss could reach as high as 100% due to omission of micronutrients in the cropping system. Yield loss with omission of Zn fertilization was reported as 10% in India (Shukla *et al.* 2009) [12].

Food and Agriculture Organization (FAO) has determined that zinc is the most commonly deficient micronutrient in agricultural soils; almost 50 percent of agricultural soils are Zn deficient. Plants growing on potentially zinc-deficient soils have reduced productivity and contain very low concentrations of zinc in the edible parts (such as in cereal grains). Therefore, zinc deficiency represents a serious nutritional and health problem in human and cattle populations, especially in the developing world where cereal-based foods are the dominating source of diet. Therefore, the present investigation was carried out to assess the impact of phasing and different levels of Zn application on productivity of cotton and soybean in Vertisols.

2. Materials and Methods

2.1 Climate

Akola is situated at 307.41 meters above mean sea level at 220 42' North latitude and 770 02' East longitude and lies in subtropical continental climate. The climate of Akola is characterized by a hot summer and general dryness throughout the year except during South-West monsoon (June to 15th Sept.). Major rainfall (80 percent) received in the month of June to September i.e. in monsoon season; however, 20 percent rainfall received during post monsoon season. Akola receives an annual mean precipitation of 805.6 mm in about 46 days and grouped under assured rainfall zone. During monsoon July is the wet month with 253.1 mm average monthly rainfall. The mean maximum temperature varies from 29.0 °C to about 42.7 °C in May, whereas, the mean minimum temperature varies from 10.3 °C during winter to 27.6 °C in summer. The data collected on rainfall, number of rainy days, temperature, relative humidity, sunshine hours and evaporation at meteorological observatory, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during the period of experimentation (2017-18 and 2018-19).

2.2 Experimental Site

The experiment 'Influence of phasing and different levels of zinc application on yield of cotton and soybean in Vertisol' Conducted during 2017-18 and 2018-19 at Research Farm, All India Co-ordinate Research Project on Micro and Secondary Nutrients and Pollutant Elements in Soils and Plants, Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. This experiment was superimposed on the ongoing experiment which was started during the year 2013-14 under AICRP on Micro and Secondary nutrients. The present experiment was conducted on same site and same randomization.

2.3 Soil of experimental site

The soil of experimental site was deep black swell shrink, Montmorillonitic mineralogy with clay texture and classified under Vertisols. The initial soil properties at the start of experiment (kharif, 2013-14) was slightly alkaline (8.26), non- saline (0.29 d S m-1), moderately calcareous (8.13%) and medium in organic carbon (5.30 g kg-1). The available nitrogen was low (216.2 kg ha-1), medium in available phosphorus (14.17 kg ha-1) and high in available potassium (346.2 kg ha-1) while marginal in available sulphur (12.42mg ka-1). The experimental soil was deficient in DTPA – zinc (0.48 mg kg-1) and sufficient in DTPA- Fe, Mn and Cu.

2.4 Experimental layout

The experiment was laid in a Factorial randomized block design with two factors *viz*, Factor A as phasing of zinc application and factor B as levels of Zinc application with 12 treatments (1 control) and three replications. Factor a (3 phasing of Zn) and factor b (4 levels of Zn).

2.5 Treatment details

Factor (a): Phasing of Zinc application (P)

P1 - once in six years
P2 - Alternate year
P3 - Every year

Factor (b): Levels of soil application of zinc (Zn)

Zn1 - 2.5 kg Zn ha^{-1}
Zn2 - 5 kg Zn ha^{-1}
Zn3 - 7.5 kg Zn ha^{-1}
Zn4 - 10 kg Zn ha^{-1}

