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Effect of potassium and zinc availability in black cotton soil of Marathwada

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Abstract
A field experiment was conducted at research farm, Department of soil science and Agricultural Chemistry, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani University to study effect of application of varying levels of potassium and zinc on productivity, nutrient uptake and quality parameters of pigeon pea during 2017-2018. During green revolution high yielding varieties introduced to meet the demand of food for growing population resulted in the depletion of soil nutrients status. Pigeon pea is mainly grown in almost all the states and larger portion of the area is in the states like Maharashtra, Uttar Pradesh, Madhya Pradesh, Karnataka and Gujarat. It is grown throughout the tropical and subtropical region of the world, between 30 N and 35 S latitudes. However, major area under pigeon pea in India is lying between 14 S and 28 N latitudes. Pigeon pea maintain soil fertility through biological nitrogen fixation, improves the soil organic matter by defoliation at the time of maturity. Hence, they occupy prominent place in various cropping system and crop mixtures, and thus pulses play a vital role in sustainable agriculture. To alleviate the problem of protein malnutrition in the country, it is very much imperative to enhance the production of pigeon pea, as it is an important pulse crop in the country as well as in the state.

Keywords: pigeon pea, potassium, zinc, available nutrient in soil

Introduction

Beginning of 19th century, potassium has been recognized as an essential element and a major nutrient for plant growth and required in large quantities. It ranks the third most important limiting nutrient next to nitrogen and phosphorus in crop production. It is a soft and silvery metallic element of group I (formerly IA) of the periodic table. Over 95 to 97 % world's potash is used in Agriculture. About 85% potassium movement in soil is by diffusion through the water films found around soil particles. As diffusion is relatively a slow process, potash fertilization is needed to maintain high levels of exchangeable potassium. Rapid plant growth and uptake deplete potassium from soil and around the root surface. The soil potassium reserves are depleted and crop yields found to be reduced. It is reported that, high clay Vertisol suppose to be having very high potassium content now responding for K application, which shows that, the K content has been depleted. (Ranade, 2011) [6].

Pigeon pea (*Cajanus cajan* L. Millsp.) is one of the most important pulse crop of India and 91 per cent of the world's pigeon pea is produced in India. The crop is extensively grown in dry land Maharashtra (Marathwada region) Karanataka, Madhya Pradesh, Andra Pradesh and Gujarat, etc. Area, production, productivity, of pigeon pea in India is the 3.96 m ha, 2.56 million tonnes, and 646 kg ha-1 respectively during the year 2015-2016. Maharashtra and Karnataka have highest area (1.23 m ha, 0.65 m ha) respectively and production (0.55 million tonnes, 0.24 million tonnes) respectively. Delhi and Bihar have highest productivity 3522 kg ha-1 and 1577 kg ha-1 respectively whereas in case of Maharashtra 450 kg / ha during the year 2015-2016. India, China, Brazil, Canada, Myanmar and Australia are major pulse producing countries with relative share of 25 %, 10 %, 5 %, 5 % and 4%, respectively.

Pigeon pea is cultivated in a multipurpose of production system for a diversity of uses grain as dhal, green seed as a vegetable and stalks as fuel wood. Its deep rooting and drought tolerating character make it a successful crop in areas of low and uncertain rainfall. The plant owes a large measure of its popularity to the fact that it possesses valuable properties as restorative of nitrogen to the soil and adds lot of organic matter to soil and thus, pigeon pea finds a promising place in crop rotation and crop mixtures. Being a leguminous plant, it is capable for fixing atmospheric nitrogen in the soil

It is a deep root system helps in extracting the nutrient and moisture from deeper crop which zone of soil by breaking the plough pans and improving soil structure and hence it is called as "Biological plough". It can withstand drought for a longer period due to uncertainty and insufficient water availability.

