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AGRONOMIC FORTIFICATION OF ZINC ENHANCES THE YIELD, NUTRIENT CONTENT, UPTAKE AND SOIL FERTILITY STATUS OF DIFFERENT GENOTYPES OF PIGEON PEA (*CAJANUS CAJAN* L.) ON SWELL-SHRINK SOIL

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ABSTRACT

The field experiment entitled "Agronomic fortification of zinc enhances the yield, nutrient content, uptake and soil fertility status of different genotypes of pigeon pea (*Cajanus cajan* L.) on swell – shrink soil" was conducted during *Kharif* season 2022-23 at Pigeon pea Breeding Field, Central Research Station, Dr. Panjabrao Deshmukh Krishi Vidyapeeth , Akola. The experiment was laid out in Split-Plot Design and fifteen treatments combination comprised of five main-plots (pigeon pea genotypes) and three sub-plots (zinc levels). The pigeon pea genotypes were AKTE 1905(G_1), AKTE 1904(G_2), AKTE 16-12(G_3), AKTE 19-01(G_4) and AKT 8811(G_5). The zinc levels were recommended dose of fertilizer (RDF) (Z_0), RDF with soil application of Zn @ 5 kg Zn ha^{-1} at the time of sowing (Z_1) and RDF with foliar spraying of $ZnSO_4$ @ 0.5% at branching and flowering stage (Z_2). The results of present investigation revealed that the yield (seed and straw) of pigeon pea was significantly highest in genotypes with (G_1) AKTE 1905 seed yield (23.08 q ha^{-1}) and straw yield (50.88 q ha^{-1}) and in zinc levels with soil application 5 kg Zn ha^{-1} at the time of sowing (Z_1) seed yield (22.81 q ha^{-1}) and straw yield (50.98 q ha^{-1}) and there interaction are also significantly highest seed yield (24.73 q ha^{-1}) of AKTE 1905 (G_1Z_1) and straw yield 52.83 (q ha^{-1}) of AKTE 16-12(G3Z1). In interactions the nutrient content of N (seed), K (seed & straw) are significant and remaining nutrient content are non-significant. The availability of nutrients such as nitrogen (180.38 kg ha^{-1}), phosphorus (13.22), potassium (335.51 kg ha^{-1}), sulphur (11.65 mg kg^{-1}), Zn (0.62 mg kg^{-1}), Fe (5.31 mg kg^{-1}), Cu(1.36 mg kg^{-1}) and Mn (4.75 mg kg^{-1}) after harvest were significantly highest with soil application of Zn @ 5 kg ha^{-1} at the time of sowing. In the interaction effect between genotypes and zinc levels all the nutrient uptake and soil parameters are non-significant.

Key words : Fortification, Yield, Nutrient content, Uptake, Pigeonpea.

Introduction

Pigeonpea commonly known as red gram or tur or arhar. After gram, pigeonpea is the second most important pulse crop in the country. It belongs to family Leguminosae. It has very deep root system and consists of a central tap root with numerous laterals and secondary branches. Pigeonpea is an often cross pollinated, C_3 short day plant. Pigeonpea p *Cajanus cajan* (L.) Millsp.], a protein rich legume crop and cultivated in tropical and subtropical regions. It is a vital grain legume crop in several countries of Asia, Africa and Latin America. The largest share approximately 75% of global pigeonpea production comes from India. In India, pigeonpea is cultivated in an area of 3.96 million ha. mainly in Maharashtra, Karnataka, Gujrat, Jharkhand, Uttar Pradesh, Odisha, Andhra Pradesh, Madhya Pradesh and Telangana (Behera *et al.*, 2020). The total world acreage under pulses is about 93.18 (M ha.) with production of 89.82 (Mt.) at 964 kg ha^{-1} yields level. India, with more than 28 M ha pulses cultivation area is the largest pulse producing country in the world. It ranks first in area and production with 31% and 28%, respectively. The India's total area coverage and production of pigeonpea has been about 47 lakhs ha. and 41 lakhs tonnes respectively. Karnataka ranked first (>13 lakhs ha.) and contributes 29% in area and 24% in production whereas Maharashtra has contributed 27% of area and 28% of total production. Maharashtra is having area of 12.81 lakhs ha., productivity 11.74 lakhs tonnes and yield of 916 kg ha^{-1} (Ministry of Agriculture & Farmers Welfare, GoI. 2020-21).

