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Integrated rainwater harvesting technique for climate resilience in pigeonpea

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ABSTRACT

Formation of conservation furrows is one of the important *in-situ* moisture conservation measures which facilitate rainwater to infiltrate by reducing the velocity of runoff flow and thus providing more opportune time for the rainwater to infiltrate where it falls. Low hp tractor drawn two row intercultivator cum conservation furrow opener was developed at Agricultural Research Station Ananthapurumu during 2016. After the development of tractor drawn intercultivator cum conservation furrow opener field experiment was conducted in arid Alfisols for two years during *kharif* 2016 and 2017. The treatments (six) consists of T1: control - rainfed (no conservation furrow) T2: conservation furrow at every row, T3: conservation furrows at every two rows, T4: conservation furrow at every row + 20 mm supplemental irrigation once at flowering, T5 - conservation furrow at every two rows + 20 mm supplemental irrigation once at flowering and T6: no conservation furrow + 20 mm supplemental irrigation once at flowering. The experiment was conducted in Randomized block design with three replications with a plot size of 9×40 m at Agricultural Research Station, Ananthapuramu, ANGRAU, Andhra Pradesh. Mean seed yield data of two years indicated that, 46 and 73% increase in seed yield was recorded due to formation conservation formation for every row (T2) and every two rows (T3), respectively compared to rainfed crop (T1). An increase in 146 and 82% was recorded due to the combined effect of conservation furrow for every row (T4) and every two rows (T5) in combination with 20 mm supplemental irrigation compared to rainfed crop (T1). Mean data of two years on economics indicated that gross returns, net returns and benefit cost ratio (BCR) was higher with conservation furrow at every row combined with 20 mm supplemental irrigation once at flowering compared to other treatments. Formation of conservation furrows is one of the important *in-situ* moisture conservation measures which facilitate rainwater to infiltrate by reducing the velocity of runoff flow and thus providing more opportune time for the rainwater to infiltrate where it falls. The impact of this *in-situ* conservation measure could be more prominently seen when it was integrated with one supplemental irrigation at critical stage of crop growth (flowering) in pigeonpea.

1. INTRODUCTION

Rainfed agriculture is likely to be more vulnerable to climate change in view of its high dependency on monsoon and the chances of increased extreme weather events like delayed onset of monsoon, high intensity rainfall, seasonal drought, early withdrawal of monsoon etc. due to aberrant behaviour of south-west (SW) monsoon. A decrease of one standard deviation from the mean annual rainfall often leads to a complete loss of the crop. Dry spells of 2 to 4 weeks during critical crop growing stages cause partial or complete crop failure (Ravindra Chary *et al.*, 2017). About 74% of annual rainfall occurs during SW monsoon (June-September). This rainfall exhibits high coefficient of variation particularly in arid and dry semi-arid regions. Aberrations in SW monsoon strongly influence the crop productivity levels and these aberrations are likely to further increase in future. Droughts and famines are the general features of rainfed agriculture in India. In India, moisture stress is a recurring chronic problem, which has a sizeable proportion of area falling in arid and semi-arid tropics (Sunitha *et al.*, 2015). Two thirds of India's agricultural land is vulnerable to moisture stress of various intensities, and the probability of occurrence of a moisture stress is over

