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Moisture Conservation and Zinc Fertilization Impacts on System Performance and Soil Fertility Status of Pearlmillet-Chickpea Cropping System under Limited Moisture Conditions

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ABSTRACT: The present study was conducted at the research farm of IARI, New Delhi for two consecutive years from 2012-13 to 2013-14 to find out the impact of moisture conservation and zinc fortification on system performance and soil fertility status of pearlmillet-chickpea cropping system under limited moisture conditions. Planting of pearlmillet and chickpea under the flat bed with 5.0 t/ha crop residue recorded significantly higher system productivity in terms of pearlmillet grain equivalent yield (8.98 t/ha), moisture use efficiency (16.13 kg/ha-mm) and total uptake of nutrients (N, P, K, Zn, Fe, Mn and Cu) over flat bed without crop residue and flat bed with 2.5 t/ha crop residue. However, the significantly higher system net returns of ₹ 83,367/ha along with B: C ratio of 1.71 was observed under narrow bed and furrow with 2.5 t/ha crop residue. Residue applied, moisture conservation practices also showed remarkable improvement in soil fertility status at the end of cropping seasons as compared to without residue applied treatment. Under zinc fertilization treatments, application of 5.0 kg Zn/ha to pearlmillet recorded significantly higher system productivity, profitability, moisture use efficiency and total uptake of N, K and Zn over the lower levels. However, total uptake of P, Fe, Mn and Cu were increased significantly only up to 2.5 kg Zn/ha. Fertilization of chickpea with 5.0 kg Zn/ha also registered significantly higher system productivity, profitability, moisture use efficiency and total uptake of nutrients (except P) as compared to lower levels. Zinc fertilization treatments also brought significant improvement in organic carbon, available N, K and DTPA extractable Zn content in soil at the end of the experiment.

Key words: Crop residue, narrow bed and furrow, system productivity, moisture use efficiency, soil fertility

Introduction

In arid and semi-arid parts of the India pearl millet (*Pennisetum glaucum* L.) are considered as the principal crop, because of the hardy nature of crop against extreme weather and poor soils. In these areas, mono-cropping was considered to be the most appropriate system due to unavailability of short duration varieties and lack of appropriate scientific management practices. But with the advent of short duration varieties and increasing population pressure, various multiple cropping systems have become popular in different parts of the country. In assured rainfall areas, pearlmillet is followed by various *rabi* crops *viz*., wheat, mustard, chickpea, toria/taramira, barley, linseed, lentil, etc. Pearlmillet is grown as rainfed crop and *rabi* crop is grown on conserved moisture. Pearlmillet-chickpea is one successful cropping sequence under such situations. In pearl millet-based cropping systems of rainfed areas, pulse crop, especially chickpea is considered as a prominent crop due to its low input requirement and capacity to withstand drought and consequently perform relatively better than other crops in the fragile and harsh climate prevailing in the regions.

Another limiting factor for double cropping in arid and semi-arid areas is the shortage of moisture due to inadequate and uneven distribution of rainfall and loss of water through runoff. Inadequate availability of water leads to low and unstable productivity due to moisture stress at critical stages of crop growth. So, in limited moisture availability conditions double cropping is possible if cultural and nutritional requirements of the first crop of the system are properly met. Crop residues are considered as an important renewable resource that can be used to conserve non-renewable soil and water resources and sustain crop production in the semi-arid tropics of India (Nalatwadmath *et al.,* 2006). Retention of crop residue on soil also adds organic matter, which improves the quality of the seedbed and increases the water infiltration and retention capacity of the soil, fixes carbon by capturing carbon dioxide from the atmosphere and retaining it in the soil, buffers the pH of the soil and facilitates the availability of nutrients, feeds the carbon cycle of the soil, captures the rainfall and thus, increases the soil moisture content, protects the soil from being eroded and reduces the evaporation of soil moisture (Bhale and Wanjari, 2009).