Pigeonpea is a legume reported to have 20-22% protein, 1.2% fat, 65% carbohydrates and 3.5% minerals. It can provide high quality protein in diet especially to the vegetarian population. It is having medicinal uses. Leaves contain anti-inflammatory, anti-bacterial and abirritative properties. Leaves can be used to treat burnt infection, traumatism, cough and diarrhoea. Genistein and apigenin is a pair of isomeric compounds found as the main constituents present in pigeonpea roots and possess a wide spectrum of pharmacological activities (Sarkar *et al*., 2020).

Biofortification of cereals and pulses through use of Zn fertilizers (*e.g*., agronomic fortification) is an economically feasible option which aims at: 1) Keeping sufficient amount of available Zn in soil solution 2) Maintaining adequate Zn transport to the seeds during reproductive growth stages 3) Optimizing the success of biofortification of staple food crops with Zn through use of breeding tools. Agronomic fortification is effective in improving grain Zn concentration.

Micronutrient deficiency is the fifth major global challenge to human health. The zinc deficiency leads to crop yield losses and human health problem. Zinc deficiency is the most common and widespread, affecting more than half of the human population (WHO, 2002; White and Broadley, 2009). Deficiency of zinc also known as 'Hidden hunger' results in poor growth and compromised psychomotor development of children, reduced immunity, fatigue, irritability, weakness, hair loss, wasting of muscles, sterility, morbidity and even death in acute cases. The recommended daily allowance (RDA) of 7 mg per day (children), 12 mg per day (adult) for zinc is necessary (Stein *et al*., 2010). The most of the developing countries, thus resulting in the high prevalence of zinc deficiencies in these populations (Cakman *et al*., 2008).

The deficiency of these micronutrients in soil leading to translocation in grains which ultimately providing less Zn in human beings and animals. The Zinc is needed in small but critical concentrations and if the amount available is not adequate, plants and/or animals will suffer from physiological stress brought about by the dysfunction of several enzyme systems and other metabolic functions in which zinc plays an important part (Alloway *et al*., 2004-b). The recommended daily allowance of zinc for adult women is 12 milligrams and for adult men is 15 milligrams (Andreini *et al*., 2008). The plants exhibited lower rate of protein synthesis and protein accumulation under zinc deficiency. The mode of zinc application proves the major factor, considering the importance of zinc to pigeonpea (Yashona *et al*., 2020-b).

Fortification works for twin objective of increasing the concentration of the micronutrients in the grains and simultaneously improving the availability of micronutrients in the grains to alleviate the micronutrient deficiency in human beings and also animals. Hence agronomic fortification of zinc can be done through soil and foliar applications. The use of micronutrient in pigeonpea is one of the ways to boost up the productivity and to improve the seed quality parameters (Sharma *et al*., 2010).

Materials and Methods

The experiment entitled "Agronomic bio-fortification of zinc enhances on growth, yield and quality of different genotypes of pigeon pea (*Cajanus cajan* L.) on swell – shrink soil" was carried out during *Kharif* season 2022-23 at Pigeon pea Breeding Field, Central Research Station, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The site is situated in the subtropical region at $22^0$42' North latitude and $77^0$02' East longitude and at an altitude of 307.42 m above mean sea level with average annual precipitation was 944.4 mm. Experimental field is situated at the latitude of 20^0 40' 35" North and longitude of 76^0 59' 10" East. The experiment was laid out in Split-Plot Design and fifteen treatments combination comprised of five main-plots (pigeon pea genotypes) and three sub-plots (zinc levels). The pigeon pea genotypes were AKTE 1905(G_1), AKTE 1904(G_2), AKTE 16-12(G_3), AKTE 19-01(G_4) and AKT 8811(G_5) and the zinc levels were RDF (Z_0), RDF with soil application of Zn @ 5 kg Zn ha^{-1} at the time of sowing (Z_1) and RDF with foliar spraying of $ZnSO_4$ @ 0.5% at branching and flowering stage(Z_2). The Recommended dose of fertilizer 25:50:30 NPK will be common to all the treatments. Nitrogen through Urea & DAP, Phosphorous through DAP, Potassium through MOP, Zinc through zinc sulphate ($ZnSO_4$) was applied as per the treatment. The experimental soil was vertisol with pH 8.32, EC 0.24 dSm^{-1}, organic carbon 4.6 g kg^{-1}, available nitrogen 168.07 kg ha^{-1}, phosphorus 12.13 kg ha^{-1}, potassium 305.50 kg ha^{-1} sulfur 10.47 mg kg^{-1}, Zn 0.52 mg kg^{-1}, Mn (4.66 mg kg^{-1}), Fe (5.23 mg kg^{-1}) and

