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Rainwater Conservation Techniques with Integrated Phosphorus Management on Productivity of Pigeonpea under Dryland Conditions

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ABSTRACT: A field experiment was conducted on effect of *in-situ* rainwater conservation techniques with integrated phosphorous management on productivity of pigeonpea under dryland condition during the *kharif* season 2007-08 to 2011-12 to find out the effect of land configuration with different phosphorus sources on productivity of pigeonpea. The experiment was laid out in factorial randomized block design with three replications. The treatment consisted of two land treatments *viz.,* M_1: flat sowing with three hoeing at 3rd, 5th and 8th weeks after sowing, M_2: flat sowing with one hoeing at 3rd week and opening of ridges and furrows at 30 days after sowing with five integrated phosphorus sources *viz.,* P_0: Control, P_1: 12.5 kg N/ha + 25 kg P_2O_5/ha (R.D.) through DAP + *Rhizobium* + PSB, P_2: 25 kg P_2O_5/ha through FYM + *Rhizobium* + PSB, P_3: 25 kg/ha P_2O_5 through SSP + *Rhizobium* + PSB, P_4: 25 kg P_2O_5/ha through Vermicompost + *Rhizobium* + PSB. Basal dose of nitrogen was adjusted through urea as per treatments details. The pooled results revealed that land treatment, flat sowing with one hoeing at 3rd week and opening of ridges and furrows at 30 days after sowing gave significantly higher grain and stalk (754 and 3323 kg/ha) yield. Among the integrated phosphorus management, the application of 12.5 kg N/ha + 25 kg P_2O_5/ha through DAP + *Rhizobium* + PSB registered significantly higher grain and stalk (897 and 3409 kg/ha) yield. The similar trend was also noticed in case of soil available phosphorus and total P uptake by pigeonpea. The higher soil moisture (136 mm) was conserved in the treatment of flat sowing with one hoeing at 3rd week and opening of ridges and furrow 30 days after sowing. Flat sowing + One hoeing + Opening of furrows at 30 DAS along with recommended dose of fertilizer 12.5:25 kg/ha N: P_2O_5 through DAP + *Rhizobium* + PSB recorded significantly higher benefit: cost ratio.

Key words: Land treatments, phosphorus sources, soil moisture conservation, pigeonpea productivity

Legumes are rich source of protein for common masses especially vegetarian community in India. Both grain and stalk of legumes contain good amount of protein and minerals, which are essential for the growth and development of human and livestock (Anonymous, 2004). Among the legumes, pigeonpea (*Cajanus cajan* L.) is an important grain legume crop in the semi-arid regions of world and is cultivated on 5.84 m ha with a production of 4.41 m t. It is also the most important *kharif* pluse crop of India contributing to 75.7% of area and 64.9% of production of the world (FAOSTAT, 2013). Pulses can meet their nitrogen requirement by symbiotic fixation of atmospheric nitrogen. However, a starter dose of nitrogen and adequate phosphorus are considered as essential for obtaining optimum yield (Solaiappan *et al*., 2002). For legume, N is more useful because it is the main component of amino acid and protein. Like other leguminous crops, N requirement is substantially fulfilled from symbiotic N fixation through *Rhizobium*. The N fixation process is influenced by main factors and P availability is one of them. Rhizobial activities and N fixation is depressed without adequate P supply. P promotes early root formation and the formation of lateral, fibrous and healthy roots, which is important for nodule formation and fixation of atmospheric N. Application of P along with *Rhizobium* inoculants has been reported to influence nodulation and N fixation in legume crops (Solaiman and Habibullah 1990). Since P deficiency results in reduced symbiotic N fixation, P fertilization usually result in enhanced nodule number and mass as well as greater N_2 fixation activity per plant (Awomi *et al.,* 2010).