Zinc is one of the seventh plant micronutrient, involved in many enzymatic activities of the plant. It functions generally as a metal activator of enzymes. It is reported that, zinc improves crop productivity almost as much as major nutrients. Besides increasing crop yield, it increases the crude protein content, amino acids, energy value and total lipid in chickpea, soybean, black gram etc. Zinc deficiency is wide spread, in Marathwada region and it varies between 62 to 89 %. The Zn plays very important role in plant metabolism by influencing the activities of hydrogenise and carbonic anhydrate, stabilization of ribosomal fractions and synthesis of cytochrome. Plant enzymes activated by Zn are involved in carbohydrate metabolism, maintenance of the integrity of cellular membranes, protein synthesis, regulation of auxin synthesis and pollen formation. The regulation and maintenance of the gene expression required for the tolerance of environmental stresses in plants are Zn dependent. Its deficiency resulted in development of abnormalities in plants which become visible as deficiency symptoms such as stunted growth, chlorosis and smaller leaves, spikelet sterility. Zn deficiency can also adversely affect the quality of harvested products, plants susceptibility to injury by high light or temperature intensity and infection by fungal diseases can also increase. Zinc seems to affect the capacity for water uptake and transport in plants and also reduce the adverse effects of short periods of heat and salt stress. As Zn is required for the synthesis of tryptophan which is a precursor of IAA, it also had an active role in production of an essential growth hormone auxin. The Zn is required for integrity of cellular membranes to preserve the structural orientation of macromolecules and iron transport systems.

The function of potassium in plant metabolism is different from that of other major nutrients. The later become part of the plant structure, whereas potassium largely remains as an ion in the cells and sap and helps to control the water intake and metabolism of the plant. Some of the specific effects of potassium are to increase root growth and improve drought resistance. (Ranade, 2011) [6].

Materials and Methods

A field experiment was conducted during *kharif* season 2017-2018 to study the influence of varying levels of potassium and zinc on yield attributes and soil nutrient dynamics in pigeon pea at Research Farm, Department of Soil Science and Agricultural Chemistry, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani.

Soil fertility status of experimental field

The soil of experimental site belongs to taxonomic class Parbhani series of mixed Montmorillonite Hyperthermic Typic Haplusterts. The soils are dominant in Montmorillonite followed by moderate amount and traces of illite.

The experiment was counducted in randomized block design with plot size of 5.4×4.2m^2 and 8 treatments were T_1: Absolute control (No fertilizer), T_2: Only RDF (25:50 N and P_2O_5 kg ha^{-1}), T_3: RDF + 15 kg K_2O ha^{-1}, T_4: RDF + 30 kg K_2O ha^{-1}, T_5: RDF + 45 kg K_2O ha^{-1}, T_6: RDF + 15 kg K_2O ha^{-1} + 15 Kg $ZnSO_4$ha^{-1}, T_7: RDF + 30 kg K_2O ha^{-1} + 15 Kg $ZnSO_4$ha^{-1}, T_8: RDF + 45 kg K_2O ha^{-1} + 15 Kg $ZnSO_4$ha^{-1}. Pigeon pea variety BSMR – 736 was sown in rows 90 cm and plant 20 cm. Application of K and Zn at sowing. One irrigation at the time of flowering were provided. The RDF viz., 25: 50 kg ha^{-1} N, P_2O_5, was applied to pigeon pea during the following kharif season. The soil of the experimental site is alkaline having pH (7.81) with organic carbon (OC) content (4.73 g kg^{-1}) with calcium carbonate ($CaCO_3$) content (55.03 g kg^{-1}) and low in available N (201.25 kg ha^{-1}) and phosphorous (P_2O_5) content (7.39 kg ha^{-1}) and available potassium (K_2O) content (704.27 kg ha^{-1}) and available iron content (4.01 mg kg^{-1}) and available zinc content (0.19 mg kg^{-1}) and available manganese content (2.15 mg kg^{-1}) and available copper content (0.85 mg kg^{-1}).

Results and Discussion

The soil analysis of the experimental plot was carried out before the establishment of field experiment and at harvest stage of the crop. The data regarding soil analysis is presented in a Table 1.

Soil properties

Soil pH before sowing and after harvest of pigeon pea was influenced by potassium and zinc application at sowing stage of pigeon pea. The range of soil pH from 7.48 to 7.67 and at initial 7.81. Soils were in alkaline range with a mean pH value of 7.61. There was numerical increase or decrease in soil pH. Highest pH value was recorded in control plot 7.67, as no fertilizer application was carried out. The relative high soil pH might be due presence of high degree of base saturation.