2.6 Methods adopted

The seed of cotton and soybean was purchased from market and sown in kharif season by dibbling and drilling respectively at the rate 12-15 kg^{-1} for cotton (Ajit-199 BGII) for soybean @ 75 kg ha^{-1} (JS-335). For the first year of cotton crop the Recommended Dose Fertilizers N, P_2O_5, K_2O was applied @ 60:30:30 basal doses out of this 50% of nitrogen, phosphorus and potassium were applied through urea, di-ammonium phosphate, muriate of potash and 50% of N was applied at 30 DAS through urea. Soil application of zinc was carried as per treatments (Zn1, Zn2, Zn3, Zn4) at the time of sowing @ (2.5, 5, 7.5, 10 kg Zn ha^{-1}) through zinc sulphate ($ZnSO_47H_2O$). $ZnSO_4$ was mixed with FYM and applied in soil to treatment plots. During second year for soybean crop the RDF of N, P2O5, K2O was 30:75:30. Soil application through urea, di-ammonium phosphate and murate of potash carried as basal dose at the time of sowing and zinc was applied as per treatments.

2.7 Statistical analysis: The test of statistical significance to the experimental data was down as per procedure described by Gomez and Gomez (1984).

3. Results and Discussion

3.1 Growth parameter and Yield attributing characters.

a) Plant height: The data in relation with growth and yield attributing characters of cotton *viz,* plant height, number of bolls and boll weight as influenced by various treatments are presented in Table 1.

From the data, it is observed that plant height recorded in range of 91.22 to 104.40 cm due to phasing of zinc application (Factor A) and found significant. The highest plant height (104.40 cm) was observed in alternate year zinc application (P_2). It could be noticed that, the reduction in plant height in treatment of every year zinc application (P_3) as compared with alternate year zinc application. It might be due to higher concentration of zinc which causes toxicity in plant; in general symptoms are stunting of shoot, /*curling and rolling of young leaves, death of leaf tips and chlorosis. Plant height of cotton showed significant increase in length with alternate year as compared with every year zinc application by 2.32 percent. Increase in plant height may be due to 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 Maurya *et al*., (2010) [5]. The finding corroborates with the results reported by Efe and Yarpur, (2011) [3]. Kulhare *et al*., (2014) [4] observed significant increase in plant height with the application of Zn. These results are in conformity with those of Yasari and Vahedi (2012) [15] and Chaudhary *et al*., (2014) [2].

The data in respect of, plant height noticed in the range of 92.56 to 104.76 cm and significantly highest plant height (104.76 cm) registered in treatment of zinc @ 7.5 kg ha^{-1}(Zn_3) as compared to other treatments and followed by treatment Zn @ 10 kg ha^{-1} (Zn_4) (103.50 cm). It could be noticed that soil application of Zn @ 10 kg ha^{-1} decreased the plant height to the extent of 1.20 percent as compared with soil application of zinc @ 7.5 kg ha^{-1}.

Table 1: Growth and yield attributing characters of cotton as influenced by phasing and levels of zinc treatments

Treatments	Plant height (cm)	No. of bolls	Boll weight (g)
Factor- A Phasing of zinc			
P1 - First year application only	91.22	30.51	3.62
P2 - Alternate year application	104.40	31.67	3.85
P3 - Every year application	101.97	31.82	3.80
S.E(m) +	0.38	0.36	0.03
CD at 5%	1.11	1.05	0.10
Factor B Levels of zinc (kg ha^{-1})			
Zn1: 2.5	92.56	27.81	3.58
Zn2: 5.0	95.96	30.21	3.83
Zn3: 7.5	104.76	33.87	4.24
Zn4: 10	103.50	33.45	3.93
SE (m) +	0.44	0.41	0.04
CD at 5%	1.28	1.20	0.12
Interaction P X Zn	Sig	N.S.	N.S.

Interaction effect of phasing and levels of zinc application is reported in Table 1. Interaction effect of both the factors was found significant and treatment combination of alternate year soil application of zinc @ 7.5 kg ha^{-1} (P_2Zn_3) recorded significantly higher plant height (113.5 cm) over all other treatment combination and followed by P_2Zn_4 and P_3Zn_3. P_2Zn_3 combination recorded 21.49 percent higher plant height as compared to control (P_0Zn_0). The close examination of data also showed that all treatment combination of P X Zn registered significantly higher plant height as compared to P_0Zn_0. The finding corroborates with the results of Pinjar *et al*., (2006) [10] and Ahmed, (2010).