With the increasing demand for food, oilseeds and pulses by the ever growing human population, a dire necessity now arise to utilize the untapped drylands effectively. Constraint limiting crop production in drylands is lack of assured supply of available soil moisture throughout the cropping season due to low and erratic distribution of rainfall. Measures to conserve soil moisture may therefore help to improve the productivity of dryland crops. Normally in drylands, seeds are sown under flat bed system. Extreme variations in rainfall, with higher intensity cause runoff, which in turn reduces the soil moisture and fertility of the soil. *In situ* moisture conservation practices are reported to provide an advantage in conserving the rainfall in soil profile and provide more opportunity time for ponded water to infiltrate in the soil leading to less runoff (Patil *et al.,* 2005). Productivity of rainfed crops primarily depends on the amount of rainfall, its intensity, distribution and number of rainy days received during the active period of crop growth. It is generally said that moisture present in the effective root zone of a particular crop at the time of sowing has a decisive effect on the crop yield which means, otherwise that, the soil profile should necessarily be recharged with adequate moisture (Mastiholi, 1994).

The low productivity of pigeonpea in Maharashtra is due to erratic and scanty rainfall, prolonged dry spell during critical growth stages such as flowering and pod formation which results in significant reduction in yield of pigeonpea. Under such conditions, it is imperative that *in-situ* rainwater conservation techniques with integrated phosphorous management play an important role in crop stand establishment and production.

Hence, the present study was carried out to know the effect of *in-situ* rainwater conservation techniques with integrated phosphorous management on growth and productivity of pigeonpea.

Materials and Methods

A field experiment was conducted during *kharif* season for the year 2007-2008 to 2011-12 at Dry farming Research Station, Solapur, to study the effect of *in-situ* rainwater conservation techniques with integrated phosphorous management on productivity of pigeonpea under dryland condition. The experiment was laid out in Factorial Randomized Block Design with three replications. The treatment consisted of two land treatments *viz.,* M_1: flat sowing with three hoeing at 3rd, 5th and 8th weeks after sowing, M_2: flat sowing with one hoeing at 3rd week and opening of ridges and furrows at 30 days after sowing with five integrated phosphorus sources *viz.,* P_0: Control, P_1: 12.5 kg N/ha + 25 kg P_2O_5/ha (R.D.) through DAP + *Rhizobium* + PSB, P_2: 25 kg P_2O_5/ha through FYM + *Rhizobium* + PSB, P_3: 25 kg/ha P_2O_5 through SSP + *Rhizobium* + PSB, P_4: 25 kg/ha P_2O_5 through Vermicompost + *Rhizobium* + PSB. The nutrient composition of FYM and vermicompost depicted in (Table 2). Basal dose of nitrogen was adjusted through urea as per treatments details (Table 3). Spacing of piegonpea was 90 cm x 20 cm with *kharif* season. The seeds were sown with dibbling method having seed rate of piegonpea (var:Vipula) was 10 kg/ha and seed treated with *PSB* + *Rhizobium* @ 250g/10 kg of seed. The various yield parameters at harvest were recorded. The crop was harvested at their physiological maturity. The soil of the experimental field was clay loam having organic carbon content 0.55%, available nitrogen 171 kg/ha, phosphorus 12 kg/ha and potash 470 kg/ha, EC 0.16 ds/m with pH 8.0. The soil available phosphorus was analyzed by the Olsen *et al.* (1954). The data on yield and economics were recorded using standard procedures.

Rainfall pattern

The amount and distribution of rainfall during experimentation period (2007-2011) varied widely that affected the crop performance, the amount of total rainfall was deficient during 2007-08 (-27.8%) and 2008-09 (-3.9%) depicted in (Table 1). The average values of metrological parameters of Solapur (2007- 2011) depicted in Figure 1.

Table 1 : Year wise seasonal distribution of rainfall

Season	2007		2008		2009		2010		2011	
	Rainfall (mm)	Rainy days	Rainfall (mm)	Rainy days	Rainfall (mm)	Rainy days	Rainfall (mm)	Rainy days	Rainfall (mm)	Rainy days
Pre-monsoon	1.6	00	72.8	07	62.5	5	60.7	6	91.7	7
Kharif	427.8	25	499.2	25	475.3	20	609.5	38	514.4	29
Rabi	93.6	8	124.9	9	288.4	11	117.1	14	155.6	7
Total	523.0	33	693.2	41	790.2	36	787.3	58	761.7	43

Normal rainfall = 721.4 mm, Pre-monsoon = 70 mm, *Kharif* – 420.7 mm, *Rabi* – 230.3 mm