At present, widespread and acute deficiency of zinc is another serious problem in arid and semi-arid soils. The widespread deficiency of zinc in dryland soils of semi-arid tropics of India was reported by Sahrawat *et al.* (2007). Zinc is essential for the normal healthy growth and reproduction of plants and plays a key role as a structural constituent or regulatory co-factor of a wide range of enzymes in many important biochemical pathways (Kabata and Pendias, 2001). Zn is also required for the regulation and maintenance of the gene expression required for the tolerance of environmental stresses in plants, such as high light intensity and high temperature (Cakmak, 2002). So, moisture conservation and zinc fertilization is essential for sustained increase in the productivity of rainfed cropping systems of India. Considering this, the present study was undertaken to find out the effect of moisture conservation and zinc fertilization on productivity and soil fertility of pearlmillet-chickpea cropping system under limited moisture conditions.

Materials and Methods

The present field study was conducted at the research farm of ICAR-Indian Agricultural Research Institute, New Delhi for two consecutive years during 2012-13 and 2013-14 to evaluate the effect of moisture conservation and zinc fertilization on performance of the system and soil fertility of pearlmillet-chickpea cropping system under limited moisture conditions. The experimental farm is situated at 28°37' N latitude, 77°09'E longitude and 224 m above mean sea level. The total rainfall received during *kharif* seasons was 416.0 and 928.6 mm, respectively, out of which 316.8 (76.1%) and 401.9 mm (43.3%) was measured as effective. The total rainfall received during *rabi* seasons were 164.4 and 152.4 mm, respectively, out of which 138.5 (84.3%) and 139.6 mm (91.6%) was measured as effective. The experimental soil was sandy loam in texture (61.48% sand, 12.66% silt and 25.86% clay) and slightly alkaline in reaction (pH 7.7). The soil was low in organic carbon (0.40%) and available nitrogen (135.4 kg N/ha), medium in available phosphorus (12.8 kg P/ha), potassium (178.8 kg K/ha) and DTPA extractable Zn (0.63 mg/kg of soil). The experiment comprised of four treatments of moisture conservation (flat bed without crop residue, flat bed with 2.5 t/ha crop residue, flat bed with 5.0 t/ha crop residue and narrow bed and furrow with 2.5 t/ha crop residue) as main plots and three treatments of zinc fertilization (control, 2.5 kg Zn/ha and 5.0 kg Zn/ha) as sub plot to pearlmillet and as sub-sub plot to chickpea. For study of direct and residual effect of zinc in succeeding chickpea crop each sub plot was divided into three sub-sub plots. Therefore the experiment was laid out in split plot design during first season and in split-split plot design during succeeding seasons with three replications. The pearlmillet variety 'Pusa composite-443' and chickpea variety 'Pusa-1103' were taken for experiment. The pearlmillet was sown at 50 cm x 15 cm spacing with 4.0 kg/ha seed rate, whereas, chickpea was sown at 30 cm x 10 cm spacing with seed rate of 80 kg/ha. A common dose of 60 kg N, 40 kg P_2O_5 and 40 kg K_2O/ha to pearlmillet and 20 kg N, 40 kg P_2O_5 and 40 kg K_2O/ha to chickpea were applied through urea, diammonium phosphate (DAP) and muriate of potash (MOP). Half dose of nitrogen and full dose of phosphorus and potassium to pearlmillet and full dose of NPK to chickpea was applied as basal dose at the time of sowing and in case of pearlmillet remaining half dose of nitrogen was top dressed at 40 DAS through urea.

