



Sustainable soil and water conservation practices for maximizing productivity and profitability of rainfed crops in different soil and agro-climatic conditions

G.R. Maruthi Sankar^{1*}, G. Ravindra Chary¹, P.K. Mishra², K. Sammi Reddy¹, G.R. Sharma³, M. Rajeswari⁴, R.N. Singh⁵, Anita Chorey⁶, D.K. Singh⁷, A.K. Kothari⁸, R. Sammauria⁸, B. John Wesley⁹, S.K. Gupta¹⁰ and A.K. Singh¹¹

¹ICAR-Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad-500059, Telangana; ²ICAR-Indian Institute of Soil and Water Conservation, Dehradun (IISWC), Uttarakhand; ³All India Coordinated Research Project for Dryland Agriculture (AICRPDA), Rajkot, Gujarat; ⁴AICRPDA, Kovilpatti, Tamil Nadu; ⁵AICRPDA, SK Nagar, Gujarat; ⁶AICRPDA, Akola, Maharashtra; ⁷AICRPDA, Ranchi, Jharkhand; ⁸AICRPDA, Arjia, Rajasthan; ⁹AICRPDA, Anantapur, Andhra Pradesh; ¹⁰AICRPDA, Rewa, Madhya Pradesh; ¹¹AICRPDA, Faizabad, Uttar Pradesh.

*E-mail: gmsankar2009@gmail.com

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ABSTRACT

Field experiments have been conducted to evaluate the sustainability of soil and water conservation (SWC) practices for crops grown in different soil and climatic conditions in India. The *in-situ* and *ex-situ* moisture conservation experiments were conducted in All India Coordinated Research Project for Dryland Agriculture (AICRPDA) research centers at Faizabad, Kovilpatti, Arjia, SK Nagar, Rewa, Rajkot, Ranchi and Akola to efficiently manage the *in-situ* and *ex-situ* soil moisture for performance of crops under rainfed condition. A critical assessment is made in this paper to evaluate the sustainability of treatments for maximizing the crop yield, monetary returns over years at different locations. The results indicated the superiority of land management practices, critical irrigation, optimum tillage and fertilizer doses for maximizing the yield and monetary returns of different crops. The sustainability yield index (SYI) values indicated that the soil and water management practices have a moderate sustainability of 30 to 60% for attaining maximum yield of crops grown at different locations. Based on the study, ridge and furrow sowing was found to be superior for pigeonpea (Narendra Arhar-2) at Faizabad; graded bund for sorghum at Kovilpatti; minimum tillage with soil mulch for maize at Arjia; compartment bunds for castor at SK Nagar; stone filter for black gram and pigeonpea at Rewa; 30 cm distance between rows having three rows on the broad bed of 90 cm and furrow of 45 cm for groundnut at Rajkot; opening of furrow after each row (30-40 DAS) together with 50% RDF + FYM @ 5 t ha⁻¹ + PSB + *Azotobacter* for cotton at Akola; 5 cm irrigation at seeding + 5 cm every week for palak saag, coriander and radish at Ranchi; sorghum + green gram (paired intercropping) with 5 cm irrigation applied at 15 days after effective rain at Arjia; two life saving irrigations + FYM @ 5 t ha⁻¹ for castor at SK Nagar.

1. INTRODUCTION

Rainfed agriculture plays an important role in

contributing to world food security. In India, the area under rainfed agriculture is about 85 Million ha (Mha) representing 60% of net cultivated area and supports

40% population of the country. Apart from climatic constraints of erratic and uncertain rainfall, soils are highly degraded physically, chemically and biologically in rainfed regions (Panigrahi, 1998; Maruthi Sankar *et al.*, 2010; Vittal *et al.*, 2003). SWC are very important for increasing and sustaining the productivity and monetary returns of crops grown in different regions. The crop productivity would depend on quantity of rainfall and its distribution during crop growing period (Maruthi Sankar *et al.*, 2011; Panigrahi *et al.*, 2002). Efficient management of (i) rainwater with suitable moisture conservation practice; and (ii) fertilizer application are needed for attaining sustainable yield of crops. The conservation furrow is an indigenous practice for *in-situ* moisture conservation and is adopted by farmers under semi-arid conditions. This practice is slowly disappearing due to non-availability of animal draft power and reduction in size of holding of farmers. The crop sowing done through tractor drawn seed-drill is not solving the problem of runoff disposal. Combined adoption of both indigenous and modern techniques could provide an opportunity to harvest more rainwater for getting higher yield (Mishra *et al.*, 2002a, 2002b; Gabhane *et al.*, 2017, Panigrahi *et al.*, 2007). This would ensure higher productivity under low and erratic rainfall conditions under any soil and agro-climatic condition. A need is always felt to identify a suitable moisture conservation practice for efficient utilization of low and erratic rainfall received during crop growing period under rainfed condition.

Amir *et al.* (1991) examined the water use efficiency (WUE) as influenced by management practices in wheat under arid condition. Zougmore *et al.* (2004) reported benefits of combining SWC and fertilizer practices on sorghum. They found that combining compost with stone rows or grass strips significantly increased yield and monetary returns. Rajeswari *et al.* (2007) screened different soil amendments for superiority for maximizing water holding capacity under erratic rainfall conditions in semi-arid Vertisols. With better WUE, fertilizer use efficiency would always improve for any rainfed crop. Apart from a suitable moisture conservation practice, there is a need of split nitrogen application in optimum number of splits for effective utilization of rainwater and attaining maximum profitability under rainfed condition. In order to minimize the risk of crop failure or low productivity, it is essential to apply

fertilizer N in optimum splits for efficient utilization of rainfall received from sowing to harvest of a crop under any soil and agro-climatic condition.

Efficient utilization of rainwater combined with optimum fertilizer dose of nutrients are essential for sustaining higher yield and monetary returns under rainfed agriculture. Studies were conducted to maximize monetary returns from different crops in different soil and agro-climatic conditions (Nema *et al.*, 2008; Maruthi Sankar *et al.*, 2012a and 2012b). Nema *et al.* (2008) optimized irrigation and fertilizer requirements of mustard under semi-arid inceptisols. Sharma *et al.* (2013) examined relationships between SYI, production efficiency index and monetary returns by growing maize and black gram under dry sub-humid Inceptisols. High soil loss and depletion of organic matter, erratic rainfall, low soil moisture retention and poor WUE are constraints for majority of crops in any rainfed region. Improving productivity would be essential for optimizing the benefit of water harvesting for agricultural crops. Sahadeva Reddy *et al.* (2013) studied about requirements of supplemental irrigation during dry spells for maximizing groundnut productivity under arid alfisols. Guled *et al.* (2003) studied on the superiority of SWC practices for maximizing productivity under semi-arid Vertisols.

