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Rainwater management technology to cope with climate variability and sustainable productivity of rainfed groundnut

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ABSTRACT

In–situ and *ex–situ* rainwater conservation techniques have great potential to conserve rainwater and provide supplement moisture to groundnut (*Arachis hypogaea* L.), especially during dryspells. Field experiment was conducted during *kharif*, 2016 with three main plots [rainfed, two supplemental irrigations (SI) each with 10 mm and 20 mm] and six sub plots [conservation furrows (CFs) 45 cm, 60 cm, 120 cm apart at time of sowing and at 30 days after sowing (DAS)] in split plot design with three replications in groundnut at ARS, Anantapur, ANGRAU, Andhra Pradesh. Since the formation of moisture CFs after crop establishment has some practical problems, they were formed at sowing time with an innovative technique of attaching shovels to the seed covering blade such that seed sowing, covering of seeds and formation of moisture CFs were done simultaneously. Mean data indicated that formation of CFs at the time of sowing increased pod yield and rainwater use efficiency 6.2% and 6.4%, respectively compared to formation CFs at 30 DAS. Two SIs (each at pegging and pod development stage) of 10 mm and 20 mm increased pod yields by 12% and 26%, respectively as compared to rainfed crop. Integration of *in–situ* CFs at the time sowing with 45 cm row spacing and SI with 20 mm during dry spells will increase productivity as well as net returns of rainfed groundnut in scarce rainfall zone of Andhra Pradesh.

1. INTRODUCTION

Groundnut, an important food legume and oilseed crop, grown under rainfed situation experiences erratic rainfall coupled with prolonged dry spells during critical phenophases of reproductive stages and results in lower productivity. Adequate soil moisture is essential during critical developmental stages of groundnut crop like flowering and pod filling, and even short periods of moisture stress during these stages results in significant loss in yield of groundnut crop (Shinde *et al.,* 2010). Depending on rainfall patterns and local characteristics, adoption of appropriate *in–situ* and micro–catchment techniques can improve soil water content in the root zone by 30% in rainfed agricultural eco–systems (Srinivasa Rao and Gopinath, 2016). Formation of CFs is one of the important *in–situ* moisture conservation measures which improves rainwater infiltration by reducing the velocity of runoff flow and providing more opportune time for the rainwater to infiltrate where it falls. *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. Since majority of the soils in Anantapur district are red sandy loams with undulating topography of 2–4% slope and shallow depth (10–25 cm), there is less chance for the rainwater to infiltrate during the high rainfall events. On an average, there are 4 runoff events per annum in the district which can be utilized either *in–situ* or *ex–situ* rainwater harvesting measures.

Previous experimental results at Agricultural Research Station, Anantapur revealed that opening of CFs at every 3.6 m interval *i.e.* for every 12 rows of groundnut crop, not only conserves moisture but also increases the pod yields by 10–14% over the years (Sahadeva Reddy *et al.,* 2015). The same technology can be advocated to other close growing crops like pulses, millets etc. In close growing crops, they should be formed after crop establishment on receipt of first rain. The positive effects of moisture conservation practices

like ridges and furrows in enhancing plant height and yield attributes of sorghum, cowpea, chickpea and sunflower have been observed (Somasundaram *et al*., 2000).

Since, the formation of moisture CFs is recommended for adoption after establishment of the crop on receipt of first rain, farmers feel it is an additional expenditure in engaging the cattle pair and labour exclusively for forming the CFs. Hence, it was thought to attach shovels to the seed covering blade such that sowing, covering of seeds and formation of moisture CFs can be done simultaneously, and thus famers need not incur additional expenditure for forming moisture CFs. In this direction, an experiment was planned to study the effect of formation of CF at the time of sowing in combination with SI in groundnut crop.

