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IN SITU MOISTURE CONSERVATION AND ZINC FERTILIZATION FOR RAINFED PIGEONPEA (*CAJANUS CAJAN* L.)

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ABSTRACT
In a two-year field experiment conducted at Junagadh (Gujarat), moisture conservation practices (flat bed, alternate between-row subsoiling, between-row subsoiling, in-row subsoiling, and broad bed and furrow) and zinc fertilization (0, 5 and 10 kg Zn ha^{-1}) were evaluated for pigeonpea (*Cajanus cajan* L.) grown under rainfed conditions. The results indicated that in-row subsoiling and broad bed and furrow reduced bulk density, conserved more soil moisture and significantly enhanced growth and yield attributes and nutrient uptake, which ultimately resulted in higher seed (1507 and 1443 kg ha^{-1}) and stalk yields (3143 and 3017 kg ha^{-1}) with higher net return (Rs. 15049 and 13991 ha^{-1}) over flat bed. Zinc fertilization @ 5 kg ha^{-1} was found effective in increasing growth and yield attributes and nutrient uptake, and eventually gave higher seed yield (1412 kg ha^{-1}) and stalk yield (2947 kg ha^{-1}) along with higher net returns (Rs. 13775 ha^{1}). Thus, the findings of present investigation indicated that in-row subsoiling or broad bed and furrow and application of 5 kg Zn ha^{-1} enhanced yield of pigeonpea and net returns under rainfed conditions.

INTRODUCTION

In India, pigeonpea (*Cajanus cajan* L.) accounts for 45% of the output of all pulses. India accounts for more than 90% of the world's pigeonpea production and area. Pigeonpea is an important crop in the semi-arid tropics because it tolerates drought, producing a relatively high yield on limited residual moisture. Wide variation in plant types and maturity groups permits pigeonpea to fit into numerous production systems, along with the additional benefits of fixing atmospheric nitrogen and recycling soil nutrients. At present, nearly 70% of the country's gross cropped area is under rainfed conditions. Rainfed agriculture accounts for more than 40% of total food grain production, 75% of oilseeds, 90% of pulses and 70% of cotton. In Gujarat 70 to 80% of total area is under dry farming.

Inadequate rainfall and its uneven distribution along with frequent droughts are the common features of arid and semi-arid regions, which lead to low and unstable crop yield. The high intensity rains causing temporary waterlogging, severe erosion and runoff, which results in only a relatively small portion of the rainfall becoming available for crop production. The decline in crop yields in arid and semi-arid regions has been partially attributed to soil compaction and the formation of a hardpan as a result of repeated mechanical cultivations at shallow depth, machinery traffic and natural sedimentation. The dense and compact layer in subsoil is characterized by high mechanical impedance for root growth and low water transmission in the soil matrix. In general, heavy textured soils are more prone to compaction than light-textured soils (McCormak, 1987). Raper and Schwab (2009) stated that hardpans frequently restrict root development thus making crops susceptible to short-term droughts. In-row subsoiling has become the tillage tool of choice for alleviation of this compacted soil condition. Subsoiling breaks the hard pan or compact layer present in the profile and helps in sinking down of the rainwater in the lower layer of soil from where it is not easily lost by evaporation and deeper rooting, which helps in better exploitation of stored soil moisture and applied nutrients from the profile (Ghosh *et al*., 2006), which ultimately boosts crop growth and yield (Singh, 1995). Subsoiling reduced surface runoff and increased soil water content (Hasegawa *et al*., 2002; Kabaki *et al*., 2002). Improved storage of water in soil profile, increased yields of cotton, soybean and peanut, and net returns were also realized with subsoiling (Wesley *et al*., 2001; Simoes *et al*., 2009).