The intensive tillage practices employing inversion implements like mould board plough would result in loss of surface crop residue and subsequent loss of soil organic carbon from soil aggregates (Mishra *et al.*, 2018). The zero or reduced tillage, green manuring, recycling of residues were effective in improving soil fertility and quality in irrigated and temperate regions. No-tillage farming practiced in combination with growing a cover crop in rotation is recognized as a viable alternative to 'plough tillage' for improving environment and sustaining natural resources. The benefits of zero till farming in combination with residue retention are substantial for erosion control, water conservation, soil fertility enhancement and C-sequestration. After harvesting, the crop residue is removed from soil surface for feeding livestock and used as fuel for domestic cooking. Due to moisture scarcity, there is little scope to grow green manure and biomass generating crops without incurring loss on account of losing cropping season. Consequently, low residue would be recycled in fields. Elimination of summer fallowing in arid

and semi-arid regions and adopting no-tillage with residue mulch improved soil structure and reduced bulk density, increased infiltration rate and productivity. Minimum tillage maintains lower temperature, water, oxygen and induces suitable environment for growth and activity of microflora and microfauna. Optimum tillage combined with weed and fertilizer would be essential to attain sustainable yield, soil health and profitable returns under Inceptisols (Nema *et al.*, 2008). The SYI could be derived as described by Singh *et al.* (1990) and Maruthi Sankar *et al.* (2011) based on field experiments conducted in different soil and agro-climatic regions. Long-term field experiments have been conducted at different AICRPDA locations with the objective of identifying efficient soil and water management practices for different rainfed crops under different soil and agro-climatic situations. The results based on the field experiments conducted over years are discussed in this paper.

2. MATERIALS AND METHODS

Details of Locations

Field experiments were conducted at Faizabad, Kovilpatti, Arjia, SK Nagar, Rewa, Rajkot and Akola to efficiently manage *in-situ* moisture, while experiments on rainwater harvesting and reuse for crops (*ex-situ*) were conducted at Ranchi, Arjia, Anantapur, Rajkot and SK Nagar under rainfed condition. Arjia is located at latitudes of 24°2'N, longitudes of 74°2'E and altitudes of 432 m above mean sea level (amsl). It is located under Northern Plain and Central Highlands including Aravalis, hot semi-arid eco-region; North Gujarat Plain (including Aravali range and east Rajasthan Uplands), hot dry semi-arid region with deep loamy grey brown and alluvium-derived soils. The soils are with fine loamy, mixed calcareous and hyperthermic Inceptisols (Sharma *et al.*, 2008).

Kovilpatti is located in Vertisol belt in southern zone of Tamil Nadu uplands and leeward flanks of South Sahayadri and Deccan (Karnataka) Plateau, between 8°43' and 9°20'N latitudes and 77°4' and 28°25'E longitudes and altitudes of 90 m amsl. The climate is hot and semi-arid with annual rainfall of 743 mm. Akola is located in Maharashtra between longitudes of 77°15'E and latitudes of 20°8'N and altitudes of 320 m amsl. Faizabad is located at a latitudes of 26°77'N and longitudes of 82°14'E and altitudes of 97 m amsl in Eastern plain zone in Uttar Pradesh. It has sub-humid hot dry climate with

annual rainfall of 1051 mm. It has Inceptisols soil with rice as predominant crop. SK Nagar is located at a latitudes of 23°52'N and longitudes of 72°43'E and altitude of 70 m amsl in northern Gujarat with annual rainfall of 670 mm. It has entisols with semi-arid climate. Pearl millet is the predominant crop grown in this region.

Rewa is located at a latitudes of 24.54°N and longitudes of 81.30°E and altitudes of 304 m amsl in Keymore plateau and Satpura hill zone in Madhya Pradesh with annual rainfall of 1088 mm. It has Vertisols with sub-humid hot dry climate. Soybean is the predominant crop grown in this region. Rajkot is located at a latitudes of 22.30°N and longitude of 70.80°E and altitude of 128 m amsl in north Saurashtra zone in Gujarat with annual rainfall of 590 mm. It has vertisols with semi-arid hot dry climate. Ranchi is located at a latitude of 23.34°N and longitude of 85.31°E and altitude of 651 m amsl in western plateau zone of Jharkhand with annual rainfall of 1149 mm. It has Inceptisols with sub-humid hot dry climate. Rice is the predominant crop grown in this region. An attempt is made in this paper to assess and identify sustainable soil and moisture conservation practices for different crops grown in different soil and agro-climatic conditions in India.

Experimental Details

In-situ moisture conservation

At Faizabad, ridge and furrow sowing, line sowing with compartmental bunding and conventional sowing (broadcasting) were tested in combination with Narendra Arhar-1, Narendra Arhar-2, Narendra Arhar-13 and Bahar varieties of pigeonpea during 2004, 2005 and 2006. At Kovilpatti, compartmental bunding, graded bund, vegetative barrier and control (no-bunding) were tested for sorghum during 2000, 2002 and 2004. At Arjia, conservation tillage, minimum tillage and raised bed sowing in combination with no-mulching, farm waste mulch, polythene mulch and soil mulch were tested for maize for 3 years during 2010, 2011 and 2012. At Rewa, vetivar grass filter, stone filter, trenches across slope, vetivar filter+trench, stone filter+trench and no-soil filter were tested for black gram during 1999, 2000 and 2002 and pigeonpea during 2000, 2001 and 2002. At SK Nagar, control (without land treatment), compartmental bunding (3.6 x 6.0 m), ditches across slope at an interval of 3.6 m and inter-culturing and forming ridges at last inter-culturing were tested for castor during 1997 to 2003.

At Rajkot, different sizes of bed at a grade viz., (i) 45 cm spacing (control), (ii) 30 cm distance between rows having 2 rows on broad bed of 60 cm and furrow 30 cm, (iii) 30 cm distance between rows having 3 rows on broad bed of 90 cm and furrow of 45 cm and (iv) 30 cm distance between rows having 4 rows on broad bed 120 cm and furrow of 60 cm were tested for groundnut during 2003 to 2008. At Akola, (i) flat bed, (ii) ridges and furrows, (iii) Opening of furrow after every two rows (30-40 DAS) and (iv) Opening of furrow after each row (30-40 DAS) in combination with (i) RDF (50:25:25 kg NPK ha⁻¹), (ii) FYM @ 10 t ha⁻¹ + PSB + *Azotobacter*, (iii) 50% RDF + FYM @ 5 t ha⁻¹ + PSB + *Azotobacter*, (iv) Vermi-compost @ 2.5 t ha⁻¹ + PSB + *Azotobacter* and (v) *Glyricidia* @ 10 t ha⁻¹ + PSB + *Azotobacter* were tested for cotton during 2008 to 2012.

Ex-situ moisture conservation

At Ranchi, irrigation of (i) 3 cm at seeding, (ii) 3 cm at seeding + 3 cm every week, (iii) 5 cm at seeding, (iv) 5 cm at seeding + 5 cm every week and (v) control were tested for palak saag, coriander and radish during 1998, 2001, 2002, 2003 and 2004. At Arjia, (i) Sole maize without irrigation (Control); (ii) maize + black gram (Paired intercropping) without irrigation; (iii) sorghum + green gram (Paired inter cropping) without irrigation; (iv) sole maize with 2.5 cm irrigation (at 15 days after effective rains); (v) maize + black gram (Paired intercropping) with 2.5 cm irrigation (at 15 days after effective rains); (vi) sorghum + green gram (Paired inter cropping) with 2.5 cm irrigation (at 15 days after effective rains); (vii) Sole maize with 5 cm irrigation (at 15 days after effective rain); (viii) maize + black gram (Paired intercropping) with 5 cm irrigation (at 15 days after effective rain); (ix) sorghum + green gram (Paired inter cropping) with 5 cm irrigation (at 15 days after effective rain) were tested during 1992 to 1995. At SK Nagar, (i) control; (ii) FYM @ 5 t ha⁻¹; (iii) one life saving irrigation; (iv) one life saving irrigation + FYM @ 2.5 t ha⁻¹; (v) two life saving irrigations; (vi) two life saving irrigations + FYM @ 5 t ha⁻¹ were tested for castor during 2006 to 2012.