35% (Bhandari *et al*., 2007). Effective rainwater management is critical for drought mitigation and successful rainfed agriculture. *In-situ* soil and water conservation (SWC) practices improve soil structure and soil porosity, increase infiltration and hydraulic conductivity, and consequently increase soil water storage that helps crops to withstand moisture stress (Venkateswarlu *et al*., 2016). Adoption of location specific soil and water management practices is both essential and a prerequisite to make rainfed farming more economical and sustainable under increasing frequency of droughts, decrease in number of rainy days, and extreme and untimely rainfall. In India, pigeonpea is the second most important pulse crop and predominantly grown under rainfed conditions. In peninsular India, where medium duration varieties of pigeonpea predominates, terminal drought (reproductive period) is the major yield limiting factor (Chandra Mohan, 1969). At present more than 92% of the area under pigeonpea is confined to unirrigated areas and in future also the bulk of production will continue to come from unirrigated areas (Panwar and Srivastava, 2012). In India pigeonpea occupies an area of 3.9 M ha with productivity of 850 kg ha^{-1} and in Andhra Pradesh it is grown in an area of 0.30 M ha with a productivity of 377 kg ha^{-1}. In recent years, due to climate change, the weather aberrations such as delayed onset of monsoon and prolonged dry spells and high rainfall events during the crop growth period have become common, thereby reducing the seed yield in pigeonpea. The extent of yield reduction depends upon the time and duration of the dryspell during the crop growth period. Since majority of the soils in Ananthapuramu district are red sandy loams with undulating topography of 2-4% slope and shallow in depth (10-25 cm), there is less chance for the rainwater to infiltrate during the high rainfall events. On an average, there will be 4 run off events per annum in the district which are to be utilized either *in-situ* or *ex-situ* rainwater harvesting measures. The low productivity is mainly due to drought and also due to non-adoption of soil and moisture conservation practices during crop season. In scarce rainfall zone (Ananthapuramu district) of Andhra Pradesh decreasing frequency of rainfall changes leading to early, mid and late season droughts, low fertility and low moisture holding capacity of soils hinder the production is affecting the production, with consequent effect on livelihoods of poor farmers. Improved water storage through *in-situ* moisture conservation and stored runoff are basic for bringing resilience to drought or moisture stress conditions often encountered by the rainfed pigeonpea. However, in recent years, a continuous crop failure forces the groundnut farmers shifting from groundnut to sole pigeonpea. Formation of conservation furrows is one of the important *in-situ* moisture conservation measures which facilitate rainwater to infiltrate by reducing the velocity of runoff flow and thus providing more opportune time for the rainwater to infiltrate where it falls. Though the crop is said to be resistant to drought but increase in productivity has been observed by supplementary irrigation (Kumar Rao *et al.,* 2001). Praharaj *et al.* (2016) concluded that critical stages for irrigation were branching and flowering in case of winter pigeonpea and enhanced the pigeonpea yields by 16%. Water is the key input for crop production in rainfed and dryland areas, therefore there is need to adopt a comprehensive approach to conserve soil moisture through *in-situ* as well as *ex-situ* techniques.

Due to fodder scarcity the draught animal population decreasing year by year and un-availability labour now a days, necessitating the development and transfer of small farmer friendly mechanized implements for timely agricultural operations which are ought to be done under high unpredictable rainfall situations (Madhusudhana Reddy *et al*., 2017). Thus, there is a need for mechanization of small sized farms, for enhancing the efficiency of resources, drudgery reduction and safeguards livelihood security of own family labour. As a consequence, the small and medium farmers are turning towards low hp tractors which are less expensive when compared to high hp tractors. Hence, it was felt that there is every need to develop matching equipments suitable for these low horse power tractors for important field operations like sowing and inter cultivation. Keeping this in view, a low hp tractor drawn intercultivator cum conservation furrow opener was developed and evaluated its performance in pigeonpea.

2. MATERIALS AND METHODS

Study Area

Low hp tractor drawn two row intercultivator cum conservation furrow opener was developed during 2016 and using this field experiment was conducted during *kharif*, 2016 and 2017 in pigeonpea, at Agricultural Research Station, Ananthapuramu, located at $14^0$41'E latitudes and $77^0$41'N longitudes with an altitude of 373 m above MSL. The soil of the experimental site was shallow red (*Typic-Haplustalfs*) with sandy loam texture (79.7% sand, 9.6% silt and 9.7% clay), pH of 6.9 and CEC of 6.6 cmol kg^{-1}. The soil was low in organic carbon (0.27%), soil N (63 kg ha^{-1}), soil K (91 kg ha^{-1}), and high in soil P (107 kg ha^{-1}). The study area receives an average rainfall of 550 mm and 60% of the rainfall is received through SW monsoon. An amount of 265.6 and 543.6 mm rainfall was received in 12 and 34 rainy days in 2016 and 2017 during the crop season, respectively.