After field preparation and before sowing of crops, the narrow beds of 70 cm wide with furrows of 30 cm width were prepared manually in respective plots and under this during *kharif* two rows of pearlmillet were sown at the spacing of 50 cm, whereas, during *Rabi* three rows of chickpea were sown at the spacing of 30 cm. Chickpea residue to pearlmillet and preceding pearlmillet residue to chickpea were applied on the surface of soil in main plots as per treatments just after sowing as moisture conservation treatments during all the seasons. During next season the applied crop residue was incorporated into the soil. The composition of crop residues is given in Table 1. Zinc fortification treatments were applied as per treatments through zinc sulphate ($ZnSO_4.7H_2O$) containing 21% Zn and 10% S at the time of sowing as basal dose. The amount of sulphur was adjusted through SSP in all the plots. The crops were grown with a recommended package of practices. The pearl millet crop was sown on 12th and 11th July and harvested on 30th and 26th September during 2012 and 2013, respectively, however, the chickpea crop was sown on 2nd November and 23rd October and harvested on 1st and 5th April during 2012-13 and 2013-14, respectively. The grain and stover yield of pearlmillet and chickpea recorded during *kharif* and *rabi* seasons were used to calculate system productivity. The market price of the produce was taken to calculate the system productivity and expressed as pearlmillet grain and stover equivalent yield. System economics of each treatment were worked out by taking into account the total cost of treatment of the system and the income obtained from system output based on the prevailing market price of pearlmillet grain and Stover. Consumptive use of water was measured by summing up the soil moisture contribution and effective rainfall. For measurement of soil moisture contribution, soil samples were taken from 0-15, 15-30, 30-45 and 45-60 cm depth at the time of sowing as well as at the harvesting of each crop from all the plots. Potential evapotranspiration to precipitation (PET/P) ratio method was used for the measurement of effective rainfall (Dastane, 1974). The moisture use efficiency of the system was worked by dividing the pearlmillet grain equivalent yield to the total consumptive use of the system. The chemical analysis of

Table 1 : Nutrient composition of crop residues

Residue	Year	Nutrient content						
		Macronutrient (%)			Micronutrient (ppm)			
		N	P	K	Zn	Fe	Mn	Cu
Chickpea	2012	0.954	0.201	1.509	37.23	220.4	44.87	18.78
	2013	0.937	0.205	1.496	39.47	221.2	44.72	19.04
Pearlmillet	2012-13	0.672	0.252	1.439	24.59	275.2	77.84	27.52
	2013-14	0.687	0.257	1.462	24.70	277.3	78.65	28.26

plant samples for concentration of N, P, K and micronutrients (Zn, Fe, Mn and Cu) were done as per standard procedures for estimation of the total nutrient uptake of the system. Soil samples were analyzed for organic carbon, available N, P and K and DTPA extractable Zn, Fe, Mn and Cu at the start and end of the experiment as per standard procedures. Statistical analysis of the data was carried out using standard analysis of variance (Gomez and Gomez, 1984).

Results and Discussion

System productivity

System productivity of pearlmillet-chickpea cropping sequence computed in terms of pearlmillet grain and stover equivalent yield was obtained significantly highest with sowing of pearlmillet and chickpea under flat bed with 5.0 t/ha crop residue (8.98 and 9.92 t/ha) followed by narrow bed and furrow with 2.5 t/ha crop residue (8.75 and 9.72 t/ha) as compared to flat bed without crop residue and flat bed with 2.5 t/ha crop residue (Table 2). The higher system productivity under aforesaid treatments ascribed to the higher grain and stover yield of component crops (pearlmillet and chickpea) under these treatments led towards higher system productivity in terms of pearlmillet grain equivalent yield. Sharma *et al.* (2010) were also reported similar kind of findings under moisture conservation practices.

System productivity of pearlmillet-chickpea cropping system increased significantly with increasing levels of zinc applied to pearlmillet and chickpea up to 5.0 kg Zn/ha (Table 2). The favourable influence of applied zinc on system productivity of pearlmillet-chickpea cropping system ascribed to its involvement in various metabolic activities, controlling auxin levels and nucleic acids (Marschner, 1995). Zinc is also an essential component of enzymes responsible for the assimilation of nitrogen, which help in chlorophyll formation and plays an important role in nitrogen metabolism, might contribute towards increased growth and development of plant and finely on the productivity of crops. The results of the present investigation are supported by the findings of Jain and Dahama (2005) and Chaudhary *et al.* (2014).