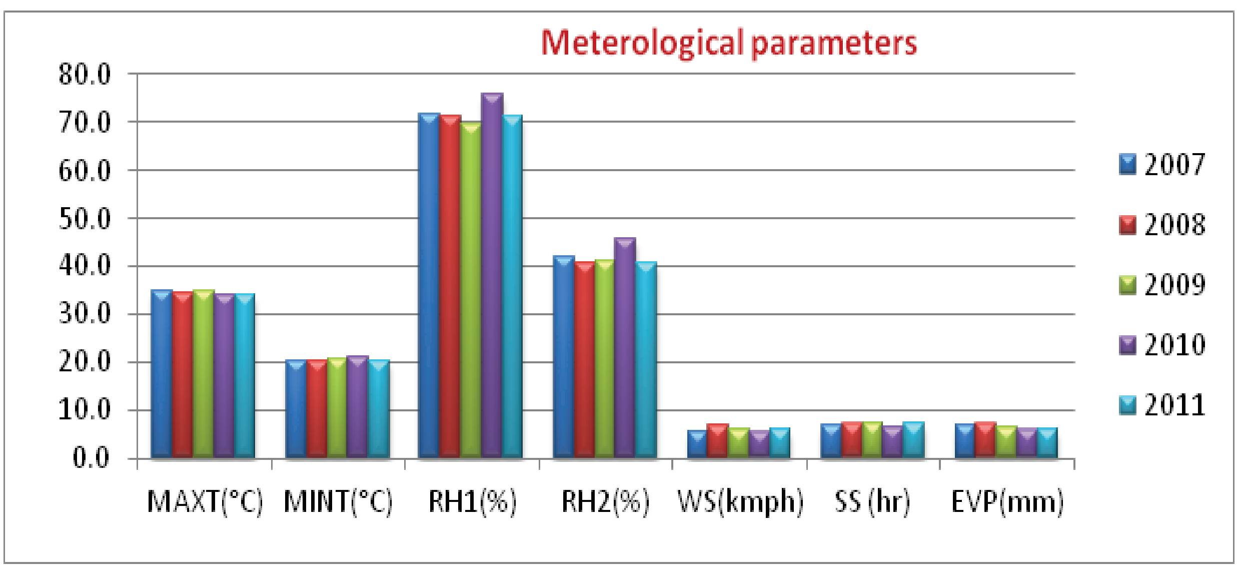

Fig. 1 : Average annual values of temperature (^{0}C), relative humidity (%), wind speed (kmph), sunshine hours (hr) and evapotranspiration (mm) of Solapur (2007 to 2011).

Table 2 : Nutrient content in FYM and Vermicompost

Particular	FYM	Vermicompost
Total N (%)	0.51-0.60 (0.55)	1.5-1.8 (1.65)
Total P (%)	0.30-0.35 (0.33)	0.60-0.90 (0.75)
Total K (%)	0.70-0.80 (0.75)	1.0-1.5 (1.25)
Organic carbon (%)	10.21-12.23 (11.22)	9.8-13.8 (11.8)
C:N ratio	20.01-20.38 (20.19)	6.5-7.6 (7.05)

Table 3 : Quantity of nutrients, chemical fertilizers and organic manure added

IPMS	Nutrient added (kg/ha)			Chemical fertilizers (kg/ha)			Organic manure (t/ha)	
	N	P_2O_5	K_2O	Urea	SSP	DAP	FYM	VC
P_0	-	-	-	-	-	-	-	-
P_1	12.5	25	-	5.78	-	54.68	-	-
P_2	12.5	25	-	27.34	-	-	7.8	-
P_3	12.5	25	-	27.34	156.25	-	-	-
P_4	12.5	25	-	27.34	-	-	-	3.3

Table 4 : Periodical soil moisture as influenced by *in-situ* moisture conservation (Pooled mean 2007-08 to 2011-12)

Moisture conservation techniques	Soil moisture (mm)					
	Integrated phosphorus management sources					
	P_0	P_1	P_2	P_3	P_4	Mean
M_1	119	126	129	122	128	125
M_2	128	136	142	134	139	136
Mean	124	131	136	128	133	
					SEm$\pm$	CD (P=0.05)
Moisture conservation techniques (MCT)					1.17	3.36
P management (P)					1.85	5.32
MCT x P					2.62	NS