Table 1a: Interaction effect of phasing and levels of zinc on growth and yield attributing characters of cotton

Treatment combinations (P X Zn)	Plant height (cm)	Number of bolls	Boll weight (g)
P1Zn1	88.5	26.92	3.44
P1Zn2	90.0	29.87	3.70
P1Zn3	91.8	33.71	4.16
P1Zn4	94.6	31.56	3.82
P2Zn1	94.0	27.40	3.58
P2Zn2	99.8	30.59	3.96
P2Zn3	113.5	34.65	4.35
P2Zn4	110.3	34.07	4.07
P3Zn1	95.2	29.12	3.73
P3Zn2	98.1	30.17	3.85
P3Zn3	109.0	34.16	4.23
P3Zn4	105.6	33.85	3.92
SE(m)±	0.76	0.716	0.072
CD at 5%	2.22	-	-
Control Vs other treatments			
P0Zn0	89.1	19.75	3.29
SE (m) ±	0.79	0.74	0.07
CD at 5%	1.63	1.54	0.15

Number of bolls per plant and boll weight influenced significantly by phasing and levels of zinc application, and found in the range 30.51 to 31.67 and 3.62 to 3.80 (g) respectively. The significantly highest number of bolls per plant (31.82) every year application of zinc and, while highest (3.85) boll weight was recorded with treatment of alternate year zinc application followed by every year zinc application. Every year soil application of zinc registered less boll weight as compared to alternate year and first year only.

The data pertaining to number of bolls and boll weight as influenced by zinc levels were ranged from 27.81 to 33.87 and 3.58 to 4.24 (g). Significantly highest number of bolls per plant (33.87) and weight of boll (4.24 g) were registered with zinc application @ 7.5 kg ha^{-1}, followed by Zn @ 10 kg ha^{-1}. Factor B also found significant effect for number of bolls and boll weight.

Interaction effect reported in Table 1a showed that, phasing and levels of zinc were found non-significant. Treatment combination of alternate year soil application with zinc @ 7.5 kg ha^{-1} (P_2Zn_3) recorded significantly higher number of bolls per plant and boll weight (34.65) and (4.35 g) respectively, over all other treatment combinations and followed by P_3Zn_3 and P_2Zn_4. The data showed that all treatment combinations of P X Zn recorded significantly higher number of bolls and boll weight as compared with P_0Zn_0.

3.2 Growth and yield attributing characters of soybean/

a) Number of pods per plant

The data showed that, the number of pods varied from 26.54 to 28.20 due to phasing of zinc application. The significantly highest number of pods was observed in alternate year phasing of zinc, while every year application of zinc showed slight reduction in number of pods. The number of pods reduced with every year application of zinc by 1.80 percent as compared to alternate year zinc application.

The significantly highest number of pods are found with the treatment receiving Zn @ 10 kg ha^{-1}, (29.27) which was found at par with application of zinc @ 7.5 kg ha^{-1} (29.19). This indicates soybean response to higher levels of zinc in zinc deficient soils.

Increase in pods might be due to pivotal role of Zn in crop growth, involving in photosynthesis processes, respiration and nitrogen metabolism-protein synthesis. Zn plays a key role in biosynthesis of IAA, regulating the auxin concentration in plant and other biochemical and physiological activities and initiation of primordial for reproductive parts. Thus ascribed the beneficial effect to better translocation of desired metabolites to the yield contributing parts of plant. The findings corroborates with results reported by Chaudhary *et al.*, (2014) [2], Nagajyothi *et al.*, (2013) [7], Shrikanth *et al.*, (2012) [13]. The increase of the number of pods with Zn application have been reported by Shripurkar *et al.*, (2006) [11] and Yasari and Vahedi (2012) [15]. These findings are also supported by Nadergali *et al.*, (2011) [6].