2. MATERIALS AND METHODS

Study Area

Field experiment was conducted during *kharif,* 2016 at Agricultural Research Station, Ananthapuram, located at $14^0$41'E latitudes and $77^0$41'N longitudes with an altitude of 373 m above mean sea level (AMSL). The soil of the experimental site is shallow red (*Typic–Haplustalfs*) with sandy loam texture (79.7% sand, 9.6% silt and, 9.7% clay), pH of 7.1 and CEC of 6.5 cmol kg^{-1}. The soil is low in organic carbon (0.20%), available nitrogen (142 kg ha^{-1}), high in available phosphorous (78 kg ha^{-1}) and potassium (395 kg ha^{-1}). The study area receives an average rainfall of 591 mm, and 60% of the rainfall is received through south–west monsoon. An amount of 265.6 mm rainfall was received in 12 rainy days during the crop season of 2016 and the crop was subjected to dry spell at pegging and pod development stages.

In–situ and *Ex–situ* SWC Measures

The treatments (18) consisted of three main plots and six sub plots laid out in split plot design with three replications in a plot size of 40 m × 30 m. The treatments were three main plots [M1 – Rainfed , M2 – SIs twice with 10 mm (each at pegging – 54 DAS and pod development stage – 103 DAS) and M3 – SIs twice with 20 mm (each at pegging – 54 DAS and pod development stage – 103 DAS] and six sub plots [S1 – CF at 45 cm apart at the time of sowing (Fig's 2, 3 and 5), S2 – CF at 60 cm apart at the time of sowing, S3 – CF at 120 cm apart at the time of sowing , S4 – CF at 45 cm apart formed at 30 DAS, S5 – CF at 60 cm apart formed at 30 DAS and S6 – CF at 120 cm apart formed at 30 DAS (Fig's 4 and 6]. Sowing of groundnut crop was done on 30.06.2016 and harvested on 24.10.2016. Spacing of 45 cm × 10 cm was adopted for sub plot treatment of CF at 45 cm (S1 and S4) and for the remaining treatments (S2, S3, S5, and S6), 30 cm × 10 cm was adopted. Since the formation of moisture CFs after crop establishment has some practical problems, they were formed at sowing time itself with an innovative technique of attaching shovels to the seed covering blade (Fig. 1) such that sowing, covering of seeds and formation of moisture CFs were done simultaneously with tractor drawn Ananta planter for treatments S1, S2, and S3. For treatments S4, S5, and S6, the crop was sown with tractor drawn Ananta planter and CFs were formed at 30 DAS with

Fig. 1. Tractor drawn Ananta planter with attached shovels for formation of CF at the time of sowing (CF at 45 cm apart at the time of sowing)

Fig. 2. Germinated crop with CFs (CF at 45 cm apart at the time of sowing)

Fig. 3. Groundnut crop at vegetative stage with CFs formed at the time of sowing (CF at 45 cm apart at the time of sowing)

Fig. 4. Groundnut crop at vegetative stage without CF (CF at 120 cm apart formed at 30 DAS)

Fig. 5. *In-situ* rainwater conservation in groundnut at pegging stage (CF at 45 cm apart at the time of sowing)

Fig. 6. *In-situ* rainwater conservation in groundnut at pegging stage (CF at 120 cm apart formed at 30 DAS)

tractor drawn intercultivation equipment. Two SIs (each at pegging – 54 DAS and pod development stage – 103 DAS) of 10 mm and 20 mm were given with harvested rainwater in farm pond as per the treatments. The first and second SI were given on 24.08.2016 and 13.10.2016 at 54 and 103 DAS, respectively as per the treatments. The recommended dose of fertilizers *i.e.* 20 N, 50 P_2O_5 and 40 K_2O kg ha^{-1} were applied by broad casting at the time of sowing in the form of urea, single super phosphate and muriate of potash, respectively.