Fabrication of Intercultivator cum Conservation Furrow Opener

Low hp tractor drawn two row intercultivator cum conservation furrow opener was developed during 2016 at Agricultural Research Station Ananthapurumu. The major components are main frame with hitching unit, intercultivation blade and conservation furrow opener. All the views of the developed implement are shown in Fig's 1 to 4. The detailed specifications of the developed implement are shown in Table 1.

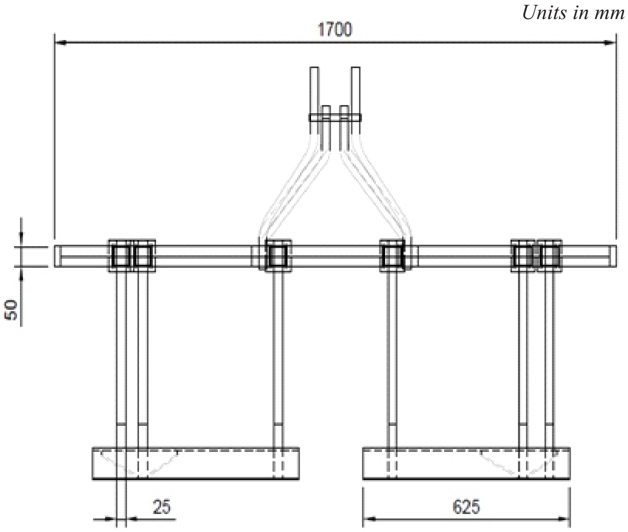

Fig. 1. Front side view of the low hp tractor drawn intercultivator cum conservation furrow opener

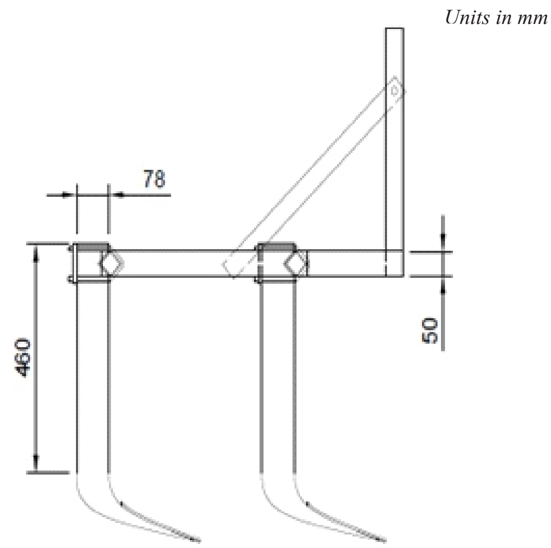

Fig. 2. Side view of the low hp tractor drawn intercultivator cum conservation furrow opener

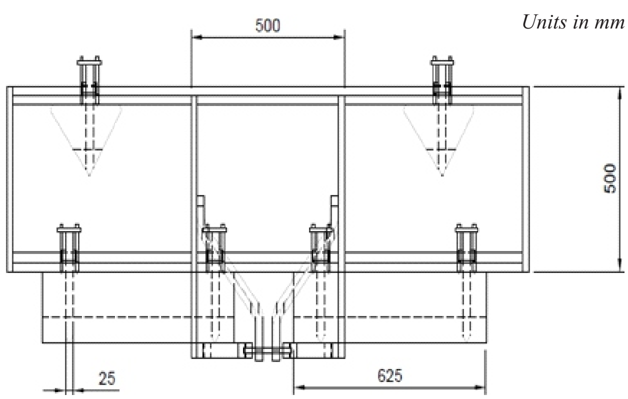

Fig. 3. Top view of the low hp tractor drawn intercultivator cum conservation furrow opener