Cu (1.31 mg kg^{-1}). The experiment was laid out in Split-plot design with five main-plots and three sub-plots replicated three times. Pigeonpea genotypes was sown at spacing 60 cm X 20 cm by the dibbling method. The seed was sown at the seed rate of 12 kg ha^{-1} in the first week of July 2022. The post-harvest soil samples were collected and analyzed for pH, EC, OC, $CaCO_3$%, available nitrogen, phosphorus, sulphur, potassium, and micronutrients *i.e.*, iron, manganese, zinc, copper and plant samples were collected and analyzed for nitrogen, phosphorus, potassium, sulphur and zinc by standard methods. The experimental data were recorded and analyzed statistically using Panse and Sukhatme (1985).

Results and Discussion

Agronomic fortification of zinc application on seed and straw yield are presented in Table 1.

Seed yield (q ha^{-1})

Main-plots: Genotypes

The data regarding of seed yield of various pigeonpea genotypes were found to be significant the highest seed yield at (G_1) AKTE 1905(23.08 q ha^{-1}) which found at par with (G_3) AKT 16-12 (22.18) and lowest in (G_4) AKTE 19-01.

Table 1 : Agronomic fortification of zinc on seed and straw yield of pigeon pea genotypes.

Treatments	Yield (q ha^{-1})	
	Seed	Straw
A) Main-plots: Genotypes		
G_1: AKTE 1905	23.08	50.88
G_2: AKTE 1904	21.51	48.19
G_3: AKTE 16-12	22.18	49.91
G_4: AKTE 19-01	20.62	47.13
G_5: AKT 8811	20.94	48.27
SE (m) ±	0.09	0.14
CD at 5%	0.31	0.47
B) Sub-plots: Zinc levels		
Z_0: Control	20.40	46.75
Z_1: SA of Zn @ 5 kg ha^{-1} at the time of sowing	22.81	50.98
Z_2: Two FS of $ZnSO_4$@0.5% of $ZnSO_4$ branching & flowering stage	21.79	48.90
SE (m) ±	0.06	0.05
CD at 5%	0.19	0.14
C) Interaction (a x b)		
SE (m) ±	0.14	0.10
CD at 5%	0.42	0.31

Singh *et al*. (2011) reported that the seed yield of pigeonpea influenced with application of zinc. Zn @5 kg ha^{-1} resulted highest grain yield which was 66.98% higher than that in control.

Sub-plots: Zinc levels

The effect of zinc levels was found significant in respect of seed yield. significantly highest seed yield (22.81 q ha^{-1}) was recorded with the treatment of soil application of 5 kg Zn ha^{-1} through $ZnSO_4$ (Z_1) which was found significantly superior over two foliar sprays @ 0.5% of $ZnSO_4$ (Z_2) at branching and flowering stage (21.79 q ha^{-1}) and lowest in control (20.40 q ha^{-1}).

Interaction

Interaction effect between pigeonpea genotypes and zinc levels of seed yield is found significant and reported Table 1a.

The significantly highest seed yield (24.73 q ha^{-1}) of AKTE 1905 genotype was registered in combination with the soil application of 5 kg Zn ha^{-1} (G_1Z_1) and followed by treatment combination of G_3Z_1.