Statistical analysis

The effect of SWC practices on crop productivity and monetary returns were assessed over years. Based on analysis of variance, differences between treatments on yield (kg ha⁻¹) were tested in each year and also when pooled over years (Gomez and Gomez,

1984). The treatments were assessed for long-term sustainability by considering mean, standard deviation and potential maximum value of a parameter observed in different years. The SYI of a treatment was derived as a ratio of difference between a treatment mean and its standard deviation and maximum value of any treatment observed in any year during the study period (Singh *et al.*, 1990; Maruthi Sankar *et al.*, 2011, 2012a).

3. RESULTS AND DISCUSSION

In-situ Moisture Conservation

Effect of moisture conservation and varieties

At Faizabad, moisture conservation methods gave pigeonpea yield in the range of 1445 to 2335 kg ha⁻¹ with mean of 1898 kg ha⁻¹ (variation of 14.4%) during 2004 to 2006. The ridge and furrow sowing was superior with significantly higher yield of 2023 kg ha⁻¹ compared to line sowing with compartmental bunding (1967 kg ha⁻¹) and conventional sowing (1704 kg ha⁻¹). The ridge and furrow sowing was superior with SYI of 72.8% over years. The ridges and furrows treatment had lowest variation of 8.8%, while line sowing with compartmental bunding had highest variation of 21.0% over years. Narendra Arhar-2 variety was superior with mean yield of 2161 kg ha⁻¹ and SYI of 77.0%. The annual variability for grain yield ranged from 8.9% (2004) to 11.9% (2006) for moisture conservation methods and 12.2 to 15.3% for varieties. The effects of moisture conservation on yield of varieties, along with SYI are given in Table 1. In a paper by Sahadeva Reddy *et al.* (2013), the authors assessed the sustainability of water management practices and suggested superior varieties of groundnut under moisture stress conditions under arid alfisols. A superior variety along with critical irrigation has been identified for sustaining maximum productivity under arid Alfisols.

At Kovilpatti, graded bund was superior with significantly higher mean sorghum grain yield of 1803 kg ha⁻¹ (variation of 34.2%) during 2000 to 2004. This is followed by vegetative barrier with yield of 1617 kg ha⁻¹ (variation of 37.4%), while control gave yield of 1529 kg ha⁻¹ (variation of 44.7%). The sorghum yield ranged from 1017 to 2501 kg ha⁻¹ with mean of 1601 kg ha⁻¹ (variation of 33.8%) over years. The yield had a variation of 5.5% (2002) to 19.7% (2000). The graded bund had maximum SYI of 50.5%, followed by

Table: 1
Effect of moisture conservation on pigeonpea yield at Faizabad

Treatments	Pigeonpea grain yield (kg ha ⁻¹)						
	2004	2005	2006	Mean	SD	CV (%)	SYI
Moisture conservation techniques							
T1: Ridge and furrow sowing	2131	2101*	1836*	2023*	162	8.8	72.8*
T2: Line sowing with compartmental bunding	2335*	1918*	1649*	1967*	346	21.0	70.5*
T3: Conventional sowing (Broadcasting)	1953	1714	1445	1704	254	17.6	59.6
Mean	2140	1911	1643	1898	248	15.1	67.7
SD	191	194	196	170			
CV (%)	8.9	10.1	11.9	9.0			
Varieties							
V1: Narendra Arhar-1	2280*	2049*	1782*	2037*	249*	14.0	71.9*
V2: Narendra Arhar -2	2402*	2176*	1904*	2161*	249*	13.1	77.0*
V3: Malvia Arhar-13	1817	1603	1551	1657	141	9.1	56.0
V4: Bahar	2030	1817	1337	1728	355*	26.5	59.0
Mean	2132	1911	1644	1896	245	14.9	66.0
SD	261	254	251	242			
CV (%)	12.2	13.3	15.3	12.8			

*above average

Table: 2
Effect of moisture conservation methods on performance of sorghum at Kovilpatti

Treatments	Grain yield of sorghum (kg ha ⁻¹)						
	2000	2002	2004	Mean	SD	CV (%)	SYI
T1: Compartmental bunding	1115	1166	2078	1453	542	37.3	36.5
T2: Graded bund	1577*	1332*	2501*	1803*	616	34.2	50.5*
T3: Vegetative barrier	1305*	1232	2313*	1617*	604	37.4	43.0*
T4: Control	1017	1265*	2306*	1529	684	44.7	39.5
Mean	1254	1249	2300	1601	605	37.8	42.4
SD	247	69	173	151			
CV (%)	19.7	5.5	7.5	9.4			

*above average

vegetative barrier with SYI of 43.0%, while control had SYI of 39.5%. However, compartmental bunding had lowest SYI of 36.5% over years (Vittal *et al.*, 2002). The effects of moisture conservation on sorghum yield along with SYI are given in Table 2. Mishra *et al.* (2002b) studied the effects of SWC practices and assessed their superiority under different soil and climatic conditions.

Effect of tillage and mulches on crop yield

At Arjia, minimum tillage gave significantly higher maize yield of 2833 kg ha⁻¹ (variation of 4.4%), while raised bed sowing was 2nd best with yield of 2669 kg ha⁻¹ (variation of 1.6%) over years. Soil mulch gave maximum yield of 3100 kg ha⁻¹, while polythene mulch gave yield of 2844 kg ha⁻¹ with variation of 2.7 and 2.3%, respectively. The tillage practices gave yield of 2480 to 2906 kg ha⁻¹ with mean of 2681 kg ha⁻¹ (variation of 5.4%), while mulches gave yield of 2101 to 3173 kg ha⁻¹ with mean of 2707 kg ha⁻¹ (variation of

13.5%). The yield had a variation of 4.4% (2011) to 6.8% (2010) due to tillage practices, compared to 12.6% (2012) to 16.3% (2010) due to mulches. Minimum tillage had SYI of 84.7% among tillage practices, while soil mulch had SYI of 86.2% among mulches. The effects of tillage and mulching practices on maize yield and its SYI are given in Table 3. Nema *et al.* (2008) observed significant effects of tillage and fertilizer practices on pearl millet yield under erratic rainfall conditions in semi-arid Inceptisols.