Observations

Observations were collected from each plot for pod, haulm yield (kg ha^{-1}) at harvest; rainwater use efficiency (kg $ha^{-1}mm^{-1}$); cost of cultivation (₹ ha^{-1}), gross monetary returns (₹ ha^{-1}); net monetary returns (₹ ha^{-1}); and benefit: cost ratio (BCR), and were statistically analyzed. The rainwater use efficiency (RWUE, kg $ha^{-1}mm^{-1}$) was derived as a ratio of groundnut pod yield and crop seasonal rainfall from sowing to harvest in each treatment as described by Maruthi Sankar *et al*. (2013).

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 return 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

Eighteen treatments consisted of three main plots and six sub plots laid out in split plot design with three replications. The main and first–order interaction effects were tested based on F–test under standard analysis of variance (ANOVA) procedure. The differences in groundnut pod, haulm yield and rainwater use efficiency 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.

3. RESULTS AND DISCUSSION

Effect on Groundnut Pod and Haulm Yield

SI (main), CFs (sub plots) and their interactions significantly influenced the pod yield of groundnut. CFs formed at the time of sowing in every row with inter row spacing of 45 cm (S1) recorded 10.3% higher pod, 9.8% haulm yield with 10% higher rainwater use efficiency compared to CFs formed at 30 DAS (S4). Mean data indicated that formation of CFs at the time of sowing increases pod yield and rainwater use efficiency 6.2% and 6.4%, respectively compared to formation CFs at 30 DAS (Table 1).

Two SIs (each at pegging and pod development stage) of 10 mm (M2) and 20 mm (M3) significantly increased the pod yields by 12% and 26%, respectively as compared to rainfed crop (M1). Integration of *in-situ* CFs at the time sowing with 45 cm inter row spacing coupled with SI of 20 mm (M3 S1) during dry spells increased productivity of

Table: 1
Pod yield (kg ha^{-1}) of groundnut as influenced by supplemental irrigation and CFs

Main plots	Sub plots								Grand Mean
	CF at the time of sowing				CF at 30 DAS				
	S1	S2	S3	Mean	S4	S5	S6	Mean	
M1 - Rainfed	835	748	777	787	749	779	668	732	760
M2 - SI 10 mm twice	908	796	868	857	834	917	775	842	850
M3 - SI 20 mm twice	1068	834	1085	996	965	916	851	911	954
Mean	937	793	910	880	849	871	765	828	
					SEm±			$CD_{0.05}$	
Main plots					1.7			6.7	
Sub plots					17.9			52.0	
Sub plot at same level of main plot					4.12			90.3	
Main plot at same level of sub plot					28.4			82.6	

S1 – CF at 45 cm apart at the time of sowing, S2 – CF at 60 cm apart at the time of sowing, S3– CF at 120 cm apart at the time of sowing, S4 – CF at 45 cm apart formed at 30 DAS, S5 – CF at 60 cm apart formed at 30 DAS and S6 – CF at 120 cm apart formed at 30 DAS

rainfed groundnut by 37% compared to CFs at 60 cm interval formed at 30 DAS (M1 S5). Higher yields were mainly due to increased availability of soil moisture by conservation of rainfall with CFs and SI at critical stages of crop growth. Sahadeva Reddy *et al*. (2013) also reported that SI recorded 26% and 4% increased yield in groundnut compared with rainfed conditions in 2009 and 2010, respectively. Maruthi Sankar *et al*. (2018) reported that *in–situ* moisture conservation practice such as 30 cm distance between rows having three rows on the broad bed of 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. Also, Pendke *et al.* (2019) reported that broad bed and furrow method and opening of furrow after every 4 rows of rainwater conservation practices increased the seed yields to an extent of 57.4% and 42.9%, respectively as compared to flat bed in soybean under rainfed agro ecosystem of Maharashtra.

