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Effect of Integrated Rainwater Management in Rainfed Crops of Scarce Rainfall Zone of Andhra Pradesh

B. Sahadeva Reddy[1]*, A. Malliswara Reddy[1], C. Radha Kumari[1], Ch. Murali Krishna[1], C. Yasmin[1], K.A. Gopinath[2] and G. Ravindra Chary[2]

[1]*Acharya N G Ranga Agricultural University, Ananthapuramu - 515001, Andhra Pradesh*

[2]*ICAR-Central Research Institute for Dryland Agriculture, Hyderabad - 500 059, Telangana*

*Email: b.sahadevareddy@angrau.ac.in

ABSTRACT: The low productivity of groundnut, pigeonpea and castor is mainly due to its cultivation in rainfed production system associated with prolonged dryspells during critical stages of crop growth period. A field experiment was conducted during *kharif* of 2015 to 2021 in rainfed alfisols with different *in-situ* and *ex-situ* moisture conservation techniques for groundnut, pigeonpea and castor at AICRPDA, Ananthapuramu, ANGRAU, Andhra Pradesh. In castor and pigeonpea, integration of *in-situ* conservation furrows and mulching recorded higher seed yield compared to rainfed crop without moisture conservation. In pigeonpea, the mean data of three years indicated that, conservation furrows in each row followed by sub soiling at one meter distance and shell mulching gave higher seed yield compared to rainfed crop without moisture conservation. In castor, mean data of three years indicated that sub soiling at one meter distance followed by conservation furrows in each row and shell mulching gave higher seed yield of 892 kg ha^{-1} compared to rainfed crop without moisture conservation (690 kg ha^{-1}). Among groundnut varieties, mean data of different years indicated that conservation furrows with supplemental irrigation recorded higher pod yield with Visista (1880 kg ha^{-1}) followed by Kadiri Lepakshi (1620 kg ha^{-1}), Harithandra (1409 kg ha^{-1}), Dharani (1406 kg ha^{-1}), K6 (1384 kg ha^{-1}) Amaravathi (1202 kg ha^{-1}) and K9 (1198 kg ha^{-1}) compared to only conservation furrows.

Key words*:* Conservation furrows, integrated rainwater management, mulching, sub soiling, supplemental irrigation

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 (wet spells), seasonal drought, early withdrawal of monsoon etc. due to aberrant behavior of south-west (SW) monsoon. Almost 56 per cent of cropped area in Andhra Pradesh is under rainfed conditions where crop yields are largely influenced by the vagaries of the weather. In Andhra Pradesh rainfed areas are spread in Ananthapuramu, Srisatyasai, Kurnool, Nandyal, YSR Kadapa, Annamayya, Prakasam, Bapatla, Palnadu, Tirupati and Chhittoor districts and these districts are vulnerable for drought. Out of 335 mandals in core rainfed eleven districts of Andhra Pradesh, there are 16 mandals (5%) with less than 500 mm, 172 mandals (51%) in the range of 500 to 750 mm, 106 mandals (32%) in the range of 750 to 1000 mm and 41 mandals (12%) with more than 1000 mm rainfall. Climate change effects are more pronounced in the frequency and intensity of extreme events in these areas. The erratic pattern and changes in quantity of rainfall and number of rainy days has led to greater uncertainty and production risks. Groundnut, an important commercial crop of Ananthapuramu district is recommended to be grown during June to July. In recent years, continuous crop failures has been observed in the groundnut farmers shifting from groundnut to sole pigeonpea and castor. Hence, castor and pigeonpea can be suggested as alternate crops to groundnut and can be grown during June to July. Dry spells of 2 to 4 weeks during critical crop growing stages cause partial or complete crop failure (Ravindra Chary *et al*., 2017). Rain water management in dryland agriculture is an important strategy to increase water productivity with adoption of efficient soil and water management practices along with suitable soil and crop management practices.

In-situ soil and water conservation practices improve soil structure, soil porosity, increase infiltration, hydraulic conductivity and consequently increases the soil water storage that helps crops to withstand the moisture stress (Venkateswarlu *et al*., 2016). Adoption of location specific *in-situ* and *ex-situ* rain water management is essential and 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. At present, more than 90 per cent of the area under groundnut, pigeonpea and castor during *kharif* is confined to rainfed areas and in future also the bulk of production will continue to come from rainfed areas. The low productivity is mainly due to drought and also due to non-adoption of soil and moisture conservation practices during crop season. Formation of conservation furrows is one of the important *in-situ* moisture conservation measures which facilitates rainwater to infiltrate by reducing the velocity of runoff flow and thus providing more opportunity 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. To provide food security to the burgeoning population, sustainable development of rainfed agriculture is the need of the hour. Water is the key input for crop production in rainfed and dryland areas, therefore, there is need to adopt a comprehensive integrated approach to conserve soil moisture through *in-situ* as well as *ex-situ* techniques in important rainfed crops like groundnut, pigeonpea and castor.