Effect of *in-situ* moisture conservation treatments on castor at SK Nagar

In a study during 1997 to 2003 at SK Nagar, compartmental bunding (3.6 x 6.0 m) was superior with significantly higher castor seed yield of 1644 kg ha⁻¹ (variation of 23.1%) compared to ditches across slope at interval of 3.6 m with yield of 1533 kg ha⁻¹, inter-culturing and forming ridges at last inter-culturing with yield of 1448 kg ha⁻¹ and control with

yield of 1246 kg ha⁻¹ with variation of 28.3%, 33.2% and 22.5%, respectively. The SYI ranged from 46.3% under control to 68.2% under compartmental bunding. The mean yield ranged from 967 kg ha⁻¹ (variation of 13.1% in 2001) to 2078 kg ha⁻¹ (variation of 11.3% in 2003). The compartmental bunding was superior compared to other treatments. The mean and variation of seed yield along with SYI of treatments are given in Table 4. T4: Inter-culturing and forming ridges at last inter-culturing was superior with maximum rate of increase of 101.0 kg ha⁻¹yr⁻¹ in castor seed yield with predictability (R²) of 0.205, followed by T2: Compartmental bunding (3.6 x 6.0 m) with rate of increase of 67.5 kg ha⁻¹yr⁻¹ with R² of 0.147. T1: Control had minimum rate of increase of 47.28 kg ha⁻¹yr⁻¹ with R² of 0.132 (Table 13). Our results are in agreement with findings made by Mishra *et al.*, 2002b; Guled *et al.*, 2003 in different eco-systems.

Effect of soil filters on crop productivity

At Rewa, stone filter was superior with significantly higher black gram yield of 565 kg ha⁻¹, followed by trenches across the slope with yield of 554 kg ha⁻¹, while control gave 538 kg ha⁻¹ with variation of 27.9, 30.2 and 40.3%, respectively during 1999, 2000 and 2002. The black gram yield ranged from 346 kg ha⁻¹ (1999) to 776 kg ha⁻¹ (2002) with variability of yield of 5.2% (1999) to 7.7% (2000). The SYI ranged from 46.6% for vetiver grass to 54.0% for stone filter with mean of 50.4% over years. The farmers could adopt stone filter for maximizing yield of black gram under similar conditions. The effects of different soil filters on black gram yield along with SYI of treatments are given in Table 5.

At Rewa, during 2000, 2001 and 2002 the stone filter treatment was superior with maximum

Table: 3
Effect of tillage and mulches on performance of maize at Arjia

Treatments	Grain yield (kg ha ⁻¹)						
Tillage	2010	2011	2012	Mean	SD	CV (%)	SYI
T1: Conservation tillage	2559	2480	2588	2542	56	2.2	75.6
T2: Minimum tillage	2903*	2691*	2906*	2833*	123	4.4	84.7*
T3: Raised bed sowing	2626	2668*	2712	2669	43	1.6	79.5
Mean	2696	2613	2735	2681	62	2.3	79.9
SD	182	116	160	146			
CV (%)	6.8	4.4	5.9	5.4			
Mulching							
M1: No mulching	2885*	2570	2668	2708*	161	6.0	73.8*
M2: Farm waste mulch	2122	2101	2301	2175	110	5.1	57.0
M3: Polythene mulch	2906*	2774*	2853*	2844*	66	2.3	78.1*
M4: Soil mulch	3173*	3008*	3119*	3100*	84	2.7	86.2*
Mean	2772	2613	2735	2707	83	3.1	73.8
SD	452	386	344	390			
CV (%)	16.3	14.8	12.6	14.4			

*above average

Table: 4
Effect of *in-situ* moisture conservation treatments on castor seed yield at SK Nagar

Treatments	1997	1998	1999	2000	2001	2002	2003	Mean	SD	CV (%)	SYI
T1: Control (farmers method- without land treatment)	1014	1350	1350	1240	865	1164	1741	1246	281	22.5	46.3
T2: Compartmental bunding (3.6 x 6.0 m)	1219*	1816*	1816*	1708*	1152*	1542*	2253*	1644*	380	23.1	68.2*
T3: Ditches across slope at an interval of 3.6 m	1015*	1808*	1808*	1652*	917	1440*	2091*	1533*	435	28.3	62.1*
T4: Inter-culturing and forming ridges at last inter-culturing	813	1660*	1660*	1524	932	1318	2227*	1448	481	33.2	57.4
Mean	1015	1659	1659	1531	967	1366	2078	1468	391	26.6	58.5
SD	166	218	218	209	127	163	236	168			
CV (%)	16.3	13.1	13.1	13.6	13.1	11.9	11.3	11.4			

*above average

Table: 5
Effect of soil filters on black gram yield at Rewa

Treatments	Black gram grain yield (kg ha ⁻¹)						
	1999	2000	2002	Mean	SD	CV (%)	SYI
T1: Vetivar grass filters	346	525	653	508	154	30.4	46.6
T2: Stone filter	394*	596*	704	565*	157	27.9	54.0*
T3: Trenches across the slope	385*	558*	720*	554*	168	30.2	52.6*
T4: Vetivar filters + Trench	370*	556*	665	530	149	28.1	49.5
T5: Stone filter + Trench	358	499	720*	526	182*	34.7	48.9
T6: Control	352	486	776*	538*	217*	40.3	50.5*
Mean	368	537	706	537	169	31.6	50.4
SD	19	41	44	20			
CV (%)	5.2	7.7	6.3	3.8			

*above average

pigeonpea grain yield of 1090 kg ha⁻¹ (variation of 17.8%). This was followed by the trenches across the slope with mean yield of 1053 kg ha⁻¹ (variation of 18.9%). The control gave lowest mean yield of 804 kg ha⁻¹ (variation of 34.1%) over years. The pigeonpea yield ranged from 610 kg ha⁻¹ attained by control (2001) to 1274 kg ha⁻¹ attained by stone filter (2000). The mean yield attained by stone filters ranged from 776 to 1145 kg ha⁻¹ (variability of 11.9 and 8.3% respectively). The SYI of treatments ranged from 48.2% for control to 70.6% for stone filter with sustainability of 64.0% over years. The farmers could adopt stone filter for maximizing the pigeonpea yield under similar conditions. The effects of soil filters on pigeonpea yield in different years along with SYI are given in Table 6. In studies made by Rajeswari *et al.*, 2007; Guled *et al.*, 2003, the authors identified efficient soil amendments for maximizing the yield in semi-arid Vertisols.