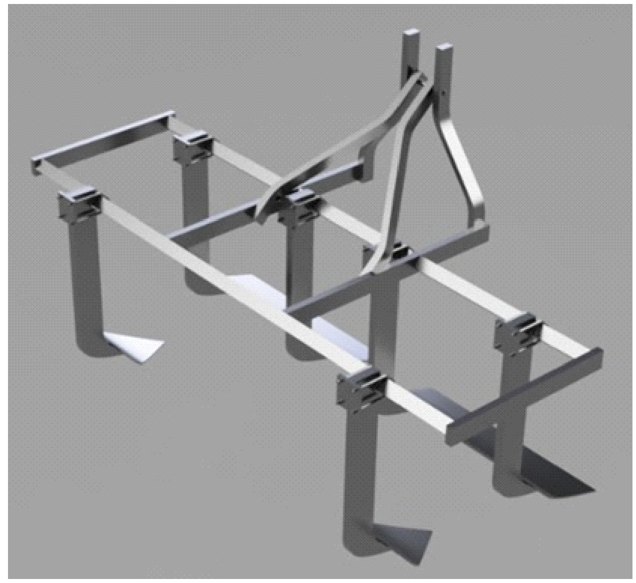

Fig. 4. Isometric view of the low hp tractor drawn intercultivator cum conservation furrow opener

Table: 1
Detailed specifications of the low hp tractor drawn intercultivator cum conservation furrow opener

Name of components	Specifications	
Power source	Mini tractor (18 -24 hp)	
Main frame	Length	1700 mm
	Width	500 mm
	Material of construction	Mild steel L-angular and flat sections
Shank	Length	460 mm
	Width	78 mm
	Thickness	25 mm
Intercultivation (weeding) blade	No. of blades	2
	Width	625 mm
	Thickness	14 mm
Conservation furrow openers	No. of furrow openers	2
	Width	150 mm
	Thickness	14 mm

Mainframe with Three-Point Hitch

Main frame was made of mild steel. L-angular iron section having dimensions 40 × 40 × 5 mm and flat iron section having dimensions 50 × 8 mm were used for the fabrication of the main frame. Overall length and width of main frame are 1700 mm and 500 mm, respectively. A three-point hitch was made from flat iron section of 50 × 8 mm and 25 mm mild steel rod and it was welded to the main frame to attach implement to the hydraulic system of the tractor.

Shank

The shanks are the main components of the implement to the bottom of which intercultivation (weeding) blades and conservation furrow openers were attached by using bolts and nuts. The top portion of shanks is attached to main frame by using U-clamps and bolts. Four numbers of shanks were made from mild steel having 460 × 78 × 25 mm sections.

Intercultivation Blade

Intercultivation or weeding blade is the soil working component made from mild steel having 625 mm width and 14 mm thickness. Two blades were attached to shanks which were attached on the front portion of main frame.

Conservation Furrow Opener

A conservation furrow opener having triangular shape with working width 150 mm and thickness 14 mm were made from mild steel. Two conservation openers were attached to shanks which were attached on the rear portion of main frame.

Treatments Execution

After the development of tractor drawn intercultivator cum conservation furrow opener field experiment was conducted in arid Alfisols for two years during *kharif* 2016 and 2017 in pigeonpea. The treatments (six) consists of T1: control - rainfed (no conservation furrow), T2: conservation furrow at every row, T3: conservation furrows at every two rows, T4: conservation furrow at every row + 20 mm supplemental irrigation once at flowering, T5 - conservation furrow at every two rows + 20 mm supplemental irrigation once at flowering and T6: no conservation furrow + 20 mm supplemental irrigation once at flowering. The experiment was conducted in Randomized block design with three replications with a plot size of 9.0 × 40 m at Agricultural Research Station, Ananthapurumu, ANGRAU, Andhra Pradesh. Pigeonpea variety PRG -176 was sown with a spacing of 90 cm × 20 cm. The seeds were sown by dibbling in furrows at a depth of 5 cm. The furrows were covered immediately after sowing and compacted sufficiently for better germination. The recommended dose of 20, 40 and 40 kg N, P_2O_5 and K_2O ha^{-1} was applied through urea, single super phosphate and muriate of potash, respectively. Conservation furrows were formed as per the treatment with low hp tractor drawn intercultivator cum conservation furrow opener after 60 days after sowing on receipt of rain. Conservation furrow for every two rows were formed by removing one tyne of the intercultivator cum conservation furrow opener. Supplemental irrigation from farm pond water was given as per the treatments.