Materials and Methods

Field experiments was conducted at AICRPDA, Agricultural Research Station, Ananthapuramu (latitude of 14°41′ N, longitude of 77°40′ E and altitude of 350 meters above mean sea level) in dryland technology park of National Innovations in Climate Resilient Agriculture (NICRA) during *kharif* of 2015 to 2021 in rainfed alfisols. The treatments consists of mulching, conservation furrows, conservation furrows + mulching and rainfed (control) tested in pigeonpea and castor during *kharif* 2015. In groundnut (variety-K6), castor (PCH-111) and pigeonpea (PRG-176), sub soiling, mulching, conservation furrows and rainfed (control) were tested for three years during *kharif* of 2019 to 2021. In another experiment, the effect of conservation furrows, conservation furrows + supplemental irrigation in different varieties of groundnut (K6, K9, Dharani, Harithandra, Amaravathi, Kadiri Lepakshi and Visista) was studied for four years during *kharif* (2015, 2017, 2020 and 2021). Each treatment was laid out in an area of 600 m^2 (30 X 20 m). The soil was low in organic carbon (0.20%), and available nitrogen (140 kg ha^{-1}), high in available phosphorous (107 kg ha^{-1}) and low in available potassium (98 kg ha^{-1}). Conservation furrow of 30 cm width and 15 cm depth in between two rows were formed at 30 days after sowing with small tractor drawn intercultivation equipment in groundnut, castor and pigeonpea. Mulching with groundnut shells @ 4 tonnes per ha was applied in between rows of castor and pigeonpea. Sub soiling with chisel plough was done once in two years at a distance of one meter before sowing. One supplemental irrigation of 20 mm by sprinklers with harvested rainwater was given to groundnut during dryspell at critical stage of pod development. An amount of 459, 480, 504, 379 mm rainfall in 23, 27, 39, 25 rainy days was received during the crop season of 2015, 2017, 2020 and 2021 respectively. The rainwater use efficiency (RWUE, kg $ha^{-1}mm^{-1}$) was derived as ratio of yield (kg ha^{-1}) attained by a crop and crop seasonal rainfall (mm) of respective crop in each year. The cost of cultivation of each crop was determined by considering inputs like seed and fertilizer costs and agricultural operations from sowing to harvest. The gross returns were computed as a product of yield of a crop and its market price (Rs. kg^{-1}). The benefit-cost ratio was computed as a ratio of gross returns and cost of cultivation for each crop.

Results and Discussion

In castor, integration of *in-situ* conservation furrows and mulching recorded higher seed yield (620 kg ha^{-1}) compared to 250 kg ha^{-1} under rainfed crop without moisture conservation. An increase of 148, 84 and 24 per cent in seed yield was recorded with conservation furrows + mulching, conservation furrows respectively compared to rainfed crop without moisture conservation. In pigeonpea, integration of *in-situ* conservation furrows and mulching recorded higher seed yield (610 kg ha^{-1}) compared to 270 kg ha^{-1} under rainfed crop without moisture conservation. An increase of 126, 31 and 28 per cent in seed yield was recorded with conservation furrows + mulching, conservation furrows respectively compared to rainfed crop without moisture conservation. In both the crops, integration of *in-situ* conservation furrows and mulching recorded higher gross returns, B:C ratio and rainwater use efficiency (Table 1).

In groundnut, mean data of two years indicated that higher pod yield of 1214 kg ha^{-1} was recorded with sub soiling at one meter distance followed by conservation furrows, shell mulching compared to rainfed crop without moisture conservation. An increase in pod yield of 14, 9 and 7 per cent was recorded with sub soiling, conservation furrows, shell mulching respectively compared to rainfed crop without moisture conservation. Gross returns, B:C ratio and rain water use efficiency also followed

Table 1: Effect of conservation furrows, mulching, conservation furrows + mulching vs rainfed in pigeonpea and castor during 2015

	Conservation furrows + mulching		Conservation furrows		Only mulching		Rainfed	
	Pigeonpea	Castor	Pigeonpea	Castor	Pigeonpea	Castor	Pigeonpea	Castor
Seed yield (kg ha^{-1})	610	620	325	310	354	460	270	250
Gross returns (Rs. ha^{-1})	36600	31000	19500	15500	21240	23000	16200	12500
Net returns (Rs. ha^{-1})	21600	16000	4500	500	6240	8000	1200	-2500
B:C ratio	2.44	2.06	1.30	1.03	1.41	1.53	1.08	0.83
RWUE (kg $ha^{-1}mm^{-1}$)	1.48	1.73	0.78	0.87	0.85	1.26	0.65	0.70