Rainwater conservation is a critical factor in stabilizing and stepping up of crop yields in drylands. Land configuration like broad bed and furrow (BBF) can increase infiltration of rainwater and thus helps to improve moisture storage in soil profile (Mathukia and Khanpara, 2009). In arid and semi-arid regions, high evaporative demand cause moisture loss from upper two to three inches layer of the loose and pulverized soil very rapidly and thus could not become available to plant. The BBF resulted in lower runoff and soil loss with higher yield, monetary returns and water use efficiency compared with flat bed (Jadhav *et al*., 2008; Suryawanshi *et al*., 2008). Devi *et al*. (1991) observed that BBF resulted in larger water storage and higher seed yield of castor than the other tillage treatments.

Among micronutrients, deficiency of zinc is most common, widespread and frequently found in arid and semi-arid soils

(Tandon, 2003). By and large, 44% out of 254000 plant sample analysis and 69% by actual biological response confirmed that about 50% of Indian soils are deficient in Zn and 20% soils have its hidden deficiency. Therefore, much research focused on zinc and zinc fertilization has become an essential component in the package of practices for ensuring higher crop productivity (Singh, 1999). Murthy and Muralidharudu (2003) reported that on low zinc Alfisols, application of zinc at 5 kg ha^{-1} improved growth, yield attributes and resultantly increased seed yield of castor over control. Mali *et al*. (2003) investigated the effects of Zn at 0, 2.5 and 5 kg ha^{-1} on pigeonpea cv. ICPL-87 and found that Zn at 5 kg ha^{-1} resulted in increased grain yield over control.

It is now clear that integrated fertilizer-rain water management holds the key to higher fertilizer and moisture use efficiency and any practice which would conserve and/or recycle rainwater will be very valuable for dryland farming, be it land configuration, tillage, mulching, water harvesting or anything else (Prihar and Sandhu, 1987). With these points in view, the present experiment was undertaken to evaluate the response of pigeonpea (*Cajanus cajan* L.) to moisture conservation practices and zinc application.

MATERIALS AND METHODS

A field investigation was carried out during rainy (*kharif*) seasons of 2012 and 2013 at Instructional Farm, Department of Agronomy, Junagadh Agricultural University, Junagadh (Gujarat). The soil was clayey in texture and slightly alkaline in reaction (pH 7.9 and EC 0.29 dS m^{-1}) with available N 263 kg ha^{-1}, available P_2O_5 24 kg ha^{-1}, available K_2O 277 kg ha^{-1} and available Zn 0.80 mg kg^{-1}. Field capacity and permanent wilting point were 29.8 and 14.6%, respectively, whereas bulk density was 1.46 Mg m^{-3} with 41.1% porosity. There were five main plots assigned to moisture conservation practices *viz*., M_1: flat bed (FB), M_2: alternate between-row subsoiling (ABRS), M_3: between-row subsoiling (BRS), M_4: in-row subsoiling (IRS) and M_5: broad bed and furrow (BBF) and three sub-plots allocated to zinc levels *viz*., 0, 5 and 10 kg ha^{-1}. The experiment was laid out in split plot design with 4 replications. Subsoiling to a depth of 30 cm was carried out by subsoiler, while a bed of 150 cm width with furrow of 30 cm width and 15 cm depth was formed by BBF former after preparatory tillage and before sowing (Mathukia and Khanpara, 2009). The crop was fertilized with 25 kg N and 50 kg P_2O_5 ha^{-1} in the form of urea and diammonium phosphate as basal application at sowing. Zinc in the form of $ZnSO_4$ was applied at sowing in furrows as per treatments. The pigeonpea variety 'GT 1' was sown at 90 cm x 20 cm on 1st July, 2012 and 20th June, 2013 and harvested according to maturity of pods. The total seasonal rainfall of 425 and 1520 mm was received in 25 and 62 rainy days during 2012 and 2013, respectively. Soil moisture content was estimated gravimetrically. Bulk density was determined by the core sampler method as suggested by Piper (1950) from the relationship of oven-dried mass of a known volume of soil. Leaf area of randomly selected five plants from each plot was measured by leaf area meter (LICOR-3000) at 90 DAS and leaf area index (LAI) was worked out accordingly. Growth and yield attributes were recorded at harvest from the randomly selected and tagged five plants in each net plot. Nitrogen in seed and stalk was estimated on per cent dry weight basis as per Modified Kjeldahl's method as described by Jackson (1967). The protein content of seed was worked out by multiplying nitrogen content in seeds with the factor of 6.25 as suggested by Gassi *et al*. (1973). Phosphorus content in seed and stalk was determined by Vanadomolybdo phosphate yellow colour method (Jackson, 1967). Potash content in seed and stalk was determined by Flame Photometer method (Jackson, 1967). Zinc in seed and stalk was estimated by Atomic Absorption Spectrophotometer (AAS) as described by Jackson (1967). The uptake of nutrients (N, P, K and Zn) was calculated by multiplying nutrient content with seed/stalk yield. Net return was worked out by deducting cost of cultivation from gross returns considering prevailing market price of input and produce.