Interaction effect of phasing and levels of zinc was recorded statistically significant (Table 2a). The treatment combination of alternate year of soil application of zinc @ 7.5 kg ha^{-1} (P_2Zn_3) (30.17) recorded significantly higher number of pods per plant and at par with P_2Zn_4, P_2Zn_2 and P_3Zn_3 treatment combinations. Lowest number of pods is recorded with control (P_0Zn_0) (21.00).

Table 2: Number of pods, plant height, number of root nodules and test weight of soybean as influenced by phasing and levels of zinc application

Treatment	No. of pods	Plant height (cm)	No. of root nodules	Test weight (g/100 seeds)
Factor A Phasing of zinc				
P1 - First year application only	26.54	53.23	26.66	12.79
P2 - Alternate year application	28.20	58.23	36.44	13.38
P3 - Every year application	27.69	54.96	30.62	12.86
S.E(m) +	0.15	0.26	1.24	0.15
CD at 5%	0.44	0.76	3.63	0.46
Factor B Levels of zinc (kg ha^{-1})				
Zn1: 2.5	28.10	53.00	31.09	13.23
Zn2: 5.0	28.53	54.96	28.47	13.39
Zn3: 7.5	29.19	57.45	33.09	13.45
Zn4: 10	29.27	56.49	32.31	13.81
S.E(m) +	0.17	0.30	1.43	0.18
CD at 5%	0.51	0.87	-	-
Interaction P X Zn	N.S.	Sig	N.S.	N.S.

b) Plant height

The highest plant height of soybean was observed with alternate year of zinc application (P_2) (58.23 cm), which was followed by phasing of every year zinc (P_3) (54.96 cm). First year application of zinc (P_1) showed lowest plant height as compared with other phasing (53.23 cm).

While in zinc levels (Factor B) plant height varied from 53.00 to 57.45 cm and significantly highest plant height registered in the treatment of zinc @ 7.5 kg ha^{-1} (Zn_3) (57.45 cm) as compared to other treatment and followed by Zn @ 10 kg ha^{-1} (Zn_4) (56.49 cm). It could be seen that, soil application of Zn @ 10 kg ha^{-1} decreased plant height to the extent of 1.67 percent as compared to soil application of Zn @ 7.5 kg ha^{-1}.

Interaction effect of phasing and levels of zinc was found significant (Table 2a). The treatment combination of alternate year soil application of zinc @ 7.5 kg ha^{-1} (P_2Zn_3) recorded significantly highest plant height (61.85 cm) over all the treatment combinations and followed by P_2Zn_4 and P_2Zn_2. Whereas, P_2Zn_3 combination recorded 20.82 percent higher plant height as compared to control (P_0Zn_0). The results from data also showed that, all the treatment combinations of P X Zn recorded significantly highest plant height as compared to P_0Zn_0.

The data indicated that, higher doses of zinc showed decrease plant height, 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 fraction, faster cell division and cell elongation and root and shoot development ultimately increased plant height of soybean. 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 (Maurya *et al*., 2010) [5]. Kulhare *et al*. (2014) [4] have also observed significant increase in plant height with the application of Zn. These results are in conformity with those of Yasari and Vahedi (2012) [15] and Chaudhary *et al*. (2014) [2].

Table 2a: Interaction effect of phasing and levels of zinc on numbers of pods per plant, test weight and numbers of root nodules