System profitability

Pearlmillet and chickpea sown on narrow bed and furrow with 2.5 t/ha crop residue remained at par to flat bed with 5.0 t/ha crop residue, fetched significantly higher net returns of ₹ 83,367 as compared to flat bed without crop residue and flat bed with 2.5 t/ha crop residue (Table 2). The same treatment also resulted into significantly higher B:C ratio as compared to rest of the moisture conservation practices, whereas, flat bed with 5.0 t/ha crop residue fetched lowest B:C ratio of the system. The increased net returns and B:C ratio under narrow bed and furrow with 2.5 t/ha crop residue might be due to higher additional returns through higher productivity obtained under this treatment as compared to cost involved. Though, flat bed with 5.0 t/ha crop residue gave significantly higher system productivity but higher cost of crop residue under this treatment reduced net returns and B:C ratio. These results are in close conformity with those of Sharma *et al.* (2010) and Rajkumara *et al.* (2014).

Among the zinc fertilization treatments, fertilization of pearlmillet and chickpea with 5.0 kg Zn/ha fetched significantly higher net returns of ₹ 80,162 and 79,854/ha with B:C ratio of 1.67 and 1.66 as compared to lower levels of zinc fertilization (Table 2). Jain and Dahama (2005) in pearlmillet-wheat and Sammauria and Yadav (2010) in pearlmillet-fenugreek cropping system also reported significant improvement in system economics with zinc fertilization.

Consumptive use of water and moisture use efficiency

Sowing of crops under residue applied treatments resulted into substantial reduction in consumptive use of water as compared to no residue applied treatment (Table 2). The significantly higher moisture use efficiency of the system (16.13 kg/ha-mm) was observed under flat bed with 5.0 t/ha crop residue as compared to flat bed without crop residue and flat bed with 2.5 t/ha crop residue. Higher moisture use efficiency of the system under flat bed with 5.0 t/ha crop residue planted pearlmillet and chickpea could be the result of better moisture conservation and reduced loss of moisture through evaporation led to higher grain yield. The improvement in moisture use efficiency with moisture conservation practices were also reported by Tetarwal and Rana (2006).

Total consumptive use of water in pearlmillet-chickpea cropping system increased slightly with increasing levels of zinc fertilization being highest at with 5.0 kg Zn/ha (Table 2). Zinc fertilization treatments brought significant variation in moisture use efficiency of pearlmillet-chickpea cropping system which was observed significantly higher (14.92 and 14.95 kg/ha-mm) under fertilization of pearlmillet and chickpea with 5.0 kg Zn/ha in comparison to lower levels.

Nutrient uptake

Nutrient uptake of pearlmillet-chickpea cropping system was improved significantly under different moisture conservation practices (Table 3). The significantly higher total uptake of N, K, Mn and Cu by pearlmillet-chickpea cropping system was recorded under flat bed with 5.0 t/ha crop residue followed by narrow bed and furrow with 2.5 t/ha crop residue. However, total uptake P, Zn and Fe, flat bed with 5.0 t/ha crop residue, proved significantly superior over other moisture conservation practices. The improvement in total uptake of nutrients under residue applied treatments ascribed to favorable moisture condition in the soil maintained for relatively longer period and improvement in available nutrient status of soil through decomposition of crop residues. Thus, the favorable moisture condition and improved nutritional environment led to higher translocation and assimilation of nutrients to grain and stover (Sharma *et al.,* 2010; Paliwal *et al.,* 2011). Further, application of crop residue lowers down the soil pH through liberation of CO_2 and organic acid during decomposition and its decomposition products might solubilize the nutrients already present in soil and rendering micronutrients available to the plant (Prasad *et al.,* 2010; Kumari and Prasad, 2014).