Effect of different sizes of bed at a grade on groundnut productivity

At Rajkot, during 2003 to 2008, 30 cm distance

between rows having three rows on the broad bed of 90 cm and furrow of 45 cm gave significantly higher groundnut yield of 1018 kg ha⁻¹ (variation of 41.0%), followed by 30 cm distance between rows having 4 rows on broad bed of 120 cm and furrow of 60 cm with yield of 983 kg ha⁻¹ (variation of 41.3%). The control gave minimum mean yield of 923 kg ha⁻¹ (variation of 35.0%). The variation of treatments ranged from 35.0% for control to 41.3% for 30 cm distance between rows having 4 rows on broad bed of 120 cm and furrow of 60 cm. The yield ranged from 344 kg ha⁻¹ attained by 30 cm distance between rows having 4 rows on broad bed of 120 cm and furrow of 60 cm (2006) to 1474 kg ha⁻¹ attained by 30 cm distance between rows having 3 rows on broad bed of 90 cm and furrow of 45 cm (2007). The yield ranged from 403 kg ha⁻¹ with variation of 10.9% to 1398 kg ha⁻¹ (variation of 5.4%). The treatments had SYI of 38.7% for control to 45.2% for 30 cm distance between rows having 3 rows on broad bed of 90 cm and furrow of 45 cm. The farmers could adopt 30 cm distance between rows having 3 rows on broad bed of 90 cm and furrow of 45 cm under similar conditions. The effect of treatments on pod

Table: 6
Effect of soil filters on pigeonpea yield at Rewa

Treatments	Pigeonpea grain yield (kg ha ⁻¹)						
	2000	2001	2002	Mean	SD	CV (%)	SYI
T1: Vetivar grass filters	1136	776	986	966	181	18.7	60.9
T2: Stone filter	1274*	887*	1108*	1090*	194	17.8	70.6*
T3: Trenches across the slope	1219*	832*	1108*	1053*	199	18.9	67.7*
T4: Vetivar filters+Trench	1108	776	1163*	1016*	209	20.6	64.8*
T5: Stone filter+Trench	1136	776	1108*	1007*	200	19.9	64.1*
T6: Control	997	610	804	804	274	34.1	48.2
Mean	1145	776	1095	1005	200	19.9	64.0
SD	95	93	65	100			
CV (%)	8.3	11.9	6.0	10.0			

*above average

yield of groundnut in different years and its sustainability are given in Table 7.

Among treatments, T3: 30 cm distance between rows having 3 rows on broad bed of 90 cm and furrow of 45 cm was superior with significantly higher rate of change of 80.97 kg ha⁻¹yr⁻¹ of groundnut yield with R² of 0.131 compared to T4: 30 cm distance between rows having 4 rows on broad bed 120 cm and furrow of 60 cm with rate of change of 53.62 kg ha⁻¹yr⁻¹, T2: 30 cm distance between rows having 2 rows on broad bed of 60 cm and furrow 30 cm with rate of change of 40.6 kg ha⁻¹yr⁻¹ and T1: Control (45 cm spacing) with rate of change of 30.54 kg ha⁻¹yr⁻¹ with low R² of 0.031 to 0.061 over years (Table 13). Our results are in agreement with those of Guled *et al.*, 2003; Mishra *et al.*, 2002a.

Effect of land configuration and fertilizer on crop yield

At Akola, opening of furrow after each row (30-40 DAS) was superior with maximum seed cotton yield of 988 kg ha⁻¹ (variation of 18.4%) with net returns of ₹ 18546 ha⁻¹ during 2008 to 2012. This was followed by ridges and furrows with yield of 945 kg ha⁻¹ (variation of 17.2%) with net returns of ₹ 16803 ha⁻¹. Similarly, 50% RDF + FYM @ 5 t ha⁻¹ + PSB + *Azotobactor* was superior with maximum yield of 1006 kg ha⁻¹ (variation of 20.0%), followed by RDF (50:25:25 kg NPK ha⁻¹) with yield of 974 kg ha⁻¹ (variation of 22.2%).

The SYI ranged from 49.6% for flat bed to 65.0% for opening of furrow after each row (30-40 DAS), while it ranged from 50.7% for Vermicompost @ 2.5 t ha⁻¹ + PSB + *Azotobactor* to 66.4% for 50% RDF + FYM @ 5 t ha⁻¹ + PSB + *Azotobactor* over years (Table 8). The seed cotton yield as influenced by land configuration

treatments ranged from 607 kg ha⁻¹ (2011) to 1149 kg ha⁻¹ (2012), while yield attained by nutrient modules ranged from 633 kg ha⁻¹ (2011) to 1263 kg ha⁻¹ (2010). The farmers could adopt superior practice of opening of furrow after each row (30-40 DAS) together with 50% RDF + FYM @ 5 t ha⁻¹ + PSB + *Azotobactor* for sustaining yield under similar conditions.

Based on assessment of effects of moisture conservation over years, T1: Flat Bed and T2: Ridges and furrows had maximum rate of change of 18.4 kg ha⁻¹yr⁻¹, followed by T4: Opening of furrow after each row (30-40 DAS) with rate of change of 8.8 kg ha⁻¹yr⁻¹. Based on effects of fertilizer on seed yield, F1: RDF (50:25:25 kg NPK ha⁻¹) had maximum rate of change of 15.9 kg ha⁻¹yr⁻¹, followed by F3: 50% RDF + FYM @ 5 t ha⁻¹ + PSB + *Azotobactor* with rate of change of 15.3 kg ha⁻¹yr⁻¹. However the R² of seed yield was low and non-significant for both moisture conservation and fertilizer application (Table 13). Sharma *et al.* (2013) discussed on efficient management of rainwater for maize under Inceptisols. Our results are also in agreement with findings of Nema *et al.* (2008) for efficient moisture management with tillage and fertilizer treatments tested for pearl millet in semi-arid Inceptisols.

Ex-situ Moisture Conservation Experiments

Effect of critical irrigation on crop productivity

At Ranchi, during 1998 to 2004, 5 cm irrigation at seeding + 5 cm every week gave significantly higher palak saag yield of 2631 kg ha⁻¹ (variation of 56.0%), followed by 5 cm irrigation at seeding with yield of 2109 kg ha⁻¹ (variation of 48.9%) compared to control yield of 1487 kg ha⁻¹ (variation of 83.3%). The

Table: 7
Effect of different sizes of bed at a grade on performance of groundnut at Rajkot

Treatments	Groundnut pod yield (kg ha ⁻¹)									
	2003	2004	2005	2006	2007	2008	Mean	SD	CV (%)	SYI
T1: Control (45 cm spacing)	672	1165	1040*	433*	1307	922	923	323	35.0	38.7
T2: 30 cm distance between rows having 2 rows on broad bed of 60 cm and furrow 30 cm	715*	1198	977	394	1366	1015	944	347	36.8	40.2
T3: 30 cm distance between rows having 3 rows on broad bed of 90 cm and furrow of 45 cm	606	1363*	1008*	439*	1474*	1220*	1018*	418	41.0	45.2*
T4: 30 cm distance between rows having 4 rows on broad bed 120 cm and furrow of 60 cm	703*	1305*	980	344	1446*	1121*	983*	406	41.3	42.8*
Mean	674	1258	1001	403	1398	1070	967	371	38.3	41.7
SD	49	92	29	44	76	129	42			
CV (%)	7.2	7.3	2.9	10.9	5.4	12.1	4.4			