Table 2: Effect of conservation furrows, sub soiling and mulching in groundnut, pigeonpea and castor during 2019 to 2021

	Conservation furrows			Sub soiling			Shell mulching			Rainfed		
	2019	2020	2021	2019	2020	2021	2019	2020	2021	2019	2020	2021
Groundnut												
Pod yield (kg ha^{-1})	1219	-	1104	1386	--	1042	1255	--	1021	1141	--	988
Gross returns (Rs. ha^{-1})	74573	--	65396	84215	--	62500	75929	--	60729	68233	--	58958
Net returns (Rs. ha^{-1})	45073	--	34896	53465	--	30750	45179	--	30229	39983	--	29708
B:C ratio	2.53	--	2.14	2.74	--	1.97	2.47	--	1.99	2.42	--	2.02
RWUE (kg ha^{-1}mm^{-1})	2.48	--	3.43	2.82	--	3.24	2.56	--	3.17	2.32	--	3.07
Pigeonpea												
Seed yield (kg ha^{-1})	417	528	148	459	421	157	399	449	143	372	380	112
Gross returns (Rs. ha^{-1})	23333	31680	8280	25717	25260	8781	22340	26940	8029	20824	22800	6272
Net returns (Rs. ha^{-1})	8083	16430	-8970	10467	10010	-8469	7090	11690	-9221	8074	10050	-8478
B:C ratio	1.53	2.08	0.48	1.69	1.66	0.51	1.46	1.77	0.47	1.63	1.79	0.43
RWUE (kg ha^{-1}mm^{-1})	0.85	0.82	0.25	0.94	0.65	0.27	0.81	0.70	0.24	0.76	0.59	0.19
Castor												
Seed yield (kg ha^{-1})	907	887	784	1088	782	806	918	867	770	805	548	717
Gross returns (Rs. ha^{-1})	34459	35480	43907	41337	31280	45161	34901	34680	43120	30594	21920	40152
Net returns (Rs. ha^{-1})	14584	15605	24032	21462	11405	25286	15026	14805	23245	13219	4545	22777
B:C ratio	1.73	1.79	2.21	2.08	1.57	2.27	1.76	1.74	2.17	1.76	1.26	2.31
RWUE (kg ha^{-1} mm^{-1})	1.85	1.38	1.33	2.22	1.21	1.37	1.87	1.35	1.31	1.64	0.85	1.22

similar trend of pod yield. In pigeonpea, mean data of three years indicated that, higher seed yield of 364 kg ha^{-1} was recorded with conservation furrows in each row followed by sub soiling at one meter distance, shell mulching compared to rainfed crop without moisture conservation (288 kg ha^{-1}). An increase in seed yield of 26, 20 and 15 per cent was recorded with conservation furrows, sub soiling, shell mulching respectively compared to rainfed crop without moisture conservation. Gross returns, B:C ratio and rain water use efficiency also followed similar trend to that of seed yield (Table 2).

In castor, mean data of three years indicated that higher seed yield of 892 kg ha^{-1} was recorded with sub soiling at one meter distance followed by conservation furrows in each row, shell mulching compared to rainfed crop without moisture conservation (690 kg ha^{-1}). An increase in seed yield of 29, 25 and 23 per cent was recorded with sub soiling, conservation furrows, shell mulching respectively compared to rainfed crop without moisture conservation. Gross returns, B:C ratio and rain water use efficiency also followed similar trend to that of seed yield (Table 2). Mulching prevents soil erosion, reduces evaporation, breaks the capillary movement and conserves moisture *in-situ.* Deep tillage with sub-soiler was found to help better rain water infiltration, higher rooting depth and 15 -20% more yields in Alfisols under semi-arid conditions (Patil *et al*., 2016).