Zinc is a constituent of several enzymes such as carbonic hydrogenase and also helps in the formation of growth hormones such as auxin, which promote the seed maturation. This might be the reason for increasing grain yield per ha^{-1}. The findings of present investigation correspond with the results quoted by Umesh *et al*. (2014), Yadav *et al*. (2020) and Behera *et al.* (2020).

Straw yield (q ha^{-1})

Main-plots: Genotypes

The data regarding straw yield of various pigeonpea genotypes was found significantly highest straw yield (G_1) AKTE 1905(50.88 q ha^{-1}) and which was found at par with (G_3) AKTE 16-12 (49.91 q ha^{-1}) and lowest in (G_4) AKTE 19-01.

Shivay *et al*. (2014) stated that zinc application on yield of pigeonpea and concluded that application of Zn @ 7.5 kg Zn ha^{-1} significantly increased the grain and straw yield of pigeonpea.

Sub-plots: Zinc levels

The effect of zinc levels was found significantly highest straw yield (50.98 q ha^{-1}) was recorded with the treatment of soil application of 5 kg Zn ha^{-1} through $ZnSO_4$ (Z_1), which was significantly superior over two foliar sprays @ 0.5 % of $ZnSO_4$ (Z_2) at branching and flowering stage and lowest control (Z_0) (46.75 q ha^{-1}).

Table 1a: Agronomic fortification of zinc on interaction between genotypes and zinc levels of seed yield of pigeon pea genotypes.

Main-plots: Genotypes	Sub-plots: Zinc levels			
	Z_0: Control	Z_1: SA of zinc @ 5 kg Zn ha^{-1} at the time of sowing	Z_2: Two FS @ 0.5% $ZnSO_4$ at branching and flowering stage	Mean
G_1: AKTE 1905	21.03	24.73	23.47	**23.08**
G_2: AKTE 1904	20.83	22.37	21.33	**21.51**
G_3: AKTE 16-12	21.00	23.20	22.35	**22.18**
G_4: AKTE 19-01	19.45	21.77	20.63	**20.62**
G_5: AKT 8811	19.67	21.98	21.17	**20.94**
Mean	**20.40**	**22.81**	**21.79**	**21.66**
SE (m) ±	0.14			
CD at (p=0.05%)	0.42			

Table 1b: Agronomic fortification of zinc on interaction between genotypes and zinc levels of straw yield of pigeon pea genotypes.

Main-plots: Genotypes	Sub-plots: Zinc levels			
	Z_0: Control	Z_1: SA of zinc @ 5 kg Zn ha^{-1} at the time of sowing	Z_2: Two FS @ 0.5% $ZnSO_4$ at branching and flowering stage	Mean
G_1: AKTE 1905	48.37	52.40	51.88	**50.88**
G_2: AKTE 1904	47.10	49.70	47.77	**48.19**
G_3: AKTE 16-12	46.70	52.83	50.20	**49.91**
G_4: AKTE 19-01	44.80	49.80	46.80	**47.13**
G_5: AKT 8811	46.80	50.17	47.83	**48.27**
Mean	**46.75**	**50.98**	**48.90**	**48.88**
SE (m) ±	0.10			
CD at (p=0.05)	0.31			

The straw yield was increased might be due to the involvement of zinc in a variety of physicochemical and biochemical processes. Similar results quoted by Umesh *et al*. (2013), Shivay *et al*. (2013), Praveena *et al*. (2018) reported that the increased straw yield over the RDF. Chalak *et al*. (2018) quoted that application of Zn significantly increased straw yield.

Interaction

Interaction effect between pigeon pea genotypes and zinc levels of straw yield was found significant in Table 1b.

The significantly highest straw yield (52.83 q ha^{-1}) was recorded in combination of AKTE 16-12 with soil application of 5 kg Zn ha^{-1}(G_3Z_1) followed by G_1Z_1.

Effect of zinc application on nutrient content in nitrogen (%), phosphorous (%), potassium (%), sulphur (%) and zinc (mg kg^{-1}) in seed and straw of pigeonpea genotypes are presented in Table 2.