As CFs at 45 cm (S1 and S4) provide enough space available for individual plants at plant density of 2.22 lakhs ha^{-1} to meet plant demands to grow vigorously and to produce more branches, thereby produced more pods plant^{-1} leading to yields comparable to other treatments. Plant density of 3.33 lakhs ha^{-1} (S2, S3, S5, and S6) witnessed higher intra and inter row plant competition for nutrients, space, light and moisture and resulted in non–economic partitioning of plant. Better availability of nutrients under lower planting density aided plants to grow profusely. Similarly, rapid initiation and expansion of leaves augmented photosynthesis, besides vigorous growth of individual plants and better filling of pods. The higher plant density increased competition between plants and created a stress for plant growth resulting in improper filling and ill filled pods, ultimately reducing pod yield. Non uniformity of pod yield with densities might be due to the reason of reduced number of pods per plant with increased plant population. These results are in accordance with the findings of Kumar (2009).

On an average, 6.2% higher pod yield was recorded by the formation of CF at the time sowing compared to formation of CFs at 30 DAS. Conservation of received rainfall in the CF after sowing might have contributed for higher pod yield compared to the CFs formed at 30 DAS. An amount of 128.4 mm rainfall (4 rainy days) was received during July and this rainfall was effectively utilized by the growing crop by formation of CFs at the time of sowing. Out of this 128.4 mm rainfall, on one day *i.e.* 28.07.2016 an amount of 70.4 mm rainfall was received which resulted into soil erosion in the treatments S4, S5, and S6. In S1, S2, and S3 there was no erosion losses, entire rainfall was conserved in the CFs formed at the time of sowing. Sandhya *et al.* (1994) reported that soil moisture content during the crop period was relatively high and resulted into increased pod and haulm yields with CFs at 30 cm interval as compared to flatbed in rainfed groundnut under sandy loam soils of Tirupati. Patode *et al*. (2017) also reported benefits due to the *in-situ* moisture conservation measures such as CF in vertisols of Akola in cotton, sorghum and soybean. Haulm yield was significantly influenced by SI (main plots) only. The haulm yield indicated that there was 19.6% increased yield with 20 mm SI compared to rainfed crop (Table 2).

Rainwater Use Efficiency

Rainwater use efficiency also showed similar trend to that of pod yield. CFs formed at the time sowing in every row with inter row spacing of 45 cm recorded higher rainwater use efficiency of 3.52 kg ha mm^{-1} compared to CFs formed at 30 DAS (Table 3).

Economics

Combination of CFs formed at the time of sowing in between two rows with inter row spacing of 45 cm with 20 mm SI recorded higher gross returns (₹ 56732 ha^{-1}), net returns (₹ 34232 ha^{-1}) and BCR of 2.52 followed by CFs at 120 cm apart at the time of sowing with 20 mm SI (Table 4).

4. CONCLUSIONS

Results clearly indicated that CFs formed at the time of

Table: 2
Haulm yield (kg ha^{-1}) of groundnut as influenced by irrigation and CFs

Main plots	Sub plots								Grand Mean
	CF at the time of sowing				CF at 30 DAS				
	S1	S2	S3	Mean	S4	S5	S6	Mean	
M1.-.Rainfed	1381	1110	1250	1247	1110	1389	1389	1296	1272
M2 - SI 10 mm twice	1527	1389	1389	1435	1527	1250	1666	1481	1458
M3 - SI 20 mm twice	1666	1527	1527	1573	1527	1250	1632	1470	1522
Mean	1525	1342	1389	1418	1388	1296	1562	1416	
					SEm±			$CD_{0.05}$	
Main plots					7.8			31.7	
Sub plots					76.7			NS	
Sub plot at same level of main plot					19.1			NS	
Main plot at same level of sub plot					121.6			NS	

S1 – CF at 45 cm apart at the time of sowing, S2 – CF at 60 cm apart at the time of sowing, S3– CF at 120 cm apart at the time of sowing, S4 – CF at 45 cm apart formed at 30 DAS, S5 – CF at 60 cm apart formed at 30 DAS and S6 – CF at 120 cm apart formed at 30 DAS

Table: 3
Rainwater use efficiency (kg ha^{-1}mm $^{-1}$) of groundnut as influenced by irrigation and CFs

Main plots	Sub plots								Grand Mean
	CF at the time of sowing				CF at 30 DAS				
	S1	S2	S3	Mean	S4	S5	S6	Mean	
M1 - Rainfed	3.14	2.81	2.92	2.96	2.82	2.93	2.51	2.75	2.86
M2 - SI 10 mm twice	3.41	2.99	3.26	3.22	3.14	3.45	2.91	3.17	3.20
M3 - SI 20 mm twice	4.02	3.14	4.08	3.75	3.63	3.44	3.20	3.42	3.59
Mean	3.52	2.98	3.42	3.31	3.20	3.27	2.87	3.11	

S1 – CF at 45 cm apart at the time of sowing, S2 – CF at 60 cm apart at the time of sowing, S3– CF at 120 cm apart at the time of sowing, S4 – CF at 45 cm apart formed at 30 DAS, S5 – CF at 60 cm apart formed at 30 DAS and S6 – CF at 120 cm apart formed at 30 DAS

Table: 4
Cost of cultivation, Gross returns, Net returns and BCR as influenced by SI and CFs in groundnut

S.No.	Treatments	Cost of cultivation (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	BCR
1	Rainfed - CF at 45 cm apart at the time of sowing	22000	44152	22512	2.02
2	Rainfed - CF at 60 cm apart at the time of sowing	22700	39620	16920	1.75
3	Rainfed - CF at 120 cm apart at the time of sowing	22700	41350	18650	1.82
4	Rainfed - CF at 45 cm apart formed at 30 DAS	22500	39670	17170	1.76
5	Rainfed - CF at 60 cm apart formed at 30 DAS	23200	41728	18528	1.80
6	Rainfed - CF at 120 cm apart formed at 30 DAS	23200	36178	12978	1.56
7	SI 10 mm twice + CF at 45 cm apart at the time of sowing	22500	48454	25954	2.15
8	SI 10 mm twice + CF at 60 cm apart at the time of sowing	23200	42578	19378	1.84
9	SI 10 mm twice + CF at 120 cm apart at the time of sowing	23200	46178	22978	1.99
10	SI 10 mm twice + CF at 45 cm apart formed at 30 DAS	23000	44754	21754	1.95
11	SI 10 mm twice + CF at 60 cm apart formed at 30 DAS	23700	48350	24650	2.04
12	SI 10 mm twice + CF at 120 cm apart formed at 30 DAS	23700	42082	18382	1.78
13	SI 20 mm twice + CF at 45 cm apart at the time of sowing	22500	56732	34232	2.52
14	SI 20 mm twice + CF at 60 cm apart at the time of sowing	23200	44754	21554	1.93
15	SI 20 mm twice + CF at 120 cm apart at the time of sowing	23200	57304	34104	2.47
16	SI 20 mm twice + CF at 45 cm apart formed at 30 DAS	23000	51304	28304	2.23
17	SI 20 mm twice + CF at 60 cm apart formed at 30 DAS	23700	48300	24600	2.04
18	SI 20 mm twice + CF at 120 cm apart formed at 30 DAS	23700	45814	22114	1.93

SI – Supplemental irrigation; CF – conservation furrow; DAS – Days after sowing; Price of groundnut pods: ₹ 50 kg^{-1}; groundnut haulm: ₹ 2 kg^{-1}

sowing in between two rows with inter row spacing of 45 cm resulted into higher pod yield and rainwater use efficiency compared to CFs formed at 30 DAS. Two SIs (each at pegging and pod development stage) with 10 mm and 20 mm increased the pod yields by 12% and 26%, respectively compared rainfed crop. Integration of *in–situ* CFs at the time of sowing with 45 cm row spacing and SI of 20 mm during dry spells increased productivity as well as net returns of rainfed groundnut in scarce rainfall zone of Andhra Pradesh. *In–situ* and *ex–situ* rainwater conservation practices have greater potential to conserve rainwater and provide supplement moisture to crops, especially during drought period.

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