Depth = 45-50 cm, PWP = 80 mm, FC = 212 mm

Table 5 : Effect of *in-situ* moisture conservation techniques (MCT) and integrated phosphorus management sources (P) on yield of pigeonpea

Treatment	Grain yield (kg/ha)					Pooled mean	Stalk yield (kg/ha)					Pooled mean	BCR
	2007-08	2008-09	2009-10	2010-11	2011-12		2007-08	2008-09	2009-10	2010-11	2011-12		
Moisture conservation techniques (MCT)													
M_1	444	768	625	756	775	674	3361	2832	2408	3358	3487	3089	1.44
M_2	485	818	735	852	878	754	3523	3082	2583	3474	3952	3323	1.67
SEm±	9.12	34.14	34.29	21.45	34.18	12.43	31	84	84	87	130	61.36	-
CD (P=0.05)	28.18	105.83	106.98	66.28	106.98	36.17	92	248	NS	NS	386	176	-
Integrated phosphorus management sources (P)													
P_0	338	711	478	638	717	577	2936	2785	1785	3440	3224	2834	1.54
P_1	593	997	914	992	991	897	3615	3208	2788	2977	4457	3409	2.27
P_2	437	739	656	779	789	680	3631	3037	2625	3632	3551	3295	1.19
P_3	447	649	566	765	763	638	3500	2773	2523	3734	3434	3193	1.62
P_4	509	869	786	847	874	777	3528	2982	2757	3297	3933	3299	1.12
SEm±	15.20	55.32	54.19	33.15	53.28	18.07	49	132	133	140	205	97.02	-
CD (P=0.05)	46.97	169.83	166.91	102.43	165.17	51.82	146	NS	394	416	610	278	-
Interactions (MCT X P)													
SEm±	21.05	77.15	77.23	46.26	75.07	25.55	69	187	188	198	290	137	-
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-
CV (%)	12.09	17.48	19.62	12.95	15.78	-	13.49	10.96	13.05	12.04	13.52	-	-

BCR = Benefit - cost ratio

Table 6 : Effect of *in-situ* moisture conservation techniques (MCT) and integrated phosphorus management sources (P) on total phosphorus uptake and soil available phosphorus. (Pooled mean 2007-08 to 2011-12)

Treatment		Total phosphorus uptake (kg/ha)	Soil available phosphorus (kg/ha)
A) Moisture conservation technique (MCT)			
M_1	Flat sowing with 3 hoeing at 3rd, 5th and 8th week after sowing.	15.57	12.11
M_2	Flat sowing with one hoeing at 3rd week and opening of ridges and furrow at 30 days after sowing	18.59	12.47
SEm±		0.45	0.30
CD (P = 0.05)		1.31	NS
B) Integrated phosphorus management sources (P)			
P_0	Control (*Rhizobium* + PSB)	14.11	10.01
P_1	12.5 kg N/ha + 25 kg P_2O_5/ha (RD) through DAP + *Rhizobium* + PSB	19.47	14.29
P_2	25 kg P_2O_5/ha through FYM + *Rhizobium* + PSB	17.18	11.94
P_3	25 kg P_2O_5/ha through SSP + *Rhizobium* + PSB	16.07	12.23
P_4	25 kg P_2O_5/ha through Vermicompost + *Rhizobium* + PSB	18.58	12.98
SE ± m		0.72	0.47
CD (P = 0.05)		2.07	1.34
Interaction			
MCT X P		NS	NS

Results and Discussion

Soil moisture

The result on periodical soil moisture is presented in (Table 4). The pooled result indicated that the periodical soil moisture was significantly higher (136 mm) in flat sowing with one hoeing at 3rd week and opening of ridges and furrow at 30 days after sowing. This may be due to opening of furrows produced greater infiltration by reduced runoff and subsequent arresting of evaporation of infiltrated water as reported by Tumbare and Bhoite 2003. Anil *et al.* (1998) revealed that crops grown with ridge and furrow land configuration showed 30% increase in grain yield as compared to flat bed. These results are in agreement with the findings of Patil *et al.* (2005) and Selvaraju *et al.* (1999). Addition of organic sources improved the soil physical properties thereby increased the porosity and infiltration rate and conserved the moisture under dryland conditions.