RESULTS AND DISCUSSION

Moisture conservation practices

Different practices of moisture conservation could impose their significant influence on bulk density, moisture content in soil as well as growth and yield attributes except seeds/pod (Table

Table 1: Effect of moisture conservation practices and zinc fertilization on physical properties of soil and growth and yield attributes of pigeonpea (pooled over two years)

Treatments	Bulk density (Mg m^{-3})	Soil moisture (%) at 90 DAS	Root length (cm)	Root dry weight (g)	Plant height (cm)	LAI at 90 DAS	Dry matter/ plant (g)	Mature pods/ plant	Seeds/ pod	100-seed weight (g)
Moisture conservation practices										
M_1- FB	1.501	15.92	36.68	21.58	163.98	1.47	95.50	68.73	2.93	9.87
M_2- ABRS	1.461	16.53	37.62	23.03	176.43	1.56	102.17	71.73	2.95	9.99
M_3- BRS	1.434	16.65	38.98	23.82	184.67	1.77	105.95	72.98	3.04	10.35
M_4- IRS	1.401	17.84	47.14	27.03	199.49	1.95	115.14	80.17	3.08	10.69
M_5- BBF	1.443	17.18	41.09	25.05	188.97	1.91	110.72	75.78	3.06	10.52
CD (P=0.05)	0.050	0.71	2.29	1.75	10.50	0.14	5.21	4.08	NS	0.48
Zinc (kg ha^{-1})										
Z_1- 0	1.435	16.88	39.53	23.67	170.80	1.66	102.95	70.57	2.96	9.95
Z_2- 5	1.448	16.81	40.65	24.04	187.68	1.74	105.96	74.28	3.04	10.41
Z_3- 10	1.461	16.78	40.73	24.59	189.65	1.79	108.78	76.80	3.05	10.49
CD (P=0.05)	NS	NS	NS	NS	7.66	0.06	3.00	3.12	NS	0.12

Table 2: Effect of moisture conservation practices and zinc fertilization on yield, quality, net return and nutrient use (pooled over two years)

Treatments	Seed yield (kg ha^{-1})	Stalk yield (kg ha^{-1})	Protein content (%)	Protein yield (kg ha^{-1})	Net return (Rs ha^{-1})	Nutrient uptake (kg ha^{-1}) Nitrogen	Phosphorus	Potash	Zinc
Moisture conservation practices									
M_1- FB	1258	2633	22.18	279	11928	74.08	9.42	25.13	0.184
M_2- ABRS	1316	2812	22.33	294	12415	78.80	10.36	26.43	0.193
M_3- BRS	1343	2869	22.36	300	12375	80.86	10.81	26.72	0.196
M_4- IRS	1507	3143	22.76	343	15049	91.53	12.81	29.09	0.214
M_5- BBF	1443	3017	22.77	329	13991	87.35	11.95	28.01	0.206
CD (P=0.05)	96	210	NS	24	1535	4.28	0.54	1.70	0.009
Zinc (kg ha^{-1})									
Z_1- 0	1278	2723	22.28	285	12058	76.55	10.65	25.03	0.182
Z_2- 5	1412	2947	22.56	318	13775	84.62	11.24	27.78	0.205
Z_3- 10	1431	3015	22.60	323	13623	86.40	11.32	28.42	0.209
CD (P=0.05)	48	101	0.21	11	760	2.44	0.28	0.73	0.005