*above average

Table: 8
Effect of land configuration and nutrient modules on cotton at Akola

Treatments	Seed cotton yield (kg ha ⁻¹)								
Land configuration	2008	2009	2010	2011	2012	Mean	SD	CV (%)	SYI
T1: Flat Bed	722	789	946	607	905	794	137	17.3	49.6
T2: Ridges and furrows	922*	948*	1017	696*	1140*	945*	163	17.2	61.6*
T3: Opening of furrow after every two rows (30-40 DAS)	844	855	987	668	938	858	122	14.2	54.7
T4: Opening of furrow after each row (30-40 DAS)	972*	970*	1144*	704*	1149*	988*	181	18.4	65.0*
Mean	865	891	1024	669	1033	896	148	16.5	57.7*
SD	109	84	85	44	130	87			
CV (%)	12.6	9.4	8.3	6.6	12.5	9.7			
Nutrient modules									
F1: RDF (50:25:25 kg NPK ha ⁻¹)	972*	940*	1116*	637	1203*	974*	216	22.2	63.9*
F2: FYM @ 10 t ha ⁻¹ + PSB + <i>Azotobacter</i>	807	856	1007	676*	951	859	129	15.0	54.8
F3: 50% RDF + FYM @ 5 t ha ⁻¹ + PSB + <i>Azotobacter</i>	931*	975*	1263*	734*	1128*	1006*	201	20.0	66.4*
F4: Vermicompost @ 2.5 t ha ⁻¹ + PSB + <i>Azotobacter</i>	817	811	841	633	934	807	109	13.5	50.7
F5: <i>Glyricidia</i> @ 10 t ha ⁻¹ PSB + <i>Azotobacter</i>	799	868	893	663	950	835	110	13.2	52.9
Mean	865	890	1024	669	1033	877	148	16.9	56.2
SD	80	66	171	41	124	88			
CV (%)	9.3	7.5	16.7	6.1	12.0	10.1			

*above average; PSB: *Phosphorus solubilizing bacteria*

variability of treatments for yield ranged from 48.9 to 83.3% over years, while variability of years over treatments ranged from 11.7% (2003) to 53.7% (2001). The yield ranged from 500 kg ha⁻¹ under control (2001) to 5200 kg ha⁻¹ under 5 cm irrigation at seeding + 5 cm every week (1998). The treatments had low sustainability for attaining maximum yield. The SYI ranged from 3.8% for control to 25.8% for 5 cm irrigation at seeding + 5 cm every week. The farmers could apply 5 cm irrigation at seeding + 5 cm every week for attaining higher palak saag yield under similar soil and climatic conditions. The effects of irrigation on palak saag yield and its sustainability are given in Table 9. T2 had maximum yield decrease of -619.5 kg ha⁻¹yr⁻¹, followed by T4 with -611.9 kg ha⁻¹yr⁻¹. T4 gave maximum R² of 0.913, followed by T3 with 0.850 over years (Table 13).

At Ranchi, during 1998 to 2004, 5 cm irrigation at seeding + 5 cm every week gave significantly higher coriander leaf yield of 1873 kg ha⁻¹ (variation of 82.7%), followed by 3 cm irrigation at seeding + 3 cm every week with yield of 1606 kg ha⁻¹ (variation of 90.6%) compared to control yield of 1194 kg ha⁻¹ (variation of 87.2%). The variability in yield ranged from 82.7 to 90.6% over years, while variability of years over treatments ranged from 9.5% (2004) to 34.5% (2001). The yield ranged from 117 kg ha⁻¹ under control (2001) to 3583 kg ha⁻¹ under 5 cm irrigation at seeding + 5 cm every week (1998). The SYI ranged from 1.7% for 3 cm

at seeding stage to 18.2% for 5 cm irrigation at seeding + 5 cm every week. The farmers could adopt the practice of providing 5 cm irrigation at seeding + 5 cm every week for attaining sustainable coriander yield in similar soil and climatic conditions. The effects of irrigation on coriander yield and SYI are given in Table 9. The coriander yield attained by T2, T3 and T4 declined, while T1 and T5 increased over years. T2 had maximum rate of change of -180.1 kg ha⁻¹yr⁻¹, followed by T4 with rate of change of -119.6 kg ha⁻¹yr⁻¹. T1 had maximum increasing rate of change of 80.67 kg ha⁻¹yr⁻¹, while T5 had minimum rate of change of 59.98 kg ha⁻¹yr⁻¹ over years. The R² was low and non-significant for all treatments over years (Table 13).

At Ranchi, during 1998 to 2004, 5 cm irrigation at seeding + 5 cm every week gave maximum mean radish tuber yield of 10684 kg ha⁻¹ (variation of 37.3%), followed by 5 cm irrigation at seeding with mean yield of 9340 kg ha⁻¹ (variation of 40.5%) compared to control yield of 5896 kg ha⁻¹ (variation of 91.2%) over years. The variability of irrigation treatments ranged from 37.3 to 91.2% over years, while variability of years over treatments ranged from 7.7% (2004) to 52.0% (2001). The yield ranged from 2030 kg ha⁻¹ under control (2002) to 16860 kg ha⁻¹ under 5 cm irrigation at seeding + 5 cm every week (2004). The SYI of treatments ranged from 8.3% for control to 36.7% for 5 cm irrigation at seeding + 5 cm every week. The effects of irrigation on the yield of radish and its

sustainability are given in Table 9. T4 had maximum rate of change in yield of 273.1 kg ha⁻¹yr⁻¹, followed by T1 with 252.2 kg ha⁻¹yr⁻¹. T2 had declining rate of change of 44.94 kg ha⁻¹yr⁻¹. The R² was low and non-significant for all treatments over years (Table 13). Guled *et al.*, 2003; Mishra *et al.*, 2002b reported similar changes in yield and its sustainability under different soil and climatic conditions.

At Arjia, the effect of rainwater through sprinkler on performance of crops was studied during 1992 to 1995. Sorghum + green gram (paired intercropping) with 5 cm irrigation applied at 15 days after effective rain was superior with significantly higher grain yield of 1731 kg ha⁻¹ (variation of 60.8%), followed by sorghum + green gram with 2.5 cm irrigation (applied at 15 days after effective rains) with grain yield of 1510 kg ha⁻¹ (variation of 65.3%), while control gave yield of 1251 kg ha⁻¹ (with variation of 35.4%) over years. Maize + black gram (paired intercropping) without irrigation had lowest variation of 34.4%, while sorghum + green gram without irrigation had maximum variation of 70.3%. The SYI ranged from 18.4% for sole maize with

2.5 cm irrigation applied at 15 days after effective rains to 37.7% for sorghum + green gram paired intercropping with 5 cm irrigation applied at 15 days after effective rain. The annual variation of yield ranged from 14.0% (1994) to 46.2% (1993). The effect different levels of irrigation on yield attained by different systems and their SYI are given in Table 10. In a study conducted by Nema *et al.* (2008), the authors found significant effects of life saving irrigation and fertilizer N for mustard under semi-arid Inceptisols. They optimized irrigation and N for sustainable yield under rainfed conditions.