The phosphorus management sources as 25 kg P_2O_5/ha through FYM + *Rhizobium* + PSB recorded higher soil moisture (136 mm) which is on par with 25 kg P_2O_5/ha through Vermicompost + *Rhizobium* + PSB and 12.5 kg N + 25 kg P_2O_5/ha through DAP + *Rhizobium* + PSB. However, flat sowing with one hoeing at 3rd week and opening of ridges and furrow at 30 days after sowing with all integrated phosphorus management sources was numerically higher for soil moisture (142,139,136 and 134 mm). This was mainly due to increased water holding capacity of the soil with application of organic manure. The results are in conformity with Patil *et al.* (2006) and Arjun Sharma *et al.* (2010).

Yield of pigeonpea: The five year pooled mean of grain, stalk yield and economics of pigeonpea (Table 5) indicated that flat sowing with one hoeing at 3rd week and opening of ridges and furrow at 30 days after sowing *in-situ* moisture techniques recorded significantly higher grain and stalk yield (754 and 3323 kg/ha) of pigeonpea. This may be attributed to increase in aeration and maintenance of soil moisture, which consequently resulted in better crop growth and development. Tumbare and Bhoite (2003) and Makkhan Lal *et al.* (2003) reported enhanced yield in crops grown under moisture conservation technique. Patil *et al.* (2006) reported that moisture conservation techniques like ridges and furrows with tied ridging recorded significantly higher grain and fodder yield of pearl millet. Similar trend was also observed in case of B-C ratio.

The phosphorus management sources as 12.5 kg N/ha + 25 kg P_2O_5/ha through DAP + *Rhizobium* + PSB recorded significantly higher grain and stalk (897 and 3409 kg/ha) yield than the rest of the integrated phosphorus management sources. The superiority of the dual application of phosphorous and bacterial inoculation may be due to positive influence of microorganisms of the inoculants on the native and applied nutrients. As well as may be due to the important role of phosphorous for helping the development of more extensive root system and thus enabling plants to extract water and nutrients from deeper depth. This, in turn, could enhance the plants to produce more assimilates which was reflected in high yield and its component reported by Habbasha *et al.* (2007). Similar trend was also observed in case of B-C ratio.

Total phosphorus uptake

Flat sowing with one hoeing at 3rd week and opening of ridges and furrow at 30 days after sowing *in-situ* moisture techniques recorded significantly higher phosphorus uptake (18.59 kg/ha). In case of integrated phosphorus management sources as 12.5 kg N/ha + 25 kg P_2O_5/ha through DAP + *Rhizobium* + PSB recorded higher total phosphorus uptake (19.47 kg/ha) which was on par with 25 kg P_2O_5/ha through Vermicompost + *Rhizobium* + PSB (18.58 kg/ha) depicted in (Table 6). Higher moisture and nutrient availability might have resulted in higher uptake of the nutrients. Mastiholi (1994) reported higher nutrient uptake at higher moisture levels through tillage and *in situ* moisture conservation practices in the vertisols under dryland conditions. Adoption of in situ moisture conservation practices not only improved the soil moisture availability in the profile at various growth stages but also improved the availability of nutrients, which might have had the additive effect on crop growth. This might have improved the nutrient uptake resulting in higher dry matter production in the pods. The results are in conformity with Solaiappan and Ramiah (1990), Nimje (1995) and Sarawgi *et al.* (1999).

Soil available phosphorus

The integrated phosphorus management sources as 12.5 kg N + 25 kg P_2O_5/ha through DAP + *Rhizobium* + PSB recorded numerically higher residual soil phosphorus (14.29 kg/ha) which was followed by with 25 kg P_2O_5/ha through Vermicompost + *Rhizobium* + PSB. However, flat sowing + 1 hoeing + ridges and furrow with integrated phosphorus management sources as 12.5 kg N/ha + 25 kg P_2O_5/ha through DAP + *Rhizobium* + PSB recorded numerically higher soil available phosphorus (12.47 kg/ha) at harvest of pigeonpea.

Conclusion

Integrated management of nutrient sources as 12.5 kg N/ha + 25 kg P_2O_5/ha through DAP + *Rhizobium* + PSB with flat sowing + 1 hoeing + ridges and furrow *in-situ* moisture conservation techniques is recommended for higher grain, stalk yield and benefit-cost ratio in inceptisols.

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