Main-plots: Genotypes

The data regarding nutrient content significantly highest in (G_1) AKTE 1905 of nitrogen content in seed (3.28%) and straw (1.37%) ,phosphorous content in seed (0.42) and straw (0.16), potassium content in seed (1.06) and straw (1.31), sulphur content in seed (0.30) and straw (0.27), zinc content in seed (35.42) and in straw (18.11) and followed by (G_3) AKTE 16-12 and lowest recorded by (G_4) AKTE 19-01 of N content in seed (3.20) and straw (1.29), P content in seed (0.37) and straw (0.13), K content in seed (0.96) and straw (1.24), sulphur content in seed (0.27) and straw (0.24) and zinc content in seed (32.22) and straw (17.96).

Dwivedi *et al*. (2002) reported that the application of zinc enhanced the nitrogen content in plants. The results were in agreement with the findings reported by Mona E. El-Azab (2015) recorded that the application of zinc increased N content in straw of maize Similar results were also reported by Sahu *et al*. (2010) and El habasha *et al.* (2013).

Sub-plots: Zinc levels

The zinc levels significantly influenced highest by soil application of 5 kg Zn ha^{-1} at the time of sowing (Z_1) recorded highest N content in seed (3.30) and straw (1.37) P content in seed (0.41) and straw (0.17), K content in

Table 2 : Agronomic fortification of zinc on nutrient content of seed and straw in pigeon pea genotypes.

Treatments	Nitrogen content (%)		Phosphorous content (%)		Potassium content (%)		Sulphur content (%)		Zinc content (mg kg^{-1})	
	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw
A) Main-plots: Genotypes										
G_1: AKTE 1905	3.28	1.37	0.42	0.16	1.06	1.31	0.30	0.27	35.42	18.11
G_2: AKTE 1904	3.21	1.32	0.35	0.12	0.99	1.27	0.28	0.25	33.14	17.86
G_3: AKTE 16-12	3.26	1.34	0.39	0.14	1.03	1.29	0.29	0.26	34.93	18.02
G_4: AKTE 19-01	3.20	1.29	0.37	0.13	0.96	1.24	0.27	0.24	32.22	17.96
G_5: AKT 8811	3.24	1.31	0.40	0.14	1.00	1.28	0.28	0.26	33.35	17.79
SE (m) ±	0.02	0.03	0.01	0.02	0.02	0.02	0.03	0.02	0.19	0.07
CD at 5%	0.06	0.09	0.04	0.06	0.05	0.07	0.10	0.07	0.62	0.21
B) Sub-plots: Zinc levels										
Z_0: Control	3.14	1.28	0.36	0.11	0.92	1.20	0.25	0.21	30.73	16.30
Z_1: SA of Zn @ 5 kg ha^{-1} at the time of sowing	3.30	1.37	0.41	0.17	1.10	1.34	0.33	0.29	37.10	19.96
Z_2: Two FS of 0.5% $ZnSO_4$ at branching and flowering stage	3.26	1.33	0.39	0.14	1.00	1.29	0.28	0.26	33.61	17.58
SE (m) ±	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.14	0.06
CD at 5%	0.03	0.05	0.03	0.04	0.03	0.03	0.04	0.03	0.40	0.17
C) Interaction (a x b)										
SE (m) ±	0.02	0.04	0.02	0.03	0.02	0.03	0.03	0.03	0.31	0.13
CD at 5%	0.07	NS	NS	NS	0.07	0.08	NS	NS	NS	NS

seed (1.10) and straw (1.34), sulphur content in seed (0.33) and straw (0.29) and zinc content in seed (37.10) and straw (19.96) and followed by two foliar spraying of 0.5% $ZnSO_4$ (Z_2) at branching and flowering stage and lowest control (Z_0) N content in seed (3.14) and straw (1.28) P content in seed (0.36) and straw (0.11), K content in seed (0.92) and straw (1.20), sulphur content in seed (0.25) and straw (0.21) and zinc content in seed (30.73) and straw (16.30).

This might be partially attributed to the favourable effect of different sources and levels of zinc to form vegetative plant material in terms of increases in nitrogen uptake by pigeonpea. The results are in conformity with finding reported by Keram *et al*. (2012) and Sahu *et al*. (2010). Increase in K content in seeds might be due to increase with application of zinc. The results are in agreement with the findings in respect of K content with Sahu *et al*. (2010) and Habbasha *et al*. (2013)

Interaction

Interaction effect between genotypes and zinc levels there was a significant variation of N content in seed and non- significant N content in straw. There was significant variation in K content in seed & straw and non -significant variation in phosphorous, sulphur and zinc content in seed and straw.

Effect of zinc application on nutrient uptake in nitrogen (kg ha^{-1}), phosphorous (kg ha^{-1}), potassium (kg ha^{-1}), sulphur (kg ha^{-1}) and zinc(mg kg^{-1}) in seed and straw of pigeonpea genotypes are presented in Table 3.

Main-plots: Genotypes

The data regarding nutrient uptake significantly highest in (G_1) AKTE 1905 of nitrogen uptake in seed (75.82) and straw (69.42), phosphorous uptake in seed (9.66) and straw (7.91), potassium uptake in seed (24.36) and straw (66.48), sulphur uptake in seed (6.93) and straw (13.57), zinc uptake in seed (79.20) and in straw (91.78) and followed by (G_3) AKTE 16-12 and lowest recorded by (G_4) AKTE 19-01 of N uptake in seed (66.86) and straw (60.75), P uptake in seed (7.59) and straw (6.28), K uptake in seed (19.70) and straw (59.16), S uptake in seed (5.59) and straw (11.19) and zinc uptake in seed (71.12) and straw (84.56).

Table 3 : Agronomic fortification of zinc on nutrient uptake of seed and straw in pigeon pea genotypes.

Treatments	Nitrogen uptake (kg ha^{-1})		Phosphorous uptake (kg ha^{-1})		Potassium uptake (kg ha^{-1})		Sulphur uptake(kg ha^{-1})		Zinc uptake (kg ha^{-1})	
	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw
A) Main-plots: Genotypes										
G_1: AKTE 1905	75.82	69.42	9.66	7.91	24.36	66.48	6.93	13.57	79.20	91.78
G_2: AKTE 1904	70.08	63.67	7.47	5.82	21.27	60.47	6.09	11.81	71.39	86.04
G_3: AKTE 16-12	71.35	67.10	9.07	7.22	22.98	63.23	6.39	12.76	77.12	89.93
G_4: AKTE 19-01	66.86	60.75	7.59	6.28	19.70	59.16	5.59	11.19	71.12	84.56
G_5: AKT 8811	67.24	62.89	8.36	6.96	20.93	61.14	5.91	12.04	71.62	85.86
SE (m) ±	0.82	1.27	0.24	0.23	0.74	1.32	0.46	0.39	0.66	0.32
CD at 5%	2.66	4.13	0.78	0.67	2.42	4.31	1.39	1.26	2.16	1.00
B) Sub-plots: Zinc levels										
Z_0: Control	64.94	62.50	7.68	5.39	20.11	58.89	5.26	10.56	66.70	79.63
Z_1: SA of Zn @ 5 kg ha^{-1} at the time of sowing	75.29	67.19	8.96	8.76	23.79	64.17	7.05	13.34	81.58	97.32
Z_2: Two FS of 0.5% $ZnSO_4$ at branching and flowering stage	70.58	64.60	8.63	6.37	21.76	63.23	6.23	12.91	74.20	85.93
SE (m) ±	1.06	0.80	0.19	0.20	0.64	0.77	0.26	0.23	0.36	0.27
CD at 5%	3.13	2.35	0.55	0.58	1.90	2.28	0.76	0.69	1.05	0.80
C) Interaction (a x b)										
SE (m) ±	2.37	1.78	0.41	0.39	1.73	3.17	0.57	0.52	0.79	0.61
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Dwivedi *et al.* (2002) reported that the application of zinc enhanced the nitrogen content in plants. The results were in agreement with the findings reported by Mona E. El-Azab (2015) recorded that the application of zinc increased N content in straw of maize. Similar results were also reported by Sahu *et al.* (2010) and El habasha *et al.* (2013).

Sub-plots: Zinc levels

The zinc levels significantly influenced highest by soil application of 5 kg Zn ha^{-1} at the time of sowing (Z_1) recorded highest N uptake in seed (75.29) and straw (67.19) P uptake in seed (8.96) and straw (8.76), K uptake in seed (23.79) and straw (64.17), sulphur uptake in seed (7.05) and straw (13.34) and zinc uptake in seed (81.58) and straw (97.32) and followed by two foliar spraying of 0.5% $ZnSO_4$ (Z_2) at branching and flowering stage and lowest control (Z_0) N uptake in seed (64.94) and straw (62.50) P uptake in seed (7.68) and straw (5.39), K uptake in seed (20.11) and straw (58.89), sulphur uptake in seed (5.26) and straw (10.56) and zinc uptake in seed (66.70) and straw (79.63).

This might be partially attributed to the favourable effect of different sources and levels of zinc to form vegetative plant material in terms of increases in nitrogen uptake by pigeonpea. The results are in conformity with finding reported by Keram *et al.* (2012) and Sahu *et al.* (2010). Increase in K content in seeds might be due to increase with application of zinc. The results are in agreement with the findings in respect of K content with Sahu *et al.* (2010) and Habbasha *et al.* (2013)

Interaction

Interaction effect between genotypes and zinc levels there was a non-significant variation in N, P, K, S and zinc uptakes in seed and straw.

Effect on soil fertility status of different genotypes in pigeonpea are presented in Tables 4, 5 and 6.

Main-plots: Genotypes

The effect of genotypes was found to be non-significant in soil pH, EC, O C, $CaCo_3$, available N, P, K, S, Zn, Fe, Cu and Mn. Similar result was also recorded by Keram *et al.* (2012). Such types of finding were also

Table 4 : Chemical properties of soil after harvest of pigeonpea as influenced by different genotypes and zinc levels.

Treatments	pH (1:2.5)	EC (dS m^{-1})	OC (g kg^{-1})	$CaCO_3$ (%)
G_1: AKTE 1905	8.23	0.20	4.81	7.23
G_2: AKTE 1904	8.25	0.22	4.77	7.24
G_3: AKTE 16-12	8.22	0.20	4.83	7.28
G_4: AKTE 19-01	8.23	0.21	4.79	7.23
G_5: AKT 8811	8.26	0.23	4.75	7.29
SE (m) ±	0.01	0.03	0.08	0.03
CD at 5%	NS	NS	NS	NS
Z_0: Control	8.27	0.23	4.76	7.29
Z_1: SA of Zn @ 5 kg ha^{-1} at the time of sowing	8.21	0.19	4.81	7.23
Z_2: Two FS of 0.5% $ZnSO_4$ at branching and flowering stage	8.24	0.21	4.79	7.25
SE (m) ±	0.02	0.03	0.05	0.02
CD at 5%	NS	NS	NS	NS
SE (m) ±	0.04	0.06	0.11	0.04
CD at 5%	NS	NS	NS	NS

reported by Alam *et al*. (2000). These results were in agreement with Singh *et al.* (2008) and Chavan *et al.* (2015).

Sub-plots: Zinc levels

The effect of zinc levels was found to be non-significant in soil pH. EC, OC, $CaCo_3$ available Fe, Cu and Mn and significant in available N,P, K,S and Zn. The highest valves are found in (Z_1) soil application of 5 kg Zn ha^{-1} at the time of sowing and followed by (Z_2) two foliar spraying of 0.5% $ZnSO_4$ at branching and flowering stage and lowest (Z_0) control.

The increase in available potassium in soil with increase in zinc application. This might be due to the beneficial effect of zinc in improving soil properties and enhancing the availability has been reported by Latha *et al*. (2002); Singh *et al*. (2007) also stated that increased in available nitrogen with the application of zinc. Kumar *et al*. (2004) reported that the availability of major nutrients N, P and K increased with the application of zinc sulphate. These results were more or less similar to those of Singh *et al*. (2007).

Kumar *et al*. (2004) reported that the availability of micronutrients (Zn, Fe, Mn and Cu) increased slightly

Table 5 : Available N, P, K and S in soil after harvest of pigeonpea as influenced by different genotypes and zinc levels.

Treatments	Available Nutrients			
	N	P	K	S
	kg ha^{-1}			mg kg^{-1}
A) Main-plots: Genotypes				
G_1: AKTE 1905	178.95	13.39	333.05	11.46
G_2: AKTE 1904	176.40	13.16	332.84	11.44
G_3: AKTE 16-12	179.94	13.55	333.07	11.49
G_4: AKTE 19-01	178.20	13.22	333.21	11.41
G_5: AKT 8811	177.95	13.20	333.69	11.47
SE (m) ±	0.84	0.11	1.59	0.07
CD at 5%	NS	NS	NS	NS
B) Sub-plots: Zinc levels				
Z_0: Control	175.86	13.43	330.35	11.33
Z_1: SA of Zn @ 5 kg ha^{-1} at the time of sowing	180.38	13.22	335.51	11.65
Z_2: Two FS of 0.5% $ZnSO_4$ at branching and flowering stage	179.63	13.26	333.66	11.39
SE (m) ±	1.20	0.06	1.10	0.08
CD at 5%	3.53	0.17	3.24	0.23
C) Interaction (a x b)				
SE (m) ±	2.58	0.13	2.46	0.17
CD at 5%	NS	NS	NS	NS

Table 6 : Micronutrient status of soil after harvest of pigeonpea as influenced by different genotypes and zinc levels.

Treatments	Available Nutrients			
	Zn	Fe	Cu	Mn
	mg kg^{-1}			
A) Main-plots: Genotypes				
G_1 : AKTE 1905	0.59	5.26	1.32	4.59
G_2 : AKTE 1904	0.55	5.30	1.38	4.54
G_3 : AKTE 16-12	0.56	5.32	1.34	4.66
G_4 : AKTE 19-01	0.53	5.27	1.35	4.67
G_5 : AKT 8811	0.58	5.24	1.33	4.56
SE (m) ±	0.02	0.05	0.04	0.22
CD at 5%	NS	NS	NS	NS
B) Sub-plots: Zinc levels				

Table 6 continud...

Table 6 continud...

Z_0 : Control	0.50	5.25	1.33	4.49
Z_1 : SA of Zn @ 5 kg ha^{-1} at the time of sowing	0.62	5.31	1.36	4.75
Z_2:Two FS of 0.5% $ZnSO_4$ at branching and flowering stage	0.54	5.27	1.34	4.57
SE (m) ±	0.02	0.04	0.02	0.13
CD at 5%	0.06	NS	NS	NS
C) Interaction (a x b)				
SE (m) ±	0.05	0.08	0.05	0.29
CD at 5%	NS	NS	NS	NS

with the application of zinc sulphate. Interaction effect of genotypes and zinc levels to available zinc, iron and manganese, copper was found non-significant.

Interaction

Interaction effect between genotypes and zinc levels there was a non-significant variation in soil pH, EC, OC, $CaCo_3$, available N, P, K, S, Zn, Fe, Cu and Mn.

Conclusion

The results of present investigation revealed that the yield (seed and straw) of pigeon pea was significantly highest in genotypes with (G_1) AKTE 1905 seed yield (23.08 q ha^{-1}) and straw yield (50.88 q ha^{-1}) and in zinc levels with soil application 5 kg Zn ha^{-1} at the time of sowing (Z_1) seed yield (22.81 q ha^{-1}) and straw yield (50.98 q ha^{-1}) and there interaction are also significantly highest seed yield (24.73 q ha^{-1}) of AKTE 1905 (G_1Z_1) and straw yield 52.83(q ha^{-1}) of AKTE 16-12(G_3Z_1). The interaction between different genotypes and zinc levels of nutrient content of N (seed), K (seed and straw) are significant and remaining N (straw), P, S and Zn (seed & straw) and in soil pH, EC, OC, $CaCo_3$, available N, P, K, S, Zn, Fe, Cu and Mn are non- significant.

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