Observations

Observations were collected from each plot on plant height (cm), seeds per pant and seed yield (kg ha^{-1}) at harvest and were statistically analyzed. Economics were calculated on cost of cultivation (₹ ha^{-1}), gross monetary returns (₹ ha^{-1}); net monetary returns (₹ ha^{-1}); and benefit cost ratio (BCR) based on prevailing market prices.

Economic Analysis

The cost of cultivation of groundnut was determined by taking into account inputs like seed and fertilizer costs and agricultural operations from sowing to harvest. The gross returns was computed as a product of yield and its market price (₹ kg^{-1}). The BCR was computed as a ratio of gross returns and cost of cultivation for each crop (Maruthi Sankar *et al*., 2012).

Statistical Analysis and Interpretation

Six treatments laid out in Randomised block design with three replications and treatment effects were tested based on F-test under standard analysis of variance (ANOVA) procedure. The differences in seed yield on different treatments were compared based on least significant difference (LSD) criteria (Gomez and Gomez, 1984). The superiority of treatments was assessed and inferences drawn about *in-situ* and *ex-situ* moisture conservation techniques. Since the economics were calculated on seed yield, statistical analysis was not done.

3. RESULTS AND DISCUSSION

The conservation furrows are formed with a bullock drawn traditional country plough. Since the formation of moisture conservation furrows is recommended to adopt after the establishment of the crop on receipt of first rain, farmers feel it as an additional expenditure in engaging the cattle pair and labour exclusively for forming the conservation furrows. Hence, it was thought tractor drawn intercultivator cum conservation furrow opener was developed. The front side blade cuts the top soil along with weeds also removed. In the same row back side conservation furrow was formed.

During both the years the pigeonpea crop was subjected to dry spell at flowering and pod development stages (terminal drought). Higher seed yield was recorded during 2017 due to more rainfall received during crop growing period compared 2016. Plant height of pigeonpea was significantly influenced by the effect of conservation furrows and supplemental irrigation during 2016 only. Mean data indicated that, more plant height was recorded due to conservation furrow and also supplemental irrigation compared to rainfed crop. In pigeonpea pods per plant and seed yield was significantly influenced due to effect of conservation furrow and supplemental irrigation during both the years (Table 2).

Seed yield of pigeonpea was significantly influenced due to conservation furrows and supplemental irrigation. During both the years significantly higher yields were recorded with conservation furrow every row + 20 mm supplemental irrigation once at flowering compared to other treatments. Mean seed yield data of two years indicated that, 46% increase in seed yield was recorded due to formation conservation for every row (T2) and 73% increase in seed yield was recorded due to formation conservation for every two rows (T3) compared to rainfed crop (T1). An increase in 146 and 82% was recorded due to the combined effect of

Table: 2
Effect of conservation furrows and supplemental irrigation on plant height, pods per plant and seed yield in rainfed pigeonpea

S.No.	Treatments	Plant height (cm)			Pods / plant			Seed yield (kg ha^{-1})		
		2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
1	T1-Control (No CF + No SI)	131	179	155	23	52	38	305	343	324
2	T2-Conservation furrow at every row	150	193	172	57	76	67	500	620	560
3	T3-Conservation furrow at every two rows	153	196	175	61	95	78	425	522	474
4	T4-Conservation furrow at every row + 20 mm supplemental irrigation once at flowering	151	191	171	55	71	63	644	954	799
5	T5-Conservation furrow at every two rows + 20 mm supplemental irrigation once at flowering	162	195	179	61	92	77	525	655	590
6	T6-No conservation furrow + 20 mm supplemental irrigation once at flowering	161	190	176	76	117	97	525	561	543
	S.Em ±	4.3	6.7		7.6	11.4		20.8	18.5	
	CD 0.05	13.7	NS		24	36		65.4	58	