FB = Flat bed, ABRS = Alternate between-row subsoiling, BRS = Between-row subsoiling, IRS = In-row subsoiling, BBF = Broad bed and furrow

1). The in-row subsoiling (M_4) recorded significantly lower bulk density and higher moisture content in soil at 90 days after sowing (DAS), however it remained statistically at par with broad bed and furrow (M_5). The in-row subsoiling (M_4) also improved length and dry weight of roots as compared to flat bed (M_1). Both these practices accelerated growth and yield parameters *viz*., plant height, leaf area index (LAI), dry matter/plant, mature pods/plant and test weight over flat bed (M_1). In-row subsoiling (M_4) and broad bed and furrow (M_5) produced significantly higher seed and stalk yields along with higher protein yield, net return and uptake of N, P, K and Zn over flat bed (Table 2). However, protein content remained unaffected under various moisture conservation practices. On an average, in-row subsoiling (M_4) and broad bed and furrow (M_5) increased seed yield by 19.8 and 14.7% and stalk yield by 19.4 and 14.6% over flat bed (M_1), respectively. This could be attributed to increased soil moisture and favourable physico-chemical properties of soil under in-row subsoiling (M_4) and broad bed and furrow (M_5). Nitant and Singh (1995) while evaluating effects of subsoiling on soil properties and yield of dryland pigeonpea found that subsoiling improved soil properties and enhanced profile water storage compared with shallow tillage. Subsoiling also induced deeper root penetration by 39 cm, resulting in 127% more seed yield than the shallow tillage by country plough. Mathukia and Khanpara (2009) observed that in-row subsoiling significantly increased growth, yield attributes, yield, quality and nutrient uptake by castor over flat bed. Nikam and Firake (2002) and Vaghasia *et al.* (2007) assessed positive influence of BBF on growth, yield and quality of rainfed groundnut.

Zinc levels

Zinc levels did not exhibit their significant effect on bulk density, soil moisture, root length and root dry weight. Whereas, growth and yield characters except seeds/pod were significantly influenced by zinc application (Table 1). Application of zinc @ 10 kg ha^{-1} (Z_3) and 5 kg ha^{-1} (Z_2), both being at par, significantly excelled growth and yield attributes *viz*., plant height, LAI, dry matter/plant, mature pods/plant and 100-seed weight. Zinc fertilization @ 10 kg ha^{-1} (Z_3) and 5 kg ha^{-1} (Z_2) also gave significantly higher seed and stalk yields as well as protein content, protein yield, net return and uptake of N, P, K and Zn over control (Z_1). On an average, application of zinc @ 10 kg ha^{-1} (Z_3) and 5 kg ha^{-1} (Z_2) increased seed yield by 12.0 and 10.5% and stalk yield by 10.7 and 8.2% over control (Z_1), respectively. By virtue of involvement in various enzyme systems, carbohydrate metabolism and redox processes, zinc might have promoted growth, yield and quality of the crop. Mali *et al*. (2003) reported that application of Zn at 5 kg ha^{-1} resulted in higher grain yield of pigeonpea as compared to control. Mathukia and Khanpara (2009) also found increased seed yield of castor with application of 5 kg Zn ha^{-1}. Choudhary *et al*. (2014) recorded higher yield of soybean and the yield attributes *viz*., plant height, branches/plant, capsules/plant, grains/ capsule and 100-grain weight with application of Zn @ 5 ppm over 0 and 2.5 ppm. The study conducted by Keram *et al*. (2014) indicated that application of 10 kg Zn ha^{-1} with 100 % NPK on wheat crop enhanced the productivity as well as maintained the quality of wheat grain.

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