Effect of critical irrigation on productivity of different crops

At SK Nagar, significantly higher castor seed yield of 958 kg ha⁻¹ was attained with application of two life saving irrigations + FYM @ 5 t ha⁻¹, followed by two life saving irrigations with yield of 815 kg ha⁻¹ with variation of 22.6 and 17.8%, respectively during 2006 to 2012. The seed yield ranged from 480 kg ha⁻¹ under control (2009) to 1420 kg ha⁻¹ under two life saving irrigations + FYM @ 5 t ha⁻¹ (2008). The variation of

Table: 9
Effect of irrigation on palak saag, coriander and radish yield at Ranchi

Treatments	1998	2001	2002	2003	2004	Mean	SD	CV (%)	SYI
Palak Saag									
T1: 3 cm irrigation at seeding	3583	883	875	1583	930	1571	1164	74.1	5.4
T2: 3 cm irrigation at seeding + 3 cm every week	5083*	1250	1251	1667	1283*	2107*	1673*	79.4	15.7*
T3: 5 cm irrigation at seeding only	3916	1750*	1746*	1834*	1300*	2109*	1032	48.9	15.7*
T4: 5 cm irrigation at seeding + 5 cm every week	5200*	2334*	2169*	2000*	1450*	2631*	1474*	56.0	25.8*
T5: Control	3533	500	504	1500	1400*	1487	1238	83.3	3.8
Mean	4263	1343	1309	1717	1273	1981	1288	65.0	13.3
SD	816	721	665	201	204	465			
CV (%)	19.2	53.7	50.8	11.7	16.0	23.5			
Coriander									
T1: 3 cm irrigation at seeding	1900	150	151	1500	2700	1280	1118	87.3	1.7
T2: 3 cm irrigation at seeding + 3 cm every week	3433*	167	165	1667	2600	1606*	1456	90.6	10.8*
T3: 5 cm irrigation at seeding only	2750*	192*	193*	1830*	2850*	1563*	1313	84.0	9.5*
T4: 5 cm irrigation at seeding + 5 cm every week	3583*	283*	280*	2100*	3117*	1873*	1548	82.7	18.2*
T5: Control	1833	117	119	1467	2433	1194	1041	87.2	-0.8
Mean	2700	182	182	1713	2740	1503	1275	84.8	7.9
SD	823	63	61	261	260	272			
CV (%)	30.5	34.5	33.7	15.2	9.5	18.1			
Radish									
T1: 3 cm irrigation at seeding	9900	4062	4461	3514	15300*	7447	5087	68.3	17.5
T2: 3 cm irrigation at seeding + 3 cm every week	11015*	5313	5315	3905	14290	7968	4468	56.1	20.5
T3: 5 cm irrigation at seeding only	10921*	7734*	7735*	5238*	15073*	9340*	3786	40.5	28.7*
T4: 5 cm irrigation at seeding + 5 cm every week	11406*	9609*	9610*	5936*	16860*	10684*	3985	37.3	36.7*
T5: Control	9156	2031	2030	2421	13840	5896	5378	91.2	8.3
Mean	10480	5750	5830	4203	15073	8267	4472	54.1	22.3
SD	926	2987	2937	1398	1160	1829			
CV (%)	8.8	52.0	50.4	33.3	7.7	22.1			

*above average

Table: 10
Effect of irrigation on yield attained under different cropping systems at Arjia

Treatments	Main crop grain yield (kg ha ⁻¹)							
	1992	1993	1994	1995	Mean	SD	CV (%)	SYI
T1: Sole maize without irrigation (Control)	884		1743	1127	1251	443	35.4	19.7
T2: Maize + black gram (Paired intercropping) without irrigation	946		1770	1103	1273	438	34.4	20.5
T3: Sorghum + green gram (Paired inter cropping) without irrigation	1375	88	2174*	1255	1223	860	70.3	18.6
T4: Sole maize with 2.5 cm irrigation (applied at 15 days after effective rains)	1287	165	2013	1405	1218	770	63.3	18.4
T5: Maize + black gram (Paired intercropping) with 2.5 cm irrigation (applied at 15 days after effective rains)	1313	194	2008	1416*	1233	757	61.4	19.0
T6: Sorghum + green gram (Paired inter cropping) with 2.5 cm irrigation (applied at 15 days after effective rains)	1968*	150	2434*	1489*	1510*	985	65.3	29.4*
T7: Sole maize with 5 cm irrigation (applied at 15 days after effective rain)	1462*	291*	2267*	1615*	1409*	823	58.4	25.6*
T8: Maize + black gram (Paired intercropping) with 5 cm irrigation (applied at 15 days after effective rain)	1433	390*	2207*	1579*	1402*	754	53.8	25.3*
T9: Sorghum + green gram (Paired inter cropping) with 5 cm irrigation (applied at 15 days after effective rain)	2302*	275*	2668*	1678*	1731*	1053	60.8	37.7*
Mean	1441	222	2143	1407	1303	797	61.1	21.6
SD	450	102	299	208	173			
CV (%)	31.2	46.2	14.0	14.8	13.3			

*above average

treatments over years ranged from 17.7% for one life saving irrigation to 22.6% for two life saving irrigations + FYM @ 5 t ha⁻¹, while annual variation of treatments ranged from 14.8% (2006) to 19.6% (2008). The treatments had a SYI of 29.4% for control to 54.6% for two life saving irrigations + FYM @ 5 t ha⁻¹ over years. The effect of irrigation and FYM application on castor yield and its SYI over years are given in Table 11.

The net returns ranged from ₹ 7495 ha⁻¹ under FYM @ 5 t ha⁻¹ (2009) to ₹ 40853 ha⁻¹ under two life saving irrigations with FYM @ 5 t ha⁻¹ (2010) with mean of ₹ 18268 ha⁻¹ (variation of 19.5%). The benefit-cost (B:C) ratio ranged from 1.18 under FYM @ 5 t ha⁻¹ (2007) to 5.87 under two life saving irrigations with FYM @ 5 t ha⁻¹ (2010) with mean of 3.17 (variation of

10.7%). The sustainability value index (SVI) ranged from 14.5% for control to 38.1% for two life saving irrigations with FYM @ 5 t ha⁻¹. The variation of treatments over years ranged from 41.2 to 44.8%, while annual variation over treatments ranged from 18.4% (2010) to 24.1% (2009). The variation of treatments for B:C ratio over years ranged from 37.1 to 42.7%, while annual variation over treatments ranged from 6.4% (2012) to 25.8% (2009). The superior practice of providing two life saving irrigations together with FYM @ 5 t ha⁻¹ for castor could be adopted by farmers for attaining sustainable yield and monetary returns under similar soil and climatic conditions. The effect of irrigation and FYM application on net returns and B:C ratio of castor in different years and their SYI over years are given in Table 12. Our results are in

Table: 11
Effect of irrigation and FYM application on castor seed yield at SK Nagar

Treatments	Castor seed yield (kg ha ⁻¹)										
	2006	2007	2008	2009	2010	2011	2012	Mean	SD	CV (%)	SYI
T1: Control	548	615	820	480	590	541	599	599	107	17.9	29.4
T2: FYM @ 5 t ha ⁻¹	567	653	898	540	645	602	651	651	117	18.1	33.0
T3: One life saving irrigation	692*	756*	1041	615	752*	701	759	760	134	17.7	40.7
T4: One life saving irrigation with FYM @ 2.5 t ha ⁻¹	748*	799*	1092*	623*	779*	729*	795*	795*	144	18.1	43.2*
T5: Two life saving irrigations	712*	772*	1132*	715*	805*	755*	815*	815*	145	17.8	44.6*
T6: Two life saving irrigations with FYM @ 5 t ha ⁻¹	800*	937*	1420*	765*	940*	885*	958*	958*	217	22.6	54.6*
Mean	678	755	1067	623	752	702	763	763	143	18.8	40.9
SD	100	114	210	106	124	121	127	127			
CV (%)	14.8	15.1	19.6	17.0	16.5	17.2	16.7	16.7			