CF - Conservation furrow; SI - Supplemental Irrigation

Table: 3
Effect of conservations furrows and supplemental irrigation on economics in rainfed pigeonpea

S.No	Treatments	Cost of cultivation (₹ ha^{-1})	Gross returns (₹ ha^{-1})			Net returns (₹ ha^{-1})			B:C ratio		
			2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
1	T1-Control (No CF + No SI)	13432	16775	18865	17820	3343	5433	4388	1.25	1.40	1.33
2	T2-Conservation furrow at every row	14282	27500	34100	30800	13218	19818	16518	1.93	2.39	2.16
3	T3-Conservation furrow at every two rows	14282	23375	28710	26043	9093	14428	11761	1.64	2.01	1.82
4	T4-Conservation furrow at every row + 20 mm supplemental irrigation once at flowering	15532	35420	52470	43945	19888	36938	28413	2.28	3.38	2.83
5	T5-Conservation furrow at every two rows + 20 mm supplemental irrigation once at flowering	15532	28875	36025	32450	13343	20493	16918	1.86	2.32	2.09
6	T6-No conservation furrow + 20 mm supplemental irrigation once at flowering	14682	28875	30855	29865	14193	16173	15183	1.97	2.10	2.03

conservation furrow for every row (T4) and every two rows (T5) in combination with 20 mm supplemental irrigation compared to rainfed crop (T1). Mean data indicated that, 68% increase in seed yield was recorded only due to 20 mm supplemental irrigation at flowering (T6) compared to rainfed crop (T1). These furrows harvest the local runoff water and improve soil moisture in the adjoining crop rows, particularly during the period of water stress. This practice has been found to increase the crop yields by 10-25% (Venkateswarlu *et al*., 2016). Praharaj *et al.,* (2016) concluded that that the critical stages for irrigation were branching and flowering in case of winter pigeonpea and enhanced the pigeonpea yields by 16%. Paul *et al*., (2016) reported that, opening of furrow in every row treatment recorded significantly higher number of capsules per plant and number of seeds per capsule as compared to flatbed method in linseed under clayey soils of Nagpur. Kantwa *et al.* (2005) stated that, broad bed and furrow method recorded significantly higher grain and stalk yield as compared to flatbed method in pigeonpea under sandy loam soils. Mankar and Nawlakhe (2013) reported that, opening of furrow in every row recorded significantly higher seed yield in pigeonpea as compared to flatbed method in Maharashtra.

Mean data of two years on economics indicated that gross returns, net returns and BCR (Table 3) was higher with conservation furrow at every row combined with 20 mm supplemental irrigation once at flowering compared to other treatments. Rao *et al*. (2018) reported that, *in-situ* moisture conservation practice of paired row planting with conservation furrow treatment realized higher net monetary returns (₹ 40540 ha^{-1}) and BCR (8.5) as compared to farmers' practice in pigeonpea. Land configuration consists of opening of furrow in every row registered significantly higher gross and net monetary returns and BCR in pigeonpea as compared to flatbed method in Maharashtra (Mankar and Nawlakhe, 2013).Venkateswarlu *et al.* (2016) reported that *in-situ* and *ex-situ* rainwater conservation practices have great potential to conserve rainwater and supplement moisture to the crops especially during drought period.

4. CONCLUSIONS

Integration of *in-situ* conservation furrows made with intercultivator cum conservation furrow opener after 60 days after sowing on receipt of rain and supplemental irrigation with 20 mm supplemental irrigation once at flowering increased productivity as well as net returns of pigeonpea in scarce rainfall zone of Andhra Pradesh. Formation of conservation furrows with tractor drawn intercultivator cum conservation opener is a best climate resilient technology under drought situations and the impact of this in-situ conservation measure could more prominently seen when it was integrated with one supplemental irrigation at critical stage of crop growth.

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