Treatment combinations (P X Zn)	No. of pods plant^{-1}	Plant height (cm)	No. of root nodules	Test weight (g/100 seed)
P1Zn1	26.98	50.03	28.77	12.54
P1Zn2	27.10	53.31	29.42	13.30
P1Zn3	27.72	54.65	30.60	13.41
P1Zn4	28.60	54.96	33.73	13.54
P2Zn1	28.95	55.50	34.34	13.75
P2Zn2	29.64	57.48	35.16	13.79
P2Zn3	30.17	61.85	39.50	13.96
P2Zn4	29.96	58.11	36.23	14.25
P3Zn1	28.37	53.49	30.18	13.40
P3Zn2	28.85	54.11	29.85	13.08
P3Zn3	29.70	55.85	29.22	13.01
P3Zn4	29.26	56.42	27.12	13.65
S.E(m)±	0.30	0.26	2.49	0.31
CD at 5%	0.88	0.76	-	-
Control Vs other treatments				
P0Zn0	22.30	48.97	24.82	11.19
S.E(m) ±	0.31	0.54	2.59	0.33
CD at 5%	0.65	1.12	5.35	0.68

c) Number of root nodules

The data pertaining to number of root nodules, found to vary from 26.66 to 36.44 due to phasing of zinc application (Factor A), and found statistically significant. The highest numbers of root nodules were registered with alternate year zinc application (P_2) (36.44) which were followed by every year application of zinc (P_3) (30.62). The examination of data indicated that every year application of zinc showed decline rate of root nodule as compared with alternate year application of zinc by 15.97 percent.

Number of root nodules influenced by levels of zinc application varied from 28.47 to 33.09. Highest number of root nodules was observed in treatment of zinc @ 7.5 kg ha^{-1} Zn_3 (33.09) as compared to other treatment and followed by Zn @ 10 kg ha^{-1} (Zn_4) (32.31) and Zn @ 2.5 kg ha^{-1} (Zn_1) (31.09).

Interaction effect of phasing and levels of zinc application showed non-significant result with respect to number of root nodules. While highest number of root nodules were recorded with treatment of alternate year zinc application of soil @ 7.5 kg ha^{-1} (39.50) which was followed by alternate year application of zinc @ 10 kg ha^{-1} (P_2Zn_4) (36.23) and alternate year application of 5 kg ha^{-1} (P_2Zn_2) (35.16). The treatment combination P_2Zn_3 showed 37.16 percent higher number of root nodules as compared to control (P_0Zn_0). The increase of the number of nodules with Zn application have been reported by Awlad *et al*., (2003) [1] Shripurkar *et al.*, (2006) [11] and Yasari and Vahedi (2012) [15]. These findings are also supported by Nadergali *et al*., (2011) [6].

d) Test weight

The data in relation to test weight of seed of soybean as influenced by various treatments are presented in Table 2 and 2a.

On the basis of forgoing results in the table, it could be noticed that, the highest test weight was registered with the phasing of alternate year of zinc application (P_2) 13.38 g, which was followed by phasing of every year zinc application (P_3) 12.86 g. the findings indicated that every year application of zinc showed decrease in test weight.

In case of effect of levels of zinc application test weight of soybean found higher with treatment of soil application of zinc @ 10 kg ha^{-1} (14.25 g) (Zn4) which was followed by Zn @ 7.5 kg ha^{-1} (13.96 g) (Zn3). The test weight increased with the application of zinc. Moreover, alternate year application of Zn recorded highest (13.38 g) test weight, while every year application of Zn reduced the test weight.

Alternate year zinc application was recorded highest test weight followed by every year. Whereas, alternate year and every year zinc application increased test weight by 4.40% and 0.54% over first year application. The soil application of 2.5, 5.0, 7.5 and 10 kg Zn ha^{-1} increased test weight by 15.41%, 16.43%, 16.80% and 18.97% respectively as compared to control.

Shrikanth *et al*., (2012) [13] also reported significantly higher seed weight which could be due attributed to the fulfillment of the demand of the crop by higher assimilation and translocation of photosynthates from source to sink. The findings corroborates with results reported by Shripurkar *et al.*, (2006) [11] also reported the increase of test weight of soybean with increasing levels of Zn.

Conclusion

It can be concluded from the results that all growth, yield attributes can be enhanced with application of zinc @ 7.5 kg ha^{-1} in alternate year. Therefore, it can be concluded that soybean and cotton productivity along with soil fertility status can be improved with 7.5 kg Zn ha^{-1} in alternate year.

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