*above average

Table: 12**Effect of irrigation and FYM on net returns and benefit-cost ratio of castor at SK Nagar**

Treatments	2007	2008	2009	2010	2011	2012	Mean	SD	CV %	SVI
Net returns (₹/ha)										
T1	9375	13971	7495	24784	14904	13298	13971	6022	43.1	14.5
T2	8825	14737	7699	26198	16318	14646	14737	6608	44.8	16.4
T3	12400*	18632*	10811*	32875*	20753*	16320	18632*	7908	42.4	25.9*
T4	11975*	18458*	9558	32856*	20832*	17069*	18458*	8199	44.4	25.5*
T5	12300*	20206*	13108*	35174*	22360*	18086*	20206*	8319	41.2	29.8*
T6	14925*	23602*	13036*	40853*	26520*	22678*	23602*	9939	42.1	38.1*
Mean	11633	18268	10285	32123	20281	17016	18268			25.0
SD	2235	3558	2482	5926	4204	3260	3558			
CV (%)	19.2	19.5	24.1	18.4	20.7	19.2	19.5			
Benefit-cost ratio										
T1	1.56	2.91	2.25	4.81	3.29	2.66	2.91	1.10	37.8	
T2	1.18	2.73	2.03	4.56	3.18	2.72*	2.73	1.14	41.5	
T3	1.91*	3.35*	2.66*	5.70*	3.96*	2.53	3.35*	1.35	40.3	
T4	1.50	3.00	2.19	5.17	3.60	2.52	3.00	1.28	42.7	
T5	1.76*	3.59*	3.87*	5.69*	3.98*	2.66	3.59*	1.33	37.1	
T6	1.76*	3.45*	2.53	5.87*	4.12*	2.99*	3.45*	1.43	41.4	
Mean	1.61	3.17	2.59	5.30	3.69	2.68	3.17			
SD	0.26	0.34	0.67	0.54	0.39	0.17	0.34			
CV (%)	16.0	10.7	25.8	10.1	10.6	6.4	10.7			

*above average

agreement with the findings made by Guled *et al.*, 2003; Nema *et al.*, 2008 who discussed on efficient irrigation management for attaining maximum yield and net returns from crops grown under erratic rainfall conditions.

4. CONCLUSIONS

The field experiments conducted on different SWC practices at different AICRPDA research centers gave scope to identify efficient soil and water management practices for long-term sustainability of yield and monetary returns attained from different crops under rainfed condition. Based on the study, ridge and furrow sowing was superior for pigeonpea (Narendra Arhar-2) at Faizabad; graded bund for sorghum at Kovilpatti; minimum tillage with soil mulch for maize at Arjia; compartment bunds for castor at SK Nagar; stone filter for black gram and pigeonpea at Rewa; 30 cm distance between rows having three rows on the broad bed of 90 cm and furrow of 45 cm for groundnut at Rajkot; opening of furrow after each row (30-40 DAS) together with 50% RDF + FYM @ 5 t ha⁻¹ + PSB + *Azotobacter* for cotton at Akola; 5 cm irrigation at seeding + 5 cm every week for palak saag, coriander and radish at Ranchi; sorghum + green gram (paired intercropping) with 5 cm irrigation applied at 15 days after effective rain was superior at Arjia; two life saving irrigations + FYM @ 5 t

ha⁻¹ for castor at SK Nagar were superior. The superior practices have been tested under the on-farm condition at different AICRPDA locations for adoption by farmers. There is a great need for revisiting the locations and revalidation of SWC practices under more number of farmers' fields for bridging the yield gap and improving the monetary returns and livelihood of farmers in different soil and agro-climatic conditions.

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Table: 13
Effect of treatments on yield of crops at different locations

Location	Crop	Treatment	Regression model	R ²
SK Nagar	Castor	T1: Control (without land treatment)	$y = 47.28x - 93325$	0.132
		T2: Compartmental bunding (3.6 x 6.0 m)	$y = 67.5x - 13335$	0.147
		T3: Ditches across slope at an interval of 3.6 m	$y = 57.17x - 11282$	0.080
		T4: Inter-culture and forming ridges at last inter-culturing	$y = 101.0x - 20069$	0.205
Rajkot	Groundnut	T1: 45 cm spacing (control)	$y = 30.54x - 60331$	0.031
		T2: 30 cm distance between rows having 2 rows on broad bed of 60 cm and furrow 30 cm	$y = 40.6x - 80479$	0.047
		T3: 30 cm distance between rows having 3 rows on broad bed of 90 cm and furrow of 45 cm	$y = 80.97x - 16137$	0.131
		T4: 30 cm distance between rows having 4 rows on broad bed 120 cm and furrow of 60 cm	$y = 53.62x - 10656$	0.061
Akola	Cotton	T1: Flat bed	$y = 18.4x - 36190$	0.044
		T2: Ridges and furrows	$y = 18.4x - 36039$	0.032
		T3: Opening of furrow after every two rows (30-40 DAS)	$y = 0.1x + 657.4$	0.001
		T4: Opening of furrow after each row (30-40 DAS)	$y = 8.8x - 16700$	0.005
		T1: RDF (50:25:25 kg NPK ha ⁻¹)	$y = 15.9x - 30985$	0.013
		T2: FYM @ 10 t ha ⁻¹ + PSB + <i>Azotobacter</i>	$y = 10.8x - 20849$	0.017
		T3: 50% RDF + FYM @ 5 t ha ⁻¹ + PSB + <i>Azotobacter</i>	$y = 15.3x - 29747$	0.014
		T4: Vermicompost @ 2.5 t ha ⁻¹ + PSB + <i>Azotobacter</i>	$y = 5.6x - 10449$	0.006
		T5: <i>Glyricidia</i> @ 10 t ha ⁻¹ + PSB + <i>Azotobacter</i>	$y = 9.7x - 18662$	0.019
Ranchi	Palak saag	T1: 3 cm at seeding	$y = -407.0x + 81641$	0.648
		T2: 3 cm at seeding + 3 cm every week	$y = -619.5x + 95900$	0.726
		T3: 5 cm at seeding	$y = -413.2x + 82933$	0.850
		T4: 5 cm at seeding + 5 cm every week	$y = -611.9x + 96150$	0.913
		T5: Control	$y = -347.0x + 69611$	0.416
	Coriander	T1: 3 cm at seeding	$y = 80.67x - 16020$	0.027
		T2: 3 cm at seeding + 3 cm every week	$y = -180.1x + 36219$	0.081
		T3: 5 cm at seeding	$y = -25.28x + 52169$	0.002
		T4: 5 cm at seeding + 5 cm every week	$y = -119.6x + 24129$	0.031
		T5: Control	$y = 59.98x - 11886$	0.017
	Radish	T1: 3 cm at seeding	$y = 252.2x - 49737$	0.013
		T2: 3 cm at seeding + 3 cm every week	$y = -44.94x + 97926$	0.000
		T3: 5 cm at seeding	$y = 124.8x - 24052$	0.005
		T4: 5 cm at seeding + 5 cm every week	$y = 273.1x - 53611$	0.024
		T5: Control	$y = 152.7x - 29974$	0.004

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