Among groundnut varieties, mean data of different years indicated that conservation furrows with supplemental irrigation recorded higher pod yield with Visista (1880 kg ha^{-1}) followed by Kadiri Lepakshi (1620 kg ha^{-1}), Harithandra (1409 kg ha^{-1}), Dharani (1406 kg ha^{-1}), K6 (1384 kg ha^{-1}) Amaravathi (1202 kg ha^{-1}) and K9 (1198 kg ha^{-1}) compared to only conservation furrows. An increase of 15 to 21 per cent increased pod yields were recorded with conservation furrows with supplemental irrigation during critical stages during dry spells compared to only conservation furrows. Gross returns, B:C ratio and rain water use efficiency also followed similar trend to that of pod yield (Table 3). Higher yields were mainly due to increased availability of soil moisture by conservation of rainfall with conservation furrows and supplemental irrigation at critical stages of crop growth. Yellamanda Reddy *et al*. (2020) reported that 12 to 25 per cent increase in seed yield of pigeonpea due to supplemental irrigation in Alfisols of Ananthapur district. Sahadeva Reddy *et al*. (2013) also reported that 27 per cent increase in pod yields with supplemental irrigation in groundnut compared with rainfed conditions. Maruthi Sankar *et al*. (2018) reported that *in-situ* moisture conservation practices such as 30 cm distance between rows having three rows on the broad bed of

Table 3: Effect of conservation furrows and supplemental irrigation in different varieties of groundnut during *kharif* in different years

Variety	Year	Conservation furrows					Conservation furrows and supplemental irrigation				
		Pod yield (kg ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C ratio	RWUE (kg ha^{-1}mm^{-1})	Pod yield (kg ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C ratio	RWUE (kg ha^{-1} mm^{-1})
K6	2015	1833	100815	58315	2.37	3.99	2192	120560	77060	2.77	4.78
	2017	1372	75460	32960	1.78	2.85	1620	89100	45600	2.05	3.37
	2020	458	25190	-17310	0.59	0.90	506	27830	-15670	0.64	1.00
	2021	1016	55880	13380	1.31	3.17	1217	66935	23435	1.54	3.57
K9	2015	1109	60995	18495	1.44	2.42	1459	80245	36745	1.84	3.18
	2017	1378	75790	33290	1.78	2.87	1598	87890	44390	2.02	3.33
	2020	464	25520	-16980	0.60	0.92	532	29260	-14240	0.67	1.05
	2021	1008	55440	12940	1.30	2.66	1202	66110	22610	1.52	3.02
Dharani	2015	1225	67375	24875	1.59	2.67	1820	100100	56600	2.30	3.97
	2017	1406	77330	34830	1.82	2.93	1612	88660	45160	2.04	3.36
	2020	578	31790	-10710	0.75	1.14	615	33825	-9675	0.78	1.22
	2021	1424	78320	35820	1.84	4.44	1576	86680	43180	1.99	4.44
Harithandra	2015	1478	81290	38790	1.91	3.22	1809	99495	55995	2.29	3.95
	2020	713	39215	-3285	0.92	1.41	798	43890	390	1.01	1.58
	2021	1332	73260	30760	1.72	4.15	1620	89100	45600	2.05	4.75
Amaravathi	2020	705	38775	-3725	0.91	1.40	763	41965	-1535	0.96	1.51
	2021	1380	75900	33400	1.79	4.30	1642	90310	46810	2.08	4.82
Kadiri	2020	845	46475	3975	1.09	1.67	876	48180	4680	1.11	1.74
Lepakshi	2021	1920	105600	63100	2.48	5.07	2364	130020	86520	2.99	5.93
Visista	2021	1548	85140	42640	2.00	4.83	1880	103400	59900	2.38	5.52

90 cm and furrow of 45 cm gave significantly higher pod yield in groundnut as compared to control under semi-arid vertisols of Rajkot in Gujarat. Sahadeva Reddy *et al*. (2020) reported that integration of *in-situ* conservation furrows at the time sowing with 45 cm row spacing and supplemental irrigation with 20 mm during dry spells increased 26 per cent pod yield as well as net returns of Rs. 34232 ha^{-1} of rainfed groundnut in scarce rainfall zone of Andhra Pradesh. Sandhya *et al.* (1994) reported that, soil moisture content during the crop period was relatively high and resulted 37 and 23 per cent increased pod and haulm yields respectively with conservation furrows at 30 cm interval as compared to flatbed in rainfed groundnut under sandy loam soils of Tirupati. Sahadeva Reddy *et al*. (2022) reported that integration of *in-situ* conservation furrows and supplemental irrigation with 20 mm once at flowering increased 67 per cent of seed yield and net returns (Rs.15183 ha^{-1}) of pigeonpea in scarce rainfall zone of Andhra Pradesh.

Conclusion

In castor and pigeonpea, integration of *in-situ* conservation furrows or sub soiling and mulching recorded higher seed yield compared to rainfed crop without conservation measures. In groundnut, integration of either each row conservation furrows or sub soiling with supplemental irrigation of 20 mm (*in-situ* and *ex-situ* rainwater conservation) during critical stages of pod development increased the pod yield by 19% compared to only conservation furrows. These practices of *in-situ* and *ex-situ* rainwater conservation have great potential to conserve rainwater and supplement moisture to the crops especially during drought periods.

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