Fertilization of pearlmillet and chickpea with 5.0 kg Zn/ha resulted into significantly higher total uptake of N (239.9 and 237.9 kg/ha) and K (245.9 and 242.7 kg/ha) by the system as compared to lower levels (Table 3). The increase in uptake of

Table 2 : Effect of moisture conservation and zinc fertilization on system productivity, economics, consumptive use of water and moisture use efficiency of pearlmillet-chickpea cropping system (pooled data of two years)

Treatment	Pearlmillet grain equivalent yield (t/ha)	Pearlmillet stover equivalent yield (t/ha)	Cost of cultivation (₹/ha)	Net returns (₹/ha)	B:C ratio	Consumptive use of water (mm)	Moisture use efficiency (kg/ha-mm)
Moisture conservation practices							
Flat bed	6.56	7.77	39,539	60,463	1.53	583.1	11.35
Flat bed + 2.5 t/ha crop residue	7.94	8.98	47,429	72,737	1.53	570.1	14.05
Flat bed + 5.0 t/ha crop residue	8.98	9.92	54,499	80,884	1.48	561.4	16.13
NBF* + 2.5 t/ha crop residue	8.75	9.72	48,659	83,367	1.71	564.9	15.62
SEm±	0.12	0.15	-	1,617	0.03	-	0.20
LSD (P=0.05)	0.35	0.47	-	4,983	0.10	-	0.62
Zinc fertilization to pearlmillet (kg/ha)							
0	7.52	8.53	47,023	66,789	1.42	564.9	13.45
2.5	8.18	9.24	47,598	76,138	1.60	570.4	14.49
5.0	8.48	9.52	47,973	80,162	1.67	574.3	14.92
SEm±	0.08	0.10	-	1,100	0.02	-	0.14
LSD (P=0.05)	0.24	0.29	-	3,168	0.06	-	0.41
Zinc fertilization to chickpea (kg/ha)							
0	7.52	8.83	47,016	67,363	1.43	565.9	13.43
2.5	8.17	9.15	47,601	75,871	1.59	570.2	14.48
5.0	8.48	9.31	47,976	79,854	1.66	573.5	14.95
SEm±	0.07	0.05	-	918	0.02	-	0.12
LSD (P=0.05)	0.19	0.13	-	2,577	0.05	-	0.34

*Narrow bed and furrow

Table 3 : Effect of moisture conservation and zinc fertilization on total uptake of nutrient by pearlmillet-chickpea cropping system (pooled data of two years)

Treatment	Macro nutrient uptake (kg/ha)			Micronutrient uptake (g/ha)			
	N	P	K	Zn	Fe	Mn	Cu
Moisture conservation practices							
Flat bed	174.7	45.9	183.4	462.6	3235.0	840.7	312.6
Flat bed + 2.5 t/ha crop residue	220.2	57.9	228.1	590.1	3941.2	1021.9	384.2
Flat bed + 5.0 t/ha crop residue	255.1	67.2	263.9	684.6	4489.4	1158.5	440.3
NBF* + 2.5 t/ha crop residue	244.2	64.1	251.9	650.7	4324.9	1119.5	424.0
SEm±	3.67	0.89	4.27	9.50	51.55	14.60	6.85
LSD (P=0.05)	11.30	2.74	13.15	29.27	158.83	45.00	21.12
Zinc fertilization to pearlmillet (kg/ha)							
0	202.9	56.1	213.7	504.0	3829.9	992.2	373.4
2.5	228.0	60.0	235.8	609.8	4042.6	1047.1	394.9
5.0	239.9	60.2	245.9	677.3	4120.4	1066.1	402.6
SEm±	1.86	0.51	2.26	6.42	36.93	10.40	4.02
LSD (P=0.05)	5.37	1.46	6.51	18.50	106.39	29.97	11.59
Zinc fertilization to chickpea (kg/ha)							
0	205.6	56.8	218.2	523.0	3875.1	1004.4	378.7
2.5	227.3	59.6	234.6	607.6	4021.4	1041.4	392.8
5.0	237.9	60.0	242.7	660.4	4096.3	1059.5	399.5
SEm±	1.33	0.31	1.24	3.99	25.20	6.19	2.09
LSD (P=0.05)	3.72	0.87	3.49	11.20	70.74	17.38	5.87

*Narrow bed and furrow

Table 4 : Effect of moisture conservation and zinc fertilization on soil fertility status at end of experiment

Treatment	SOC (g/kg soil)	Available macro-nutrients (kg/ha)			DTPA extractable micro-nutrients (mg/kg)			
		N	P	K	Zn	Fe	Mn	Cu
Moisture conservation practices								
Flat bed	3.92	135.1	12.3	174.2	0.67	4.67	5.03	1.66
Flat bed + 2.5 t/ha crop residue	4.22	141.7	13.2	186.4	0.71	4.93	5.29	1.77
Flat bed + 5.0 t/ha crop residue	4.38	146.6	13.7	192.4	0.74	5.05	5.39	1.82
NBF* + 2.5 t/ha crop residue	4.28	143.1	13.4	188.2	0.72	4.97	5.32	1.79
SEm±	0.04	1.41	0.11	1.67	0.007	0.047	0.049	0.018
LSD (P=0.05)	0.15	4.88	0.37	5.77	0.023	0.164	0.171	0.062
Zinc fertilization to pearlmillet (kg/ha)								
0	4.14	140.3	13.3	183.3	0.63	4.96	5.31	1.78
2.5	4.21	141.9	13.2	185.6	0.72	4.90	5.25	1.76
5.0	4.26	142.6	13.0	187.0	0.79	4.86	5.22	1.75
SEm±	0.03	0.97	0.09	1.17	0.006	0.041	0.039	0.016
LSD (P=0.05)	NS	NS	NS	NS	0.018	NS	NS	NS
Zinc fertilization to chickpea (kg/ha)								
0	4.12	139.2	13.4	182.4	0.58	4.98	5.33	1.79
2.5	4.21	142.1	13.2	185.8	0.73	4.90	5.25	1.76
5.0	4.28	143.5	12.9	187.7	0.82	4.84	5.20	1.74
SEm±	0.03	0.76	0.07	1.09	0.006	0.039	0.036	0.016
LSD (P=0.05)	0.08	2.15	0.21	3.10	0.017	NS	NS	NS

*Narrow bed and furrow

Initial status: SOC- 4.0 g/kg soil, Available N- 135.4 kg/ha, P- 12.8 kg/ha and K- 178.8 kg/ha and DTPA extractable Zn- 0.63 mg/kg, Fe- 4.75 mg/kg, Mn- 5.12 mg/kg and Cu- 1.70 mg/kg***++++++

N and K might be due to the beneficial role of Zn in increasing CEC of roots which helped in increasing absorption of nutrients from the soil. The findings are in the close conformity with the findings of Singh and Bhati (2013). Zinc interact antagonistically with phosphorus at higher levels, which resulted in to decreased content of phosphorus, but higher yield at higher levels resulted in increased uptake of P, however, the response was significantly only up to 2.5 kg Zn/ha (Table 3). Such types of findings were also reported by Keram *et al.* (2012). The total uptake of Zn by pearlmillet-chickpea cropping system was increased significantly with increasing levels of Zn fertilization up to 5.0 kg Zn/ha (Table 3). The increased Zn uptake by the crop owing to its higher availability in the soil due to addition of zinc in the soil with low availability (Sharma and Abrol, 2007). Fe, Mn and Cu were also interacting antagonistically with zinc at higher levels though the uptake was increased with increasing levels because of higher yields (Table 3). Application of 5.0 kg Zn/ha being at par with 2.5 kg Zn/ha recorded significantly higher uptake of Fe, Mn and Cu by pearlmillet-chickpea cropping system. The reduced content of Fe, Mn and Cu in plant parts owing to application of zinc might be due to that Zn competes with these micronutrients for absorption on the same site of root, thus the increased content of zinc created hindrance in absorption and translocation of Fe, Mn and Cu from the root to the above ground plant parts. The antagonistic interactions of zinc with other cationic micronutrients were also reported by Soleimani (2012).

Soil fertility status

Residue applied, moisture conservation practices showed remarkable improvement in soil fertility status at the end of experiment as compared to without residue applied treatment (Table 4). Flat bed with 5.0 t/ha crop residue recorded significantly higher organic carbon content in soil (4.38 g/kg soil) at end of experiment followed by narrow bed and furrow with 2.5 t/ha crop residue. The improvement in soil organic carbon status under residue applied treatment might result from the incorporation of crop residues led to improved soil moisture conditions which might have an increased microbial population that hastened decomposition of crop residues resulting in build up of organic carbon in the soil (Tiquia *et al.,* 2002). The significantly higher available N, P and K and DTPA extractable Zn in soil at harvest of the last crop of the system were founded under the flat bed with 5.0 t/ha crop residue, but it was found at par with narrow bed and furrow with 2.5 t/ha crop residue (Table 4). All the moisture conservation practices those received crop residue being at par with each other and proved significantly superior over without residue applied treatment in terms of DTPA extractable Fe, Mn and Cu at end of experiment (Table 4). The increase in content of available macro and micro nutrients in soil after harvest of crop under residue applied, moisture conservation practices endorsed due to decomposition of added crop residue through soil micro-organisms in the presence of adequate conserved moisture under these treatments led to improved available nutrient status in the soil (Kachroo and Dixit, 2005; Kuotsu *et al.*, 2014).

Zinc fertilization treatments applied to pearlmillet could not bring any significant impacts on organic carbon, available N, P and K and DTPA extractable Fe, Mn and Cu at the end of experiment (Table 4). However, fertilization of pearlmillet with 5.0 kg Zn/ha resulted into significantly higher DTPA extractable Zn in soil (0.79 mg/kg soil) at the end of experiment as compared to lower levels of zinc. Zinc fertilization treatments applied to chickpea brought significant improvement in organic carbon, available N and K and DTPA extractable Zn content in soil at the end of experiment, whereas, the available P content in soil decreased with increasing levels of zinc fertilization (Table 4). Application of 5.0 kg Zn/ha to chickpea resulted into significantly higher organic carbon (4.28 g/kg soil), available N (143.5 kg/ha) and K (187.7 kg/ha) over control. The improvement in soil organic carbon content under zinc applied treatments might be due to proliferation of root growth which on decomposition adds organic carbon into soil (Tamboli *et al.,* 2013). The increase in available N and K in soil with addition of zinc attributed to synergistic effect between N and Zn and due to the positive interaction of K and Zn, respectively. Similar finding were also reported by Badiyala and Chopra (2011) and Tamboli *et al.* (2013). Available P in soil at the end of experiment was decreased significantly with increasing levels of Zn fertilization. The decreased availability of P in soil with the application of Zn might be due to the antagonistic effect between Zn and P in soils forming insoluble compounds, $Zn_3(PO_4)_2$ resulting in the low amount of P in the available pool (Jain and Dahama, 2006; Sharma *et al.,* 2010). The significantly higher DTPA extractable Zn in soil (0.82 mg/kg soil) was observed under 5.0 kg Zn/ha as compared to control and 2.5 kg Zn/ha. The increase in DTPA extractable Zn possibly ascribed to higher solubility, diffusion and mobility of the applied inorganic zinc fertilizer led to the increased Zn status of soil (Tamboli *et al.,* 2013; Chaudhary *et al.,* 2014).

Conclusion

From the results of present investigation, it can be inferred that based on availability of crop residues, pearlmillet and chickpea can be sown either on flat bed with 5.0 t/ha crop residue or narrow bed and furrow with 2.5 t/ha crop residue and fertilized with 5.0 kg Zn/ha for achieving higher productivity and profitability with improved fertility status of the soil in pearlmillet-chickpea cropping system under limited moisture and zinc deficient conditions of arid and semi-arid areas.

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