Electrical conductivity

Electrical conductivity presented in (Table 1.) of soil before sowing and after harvest, before sowing 0.27 dSm^{-1}and after harvest ranges from 0.15 to 0.19 dSm^{-1}.In different treatment application potassium and zinc significant differences were observed in electrical conductivity. Minimum EC 0.15 dSm^{-1} was observed in treatment T_1 (control). The safe soluble salt concentration in soils might be due to proper management of soil from surface to sub-surface. Macro and micronutrients through soil application improves electrical conductivity of soil after harvest of pigeon pea.

Organic carbon

Organic carbon content of soil at before sowing and after harvest in (Table 1). It varied from 5.40 to 6.68 g kg^{-1} and before sowing 4.73 g kg^{-1}. Whereas, lowest 5.40 g kg^{-1} organic carbon was recorded in treatment T_1 (Absolute control). Organic carbon content in soil depends on the range of precipitation is observed at Hot and dry climate is directly related with the temperature variation which is responsible for hastening rate of oxidation of organic matter.

Table 1: Soil properties of the experimental soil before sowing and after harvest of crop

	Treatments	p^H	EC (dSm^{-1})	Organic carbon (g kg^{-1})	$CaCo_3$ (g kg^{-1})
	Before sowing				
	Initial	7.81	0.27	4.73	55.03
	After harvest				
T_1	Absolute control	7.67	0.16	5.40	42.39

T_2	Only RDF (25:50 N and P_2O_5 kg ha^{-1})	7.48	0.18	6.38	45.48
T_3	RDF + 15 kg K_2O ha^{-1}	7.59	0.15	6.68	43.43
T_4	RDF + 30 kg K_2O ha^{-1}	7.61	0.17	5.83	44.50
T_5	RDF + 45 kg K_2O ha^{-1}	7.64	0.19	6.57	43.59
T_6	RDF + 15 kg K_2O ha^{-1} + 15 kg $ZnSO_4$ ha^{-1}	7.63	0.19	6.66	42.44
T_7	RDF + 30 kg K_2O ha^{-1} + 15 kg $ZnSO_4$ ha^{-1}	7.59	0.16	5.68	45.13
T_8	RDF + 45 kg K_2O ha^{-1} + 15 kg $ZnSO_4$ ha^{-1}	7.65	0.17	6.65	41.52
	Grand Mean	7.61	0.17	6.23	43.56
	SEm (±)	0.39	0.01	0.67	0.96
	CD at 5%	NS	NS	NS	NS

Calcium carbonate

Calcium carbonate content of soil before sowing 55.03 g kg^{-1} and after sowing ranges from 41.52 to 45.48 g kg^{-1} of pigeon pea presented in (Table 1). The $CaCO_3$ content was not significant due to application of various treatments. However, there was numerical increase or decrease in $CaCO_3$ content. The calcareous nature along with dominance of Montmorillonite clay influence greatly the availability of nutrients for plants.

Available nitrogen

Influence of varying levels of potassium and zinc application on available nitrogen at critical growth stages of pigeon pea was presented in Table 2.

Table 2: Influence of varying levels of potassium and zinc on available nitrogen

Treatments		Flowering	Pod development	Harvesting
T_1	Absolute control	199.15	214.32	195.15
T_2	Only RDF (25:50 N and P_2O_5 kg ha^{-1})	201.56	237.30	195.53
T_3	RDF + 15 kg K_2O ha^{-1}	227.29	251.22	198.18
T_4	RDF +30 kg K_2O ha^{-1}	226.41	262.09	215.38
T_5	RDF + 45 kg K_2O ha^{-1}	218.25	247.37	205.67
T_6	RDF + 15 kg K_2O ha^{-1} + 15 kg $ZnSO_4$ha^{-1}	228.62	253.56	224.54
T_7	RDF + 30 kg K_2O ha^{-1} + 15 kg $ZnSO_4$ ha^{-1}	240.51	273.39	227.70
T_8	RDF + 45 kg K_2O ha^{-1} + 15 kg $ZnSO_4$ ha^{-1}	238.58	269.14	226.65
Grand Mean		222.55	251.05	211.10
SEm		2.68	3.70	3.07
CD at 5 %		8.15	11.23	9.32

The soil available nitrogen was in the range of 199.15 to 240.51 kg ha^{-1} at flowering stage with an average of 222.55 kg ha^{-1} which was further increased to 251.05 kg ha^{-1} during pod development stage and then reduced to 211.10 kg ha^{-1} at harvesting stage. The treatment T_7 (RDF + 30 kg K_2O ha^{-1} + 15 kg $ZnSO_4$ ha^{-1}) showed highest N 240.51, 273.39, 227.70 kg ha^{-1} availability and at par with treatment T_8 (RDF + 45 kg K_2O ha^{-1} + 15 kg $ZnSO_4$ ha^{-1}) 238.58, 269.14, 226.65 kg ha^{-1} and T_6 (RDF + 15 kg K_2O ha^{-1} + 15 kg $ZnSO_4$ ha^{-1}) 228.62, 253.56, 224.54 kg ha^{-1} at all the growth stages of pigeon pea. Increase while available N content at pod development stage may be attributed to addition of N through nodules. The available N content was lowered down at harvest might be due to its higher utilization of N at grain formation stage. Pigeon pea being a pulse crop required more N for protein synthesis. Further, it was noticed that available N content was increased in the treatment receiving potassium and zinc. This might be because of synergistic effects between N, K and zinc. Similar results have also been reported by Balpande *et al.* (2016) [2].

Available phosphorus

Table 3: Influence of varying levels of potassium and zinc on available phosphorous

Treatments		Available P (kg ha^{-1})		
		Flowering	Pod development	Harvesting
T_1	Absolute control	10.34	8.19	7.66
T_2	Only RDF (25:50 N and P_2O_5 kg ha^{-1})	13.03	10.09	8.86
T_3	RDF + 15 kg K_2O ha^{-1}	13.28	10.21	8.96
T_4	RDF +30 kg K_2O ha^{-1}	13.63	10.37	9.35
T_5	RDF + 45 kg K_2O ha^{-1}	13.74	10.26	8.15
T_6	RDF + 15 kg K_2O ha^{-1} + 15 kg $ZnSO_4$ ha^{-1}	13.77	10.75	9.43
T_7	RDF + 30 kg K_2O ha^{-1} + 15 kg $ZnSO_4$ ha^{-1}	14.32	12.65	9.56
T_8	RDF + 45 kg K_2O ha^{-1} + 15 kg $ZnSO_4$ ha^{-1}	13.78	10.86	9.74
Grand Mean		13.23	10.42	8.96
SEm		0.60	1.15	0.42
CD at 5 %		1.82	3.50	1.28

The data presented in Table 3. revealed that, the available phosphorus was in the range of 10.34 to 14.32 kg ha^{-1}, 8.19 to 12.65 kg ha^{-1} and 7.66 to 9.56 kg ha^{-1} at flowering, pod development and at harvesting stage of the crop, respectively. The treatment T_7 (RDF + 30 kg K_2O ha^{-1} + 15 kg $ZnSO_4$ ha^{-1}) recorded the highest P availability 14.32, 12.65, 9.56 kg ha^{-1}, which was at par with treatment T_8 (RDF + 45 kg K_2O ha^{-1} + 15 kg $ZnSO_4$ ha^{-1}) 13.78, 10.86, 9.74 kg ha^{-1}, and T_6 (RDF + 15 kg K_2O ha^{-1} + 15 kg $ZnSO_4$ ha^{-1}) 13.77, 10.75, 9.43 kg ha^{-1}, but significantly superior over the remaining treatment with minimum value under absolute control T_1 10.34, 8.19 and 7.66 kg ha^{-1} at flowering, pod development and harvesting stage, respectively. These results are in agreement with the findings of Balpande *et al.* (2016) [2].

Available potassium

Table 4: Influence of varying levels of potassium and zinc on available potassium

Treatments		Available K (kg ha^{-1})		
		Flowering	Pod development	Harvesting
T_1	Absolute control	841.15	818.96	713.35
T_2	Only RDF (25:50 N and P_2O_5 kg ha^{-1})	872.17	871.18	716.08
T_3	RDF + 15 kg K_2O ha^{-1}	898.49	879.22	720.86
T_4	RDF +30 kg K_2O ha^{-1}	908.22	882.08	771.83
T_5	RDF + 45 kg K_2O ha^{-1}	938.22	894.20	778.39
T_6	RDF + 15 kg K_2O ha^{-1} + 15 kg $ZnSO_4$ ha^{-1}	920.12	842.29	738.13
T_7	RDF + 30 kg K_2O ha^{-1} + 15 kg $ZnSO_4$ ha^{-1}	959.30	919.36	812.46
T_8	RDF + 45 kg K_2O ha^{-1} + 15 kg $ZnSO_4$ ha^{-1}	956.17	909.21	805.49
Grand Mean		911.73	877.06	757.07
SEm		3.01	3.77	4.71
CD at 5 %		9.14	11.43	14.29

The data presented in Table 4 and fig. 1. Revealed that, the availability of potassium varied from 841.15 to 959.30 kg ha^{-1}, 818.96 to 919.36 kg ha^{-1} and 713.35 to 812.46 kg ha^{-1} at flowering, pod development and harvesting stage, respectively. The available K with an average values decreased from 911.73 to 757.07 kg ha^{-1} at flowering to harvesting stage of pigeon pea. In case of available K different levels of potassium was significantly superior over control 841.15, 818.96, 713.35 kg ha^{-1} at flowering, pod development and harvesting stage, respectively. The treatment T_7 (RDF + 30 kg K_2O ha^{-1} + 15 kg $ZnSO_4$ ha^{-1}) showed maximum K availability 959.30, 919.36, 812.46 kg ha^{-1} followed by T_8 (RDF + 45 kg K_2O ha^{-1} + 15 kg $ZnSO_4$ ha^{-1}) 956.17, 909.21, 805.49 kg ha^{-1} and T_5 (RDF + 45 kg K_2O ha^{-1}) 938.22, 894.20, 778.39 kg ha^{-1} at all the growth stages of pigeon pea. The application of higher levels of K showed an increasing tendency of K accumulation. Application of RDF and potassium resulted in higher productivity of pigeon pea and the buildup of available K and relatively lower mining of K from non-exchangeable pool. The high content of K_2O is due to the presence of K rich minerals in Vertisols and associated soils of Marathwada region. Balanced nutrition, particularly balancing N and K nutrition and tapping into the synergistic effect between N and K, is important in crop production system to improve nutrient use efficiency Kurhade *et al.*, (2015) [5], Balpande *et al.* (2016) [2], also observed higher available potassium with the application of 45 kg K_2O ha^{-1} along with recommended N and P_2O_5.

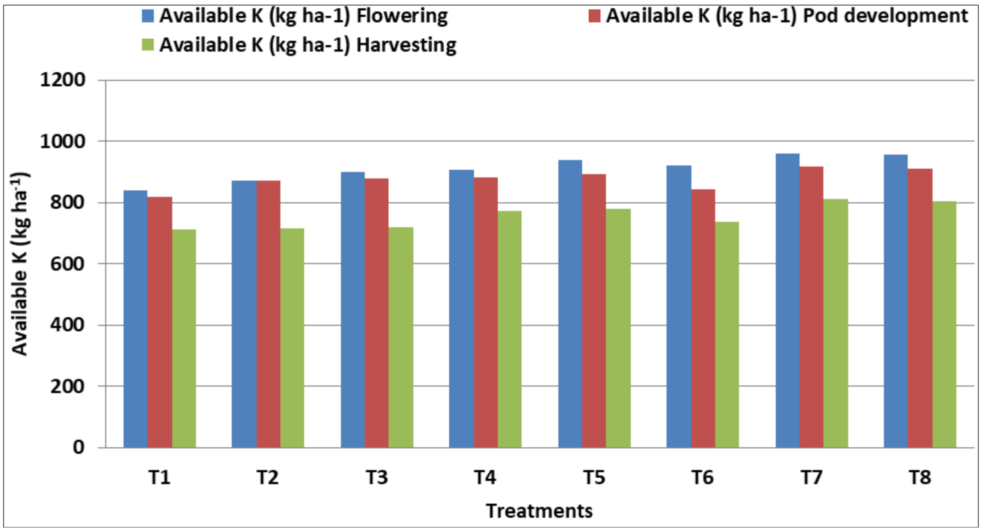

Fig 1: Influence of varying levels of potassium and Zinc application on available potassium

DTPA extractable zinc

The data pertaining to the influence of varying levels of potassium and zinc application on DTPA extractable zinc at critical growth stages of pigeon pea is presented in Table 5. and fig. 2. The DTPA extractable zn content was ranged from 0.37 to 0.81 mg kg^{-1}, 0.31 to 0.65 mg kg^{-1} and 0.25 to 0.63 mg kg^{-1} at flowering, pod development and harvesting stage, respectively. The treatment T_7 (RDF + 30 kg K_2O ha^{-1} + 15 kg $ZnSO_4$ ha^{-1}) noticed maximum zinc availability 0.81, 0.65, 0.63 kg ha^{-1} followed by T_6 (RDF + 15 kg K_2O ha^{-1} + 15 kg $ZnSO_4$ ha^{-1}) 0.61, 0.54, 0.50 kg ha^{-1} and T_8 (RDF + 45 kg K_2O ha^{-1} + 15 kg $ZnSO_4$ kg ha^{-1}) 0.55, 0.52, 0.51 kg ha^{-1} at all the growth stages of pigeon pea. The soils are usually low in available zinc and respond to the application of fertilizers. Zinc is found to be deficient in black soils because presence of calcium carbonate decreases the availability of zinc due to higher soil pH Arunachalam *et al.* (2013) [1]. This might be due to the fact that under alkaline condition zinc cation charged largely to their oxides or hydroxides and thereby lower the availability of Zn. These results are in line with the findings of Kannan *et al.* (2014) [4].

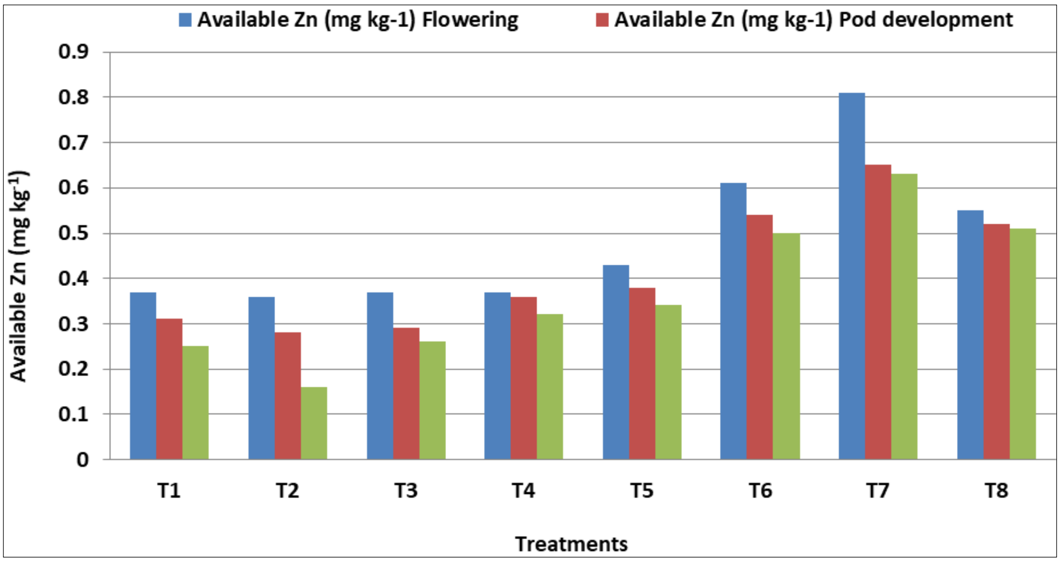

Fig 2: Influence of varying levels of potassium and zinc application on available zinc.

Table 5: Influence of varying levels of potassium and zinc on available zinc

Treatments		Available Zn (mg kg^{-1})		
		Flowering	**Pod development**	**Harvesting**
T_1	Absolute control	0.37	0.31	0.25
T_2	Only RDF (25:50 N and P_2O_5 kg ha^{-1})	0.36	0.28	0.16
T_3	RDF + 15 kg K_2O ha^{-1}	0.37	0.29	0.26
T_4	RDF +30 kg K_2O ha^{-1}	0.37	0.36	0.32
T_5	RDF + 45 kg K_2O ha^{-1}	0.43	0.38	0.34
T_6	RDF + 15 kg K_2O ha^{-1} + 15 kg $ZnSO_4$ ha^{-1}	0.61	0.54	0.50
T_7	RDF + 30 kg K_2O ha^{-1} + 15 kg $ZnSO_4$ ha^{-1}	0.81	0.65	0.63
T_8	RDF + 45 kg K_2O ha^{-1} + 15 kg $ZnSO_4$ ha^{-1}	0.55	0.52	0.51
Grand Mean		0.48	0.41	0.37
SEM		0.02	0.03	0.01
CD at 5 %		0.07	0.10	0.06

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