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S Vijayakumar
Krishi Vigyan Kendra, Ranga Reddy, Telangana, India

GV Chauhan
Krishi Vigyan Kendra, Ranga Reddy, Telangana, India

KV Rao
ICAR-Central Research Institute for Dryland Agriculture (CRIDA), Telangana, India

I Srinivas
ICAR-Central Research Institute for Dryland Agriculture (CRIDA), Telangana, India

G Pratibha
ICAR-Central Research Institute for Dryland Agriculture (CRIDA), Telangana, India

B Sanjeeva Reddy
ICAR-Central Research Institute for Dryland Agriculture (CRIDA), Telangana, India

Chandrakant MH
Krishi Vigyan Kendra, Ranga Reddy, Telangana, India

VK Singh
ICAR-Central Research Institute for Dryland Agriculture (CRIDA), Telangana, India

Corresponding Author:
GV Chauhan
Krishi Vigyan Kendra, Ranga Reddy, Telangana, India

Adaptation and assessment of in-situ moisture conservation farm machinery implements to enhance crop productivity in rainfed agriculture

S Vijayakumar, GV Chauhan, KV Rao, I Srinivas, G Pratibha, B Sanjeeva Reddy, Chandrakant MH and VK Singh

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Abstract
Advanced farm mechanization technologies were introduced in the watershed area under the in-situ moisture conservation component for on-farm assessment. Experimental demonstrations were conducted in farmers' fields, and results were compared with conventional practices. The implements evaluated included a paired row planter, a Broad Bed Furrow (BBF) planter, and a multipurpose plastic mulch sheet-laying machine. The Paired row planting method increases yield by 13 to 17% and enhances rainwater harvesting by 27 to 42% compared to traditional practices, thereby improving water-use efficiency and reducing input costs. The observed yield variations were associated with enhanced rainwater conservation and optimized seed and fertilizer use.
The BBF planting system significantly improved growth characteristics in crops such as bottle gourd, bitter gourd, and tuberose compared to flatbed sowing. The adoption of plastic mulching, which has increased by nearly 50% since the early 1990s, proved beneficial for early production, improved fruit quality and higher yields in horticultural crops. Black polythylene mulching is particularly effective in conserving soil moisture and enhancing productivity in water-scarce rainfed regions.

Keywords: Rainfed, in-situ moisture, BBF, paired row planting and mulching

Introduction
The ICAR-CRIDA (Central Research Institute for Dryland Agriculture), Krishi Vigyan Kendra (KVK) Ranga Reddy District, initiated a project to assess in-situ moisture conservation farm machinery in rainfed agriculture. Beginning in 2011-12, the project involved collaboration with the Joint Director of Agriculture, State Agricultural Officials and progressive farmers. The interventions were implemented in two hamlets, Sheriguda and Chenchupally of Pudur Mandal, Ranga Reddy District, which typify the district's agro-climatic and were selected to demonstrate climate-resilient technologies.
In-site moisture conservation practices are essential for sustaining crop growth and improving yields in rainfed areas. However, the adoption of such practices remains limited due to the unavailability of suitable tractor-operated implements and the inefficiency and paired row seeders, which provide opportunities for efficient rainfall capture and soil moisture retention from the onset of sowing (Behera *et al* 2025) [2].

Location of the Cluster and Cropping Pattern
The project clusters were located approximately 70-80 km from Hyderabad. Mapping of gram panchayats. Benchmark Natural Resource Management (NRM) status and participatory rural appraisal (PRA) exercises facilitated implementation with the farmers shown in Figure 1.

Fig 1: Villages Map and PRA exercise with the farmers

The major crops in the Pudur Mandal in Vikarabad District include rice, jowar, maize (*Kharif* Season), chickpea and groundnut (*Rabi* season), as well as vegetables & flowers, red gram, and cotton, etc. Food crops account about 65% and non-food crops 35% of the gross area sown. Farm mechanization proved crucial for timely operations and overcoming labour shortages in the production of these crops.

1. In-situ moisture conservation plays a vital role in rainfed farming to protect the soil and to conserve water.
2. Paired Row Planter, BBF and Mulching Sheet Laying Machine technologies were identified for evaluation, as their significance is correlated with resource conservation technologies
3. As the farm holdings of rainfed farmers are very small, the optimal use of these three implements needs to be explored properly.
4. Few studies are available for the rainfed farming systems. Hence, three technologies were planned to be evaluated at the field level.

Paired row planter | BBF planter | Mulching sheet laying machine

Objective of research

1. **Assess the efficacy of machinery:** To evaluate how effectively different *in-situ* moisture conservation implements, such as tractor-drawn implements, perform under specific agro-ecological conditions.
2. **Effective use of inputs and timely execution of operations:** Improved moisture availability leads to more efficient use of fertilizers and other crop inputs. These machines enable farmers to complete field preparations accurately and on time, increasing limited soil moisture, further improving efficiency and reducing costs.
3. **Enhance crop productivity:** To determine how the use of moisture-conserving implements impacts the growth, yield, and overall water use efficiency (WUE) of rainfed crops.
4. **Measure *in-situ* moisture conservation:** To quantify the improvements in soil moisture content and reductions in surface runoff achieved by using the implements compared to traditional practices.

Materials and Methods

To finalize the NRM activities in the cluster, the following steps were followed. Participatory rural appraisal survey, baseline survey, village transect walk and Organization of village-level meetings to finalize the beneficiaries in consensus with farmers of the cluster. To impart direct benefits to the farmers, *In-situ* moisture conservation practices through the use of farm machinery for climate resilience enhancement were proposed and the project implementation period was 2011-16 through selected agricultural machinery.

Selected Practices and Crops

Four technologies were selected and implemented in the farmers' fields as detailed below, shown in Table 1, and a) Making Conservation Furrows - A farmer's practice b) Broad Bed and Furrow sowing, c) Plastic Mulching Sheet laying and Crop Planting with a Multifunctional in a single pass. These practices were implemented on a large scale in the cluster. Criteria considered for the adoption of farm machinery and simple device-based practices were included to empower the farmers to overcome labor shortages and higher field coverage in a shorter period of time. The benefits that occur directly to farmers through natural resource conservation were also kept in mind.

Table 1: Crops and respective i*n-situ* moisture conservation practices implemented.

S. No.	Crops	Technology and the Machinery
1	Pigeon pea, Cotton and other crops	ICAR-CRIDA Designed Paired Row Planter
2	Vegetables, flowers and other crops	ICAR-CRIDA Designed Broad Bed Furrower (BBF) planter
3	Vegetables	Multipurpose Plastic mulch sheeting and punching machine

Paired Row Planter

Raghavendra *et al*. (2013) evaluated ridger planter performance in the planting of cotton and found the field efficiency of the planter was 0.89 ha/h with a field efficiency of 73.55 per cent. CRIDA designed a paired row planter for making rainwater harvesting furrows and simultaneously sowing one row of crop on either side of the furrows. This will enhance soil moisture availability to the crop when compared with flat sowing, as is the case with farmers' practice shown in Figure 2.

Fig 2: Paired Row Planter in the Pigeon pea crop

Broad Bed Furrower system

The CRIDA-designed broad-bed furrow-making machine was used to make the beds. Seedling transplanting was carried out using manual labor Khambalkar *et al*. (2014) [4], Asewar *et al*. (2017) [1], Kumar, S. *et al*. (2023) [7] and Sonwani, *et al*. (2025) [12] carried out mechanical sowing of safflower with the Broad Bed Furrow method, which saved 58% of the operational cost over the conventional method shown in Figure 3.

Fig 3: Broad Bed Furrow technology in Cluster.

Plastic Mulching Sheet Laying Machine

In the cluster of villages, most of the vegetable crops taken up in the rabi season suffer due to water stress from February to June and shown in Figure 4 below. Therefore, farmers take up these crops to a limited extent due to a lack of sufficient irrigation water. Despite these limitations, farmers plant vegetable crops, as it is highly profitable. Soil moisture conservation techniques were more useful to facilitate such farmers. The optimum soil moisture during the growing, flowering and fruiting stages is essential for the proper uptake of nutrients and good crop yields.

Taking up these crops with plastic sheet mulching in combination with a drip system is an option to reduce the number of irrigations and increase the yields Tuzen, *et al*. (2021) [24] Kumar & Meena *et al*. (2020) [6].

Fig 4: Plastic sheet and drip pipes laying machine and a Tomato crop planted.

Results and Discussion

In the selected cluster, a mechanized and simple device-based technology was assessed in a participatory research mode with a considerable number of farmers across a substantial area during the project period, as detailed in Table 2.

Table 2: No. of Farmers who participated and the area under selected interventions.

S. No.	Title of the Technology Demonstrated	No. of Farmers benefited	Area covered (ha)
1	Paired Row Planting	85	63
2	Broad Bed Furrower (BBF) Planting	38	29
3	Plastic Mulch Sheeting and Drip Lateral Laying Machine	39	10
	Total	162	102

Paired Row Planter

In rainfed farming, seed placement in proper conditions for a better germination rate is important for good crop establishment. In the traditional sowing method with bullock-operated implements, it is difficult to maintain the proper seed rate. But, it is well known that seed planters help to maintain the plant-to-plant spacing and row-to-row spacing as per the agronomical requirements of the crop. Moreover, the selected planter has a provision to maintain the uniform depth of sowing more or less, which helps to increase the germination rate, besides aiding in conserving moisture and draining the excess rainfall water from the crop fields Korwar *et al*. 2018 [5], and Kumar, S. 2023 [7]. The details about the performance of technologies were explained in the subsequent sections.

The Paired Row Planter recorded the depth of sowing, spacing, and furrow width more uniformly when compared with farmers' practice. The result showed that sowing pigeon pea with a paired row planter saved seed by 16% and fertilizer by 45% (Table 4). Most of the farmers broadcast the seed and fertilizer in conventional practice and typically use a high seeding rate and fertilizer to compensate for the plants' loss due to the unevenness in seed placement depth, leading to wastage of seed & fertilizer. The seed rate and basal dose of fertilizer are uniformly applied using a paired row planter, rather than bullock-operated implements and conservation furrows made during intercultural operations. Higher moisture conservation resulted in a 34.25% higher yield in paired rows compared to conventional methods shown in Table 3.

Table 3: Field performance evaluation results of the paired row planter for pigeon pea crop.

S. No	Particulars of the different activity	Conventional Method	Paired row Planter	% Saving
1	Seed rate (kg/ha)	16-19	14 -16	16
2	Fertilizer rate(kg/ha)	350-400	220	41
3	Depth of sowing (mm)	45-65	30-50	-
4	Row to row distance (cm)[furrow width]	45,60 (120)	60 (90)	-
5	Seed to seed distance (cm)	Not following	20-30	-
6	Furrow width (cm)	No furrows	30	-
7	Furrow depth, cm	NA	20-25	-
8	Germination%	70-75	90-95	27.5
9	Speed of operation, km/h	1-2	3-4	-
10	Fuel consumption (lit/h)	-	3-4	-
11	Field efficiency (%)	62.75	85	35.4
12	Plant population No./ha	42900	36300	15
13	Cost of sowing (Rs/ha)	2000 to2500	1000 to1500	50
14	Crop Yield (q/ha)	10 to 15	20 to 25	30to35
15	*In-situ* Runoff water collected (ha area)	No furrow	230 Cu.m	-

Paired row planting reported lower cultivation costs despite the investment in fuel consumption. Savings that can be achieved with fertilizer, seed, and labor result in a low cultivation cost. Rao *et al*. (2018) studied paired row planting practice and an increase in crop yield was observed was found to be 34.25% with low cultivation cost and can store 250 m3 water/ha in fields, accounting for about 30 mm rainfall saving during the crop establishment to growth period. It is observed that the net return was high (Rs 41000/-) in the paired row planting method, partly due to conservation of moisture in the fields, saving of inputs (seed and fertilizer) and labor to some extent when compared to farmers' practices shown in Figure 5. The high B:C ratio of the paired row planting method was 8.0, indicating that paired row planting is beneficial compared to the farmer planting method shown in Table 4.

Table 4: The Economics of Farmer and Machine Methods

S. No.	Particulars	Farmers Method	Planter	Difference
1	Cost of cultivation (Rs.)	20000	16000	4000
2	Annual Gross Returns (Rs.)	106000	143000	37000
3	Annual Net Returns (Rs.)	86000	127000	41000
4	B:C Ration	4.3	8.0	3.7

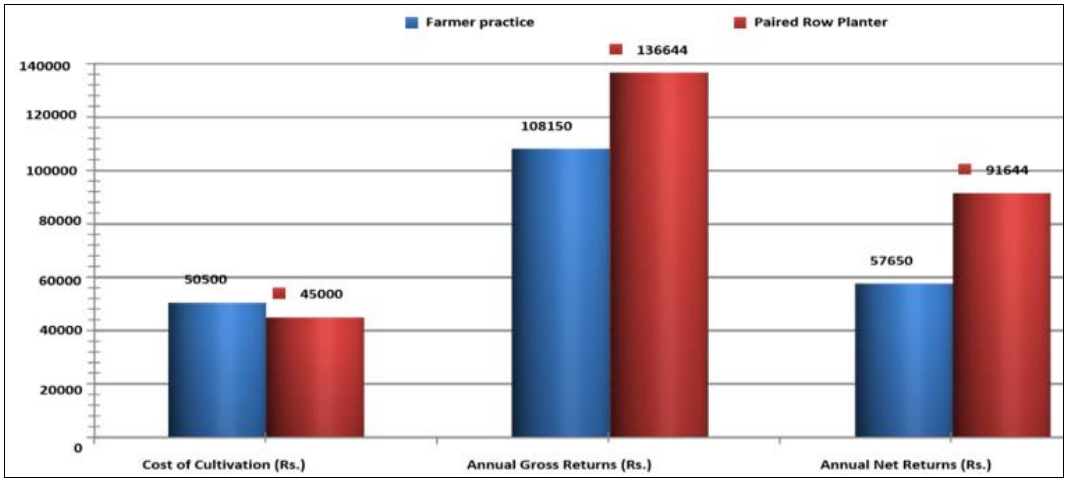

Fig 5: Comparison of paired row planting with farmer practice

Broad Bed and Furrow System of planting

The BBF system has been used successfully for transplanting of Flower crop and the same implement can be used with minimal adjustments needed for different types of crops. The system also facilitates *in-situ* water conservation on-site. The proper size of the bed and furrow size to be selected, depending on crop row spacing and plant growth characteristics (Soujanya *et al*. 2025) [13]. The cost economics of the BBF planting system of flower crop cultivation were provided in Table 5. In Table 5, it can be observed that the B:C ratio of the BBF planting system is about 3.59, which is more than that of farmer practice (1.17).

Table 5: BBF System and Farmer's method for bottle gourd crop.

S. No.	Item of Expenditure	Farmers Method	BBF Method	Change, Rs ↑↓
1	Field preparation	Rs 5500/-	Rs 7500/-	(-) Rs 2000 ↓
2	Plant protection operations	Rs 25000/-	Rs 15000/-	(+) Rs 10000 ↑
3	Weeding(2-3times)	Rs 30000/-	Rs 21000/-	(+) Rs 9000 ↑
4	Total no. of irrigations	60	30-40	(+) 20-30 ↑
5	Waterlogging	Medium	Nil	-------
6	Total no. of pickings	15	21	(+) 6 Picks ↑
7	Total yields (t/ha)	35	55	(+) 20 tons ↑
8	Total expenditure (Rs.)	Rs 72460/-	Rs 76500/-	(+) 4040 ↑
9	Gross income (Rs.)	Rs 175000/-	Rs 275000/-	(+) 100000 ↑
10	Net income (Rs.)	Rs 102540	Rs 198500	(+) 95960 ↑
11	BC ratio	2.41	3.59	(+) 1.17 ↑

Table 6: Bitter gourd crop details in BBF and Farmers' practice.

S. No.	Particulars (per/ha)	Farmer practice	BBF System
1	Total yield(t/ha)	25.4	29.6
2	Marketable yield (t/ha)	19.8	27.6
3	Unmarketable yield (t/ha)	5.6	2.0
4	% increase in marketable yield	--	39.3
5	Cost of cultivation Rs/ ha.	126500	121200
6	Gross income Rs/ha.	229200	291800
7	Net returns Rs/ha.	102700	170600
8	B:C ratio	1.81	2.42

In Table 6, it can be observed that the B:C ratio of the BBF planting system is about 2.42, which is more than that of farmer practice (0.61).

Table 7: Tuberose crop details in BBF and Farmers' practice.

S. No.	Particulars	Farmers practice	BBF System
1	Days to first blooming	118 DAS	97 DAS
2	No.of flowers per kg	830	625
3	Yield during winter, kg/day	32	71
4	Flower Yield (kg/month/ha)	495	1120
5	Total Yield(t/ha)	6.3	11.8
6	% increase in yield		87.3
7	Cost of cultivation, Rs/ha	188000	285600
8	Gross income, Rs/ha	311500	798600
9	Net income, Rs/ha	123500	513000
10	BC ratio	1.65	2.79

A 70 to 80% increase in yield, quality and shelf-life of the flowers was achieved. Consistency in yield during the winter months, high demand for quality produce, fetched a good price. In Table 7, it can be observed that the B:C ratio of the BBF planting system is about 2.79, which is more than that of farmer practice (1.14).

Table 8: Effect of BBF on the productivity of crops

S. No.	Crop	Crop yield(t/ha)		
		Farmer practice	BBF system	Increased in yield
1	Bottle gourd	35	55	57.14%
2	Bitter gourd	2.0	5.6	180%
3	Tube rose	6.3	11.8	87.30%

The increased yield for the bottle gourd, bitter gourd and tube roses was indicated in percentage-wise in Table 8.

Water conservation through a multipurpose plastic mulch sheet laying machine in vegetables

Using the mulch sheet laying machine, five activities can be carried out in a single pass. The advantages of polyethylene mulch sheet are increasing soil temperature, especially in winter, reducing weed problems, improving moisture conservation, increasing crop yields and making soil nutrients more efficient.

- Poly Vinyl Chloride (PVC) flexible film is fit for mulching and images show all the benefits of mulch, such as moisture conservation and weed growth control.
- Water savings were the main benefit, which varied from 20% to 75%.
- The use of mulching may not increase crop yields significantly, but more land can be irrigated with available water and thereby increasing overall crop yield.
- Based on typical compositions, 150 to 200-gauge PVC film can last for 2 seasons, if proper care is taken.
- Black PVC film shows better control of weed growth than pure opaque white and natural opaque film. The cost economics of a mulch-laying machine were given in Table 9.

Table 9: Benefits of the mulching machine Vs the farmer's practice

S. No.	Particulars for the tomato crop	Conventional Method	Mulching Machine	Change ↑↓
1	Cost of field preparation	Rs 5500/-	Rs 1400/-	(+) Rs 4100 ↑
2	Cost of mulching sheet	-	(13 rolls) Rs.27300	(-) Rs.27300 ↓
3	Cost of Pesticide application	15000	6000	(+) Rs.9000 ↑
4	Weeding (3-4times)	Rs 31500	Nil	(+) Rs 31500 ↑
5	Total no.of pickings	9	15	(+) 6 Picks ↑
6	Total yields(t/ha)	23	41	(+) 8 tons ↑
7	Cost of Cultivation (Rs.)	92460	96500	(+) 4040 ↑
8	Gross income (Rs.)	207000	369000	(+) 162000 ↑
9	Net income (Rs.)	118500	222200	(+) 157960 ↑
10	BC ratio	2.23	3.82	(+) 1.5 ↑

From Table 9, it can be observed that the B:C ratio of mulching machines is 3.82, which is more than that of farmer practice by 2.23.

Table 10: Mulching practice in green chilli (per/ha)

S. No.	Particulars	Farmers practice	Mulching
1	No. of manual weeding required in the crop season &cost	3(12000)	nil
2	Pest & disease incidence	More visible	Negligible
3	Cost of controlling pests &Diseases	15	9
4	Total cost	24500	18200
5	Cost of Inputs for mulching	---	11500
6	Total no. of pickings	6	10
7	Total yields(t/ha)	10	12
8	Cost of cultivation (Rs.)	129000	127000
9	Gross income (Rs.)	182000	244000
10	Net income (Rs.)	53000	117000
11	BC ratio	1.41	2.23

From Table 10, it can be observed that the B:C ratio of mulching machines is 2.23, which is more than that of farmer practice by 1.41 and it is shown in graphical Figure 6.

Table 11: Effect of mulching on the productivity of crops in the watershed project

S. No.	Crop	Crop yield t/ha		
		Farmer practice	Mulching system	Increased yield
1	Tomato	23	41	78.26%
2	Green Chilli	10	12	20.00%

In tomato, the yield increases 78.26% and in Green Chilli, the yield increases 20.00%. Hence, by using this implement, the farmers are getting the benefit, the details are shown in Table 11

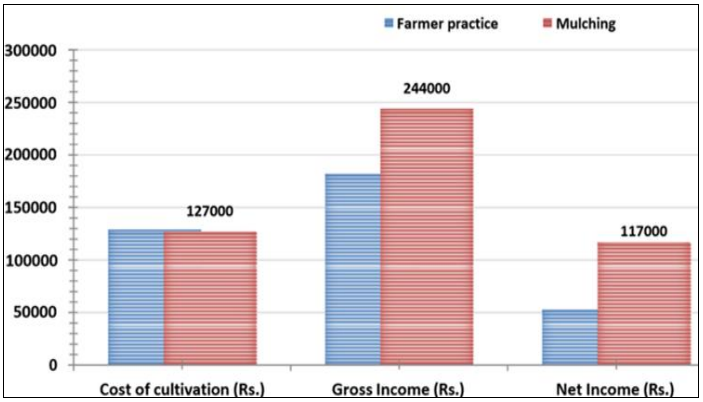

Fig 6: Comparison of mulching and farmer practice

Conclusion

Implementation of *in-situ* moisture conservation farm machinery benefited 1,164 farmers across 790 hectares. Four major technologies were assessed during the project period:

- **Paired Row Planter (Pigeon pea):** Benefited 85 farmers, the area covered was 63 ha. Increased theoretical field capacity by 22.2%, actual field capacity by 28.5%, and field efficiency by 35.4%. Plant population rose by 15% and in-situ moisture in conservation reached 230 cu.m/ha, the cost of cultivation decreased by Rs 4000/ha, gross returns increased by Rs 37,000/ha, net returns by Rs 41000/ha and B:C ratio improved 3.7%.
- **Broad Bed Furrow (BBF) Planter (Vegetables):** It provides seeds and fertilizers on the ridges along with conservation furrows. Benefited 38 farmers and 29ha area covered. Reduced labor and energy use by 80% saved Rs. 31,500 on weeding, reduced irrigation by 30%, increased yield by 20 t/ha and improved net return by Rs. 95,960 with a B:C ratio increase of 1.17.
- **Plastic Mulch Sheet (Vegetables):** Plastic mulch sheet in vegetables benefited 39 farmers and covered 10 ha area covered. Reduced field preparation cost by Rs 4100/ha, saved weeding cost by Rs 31500/ha for 3-4 times, pickings increased by six times, increased yield by 8 t/ha, improved gross income by Rs 1,62,000/ha, and net income by Rs 157960/ha with a B:C ratio increase by 1.5. Irrigation water saving ranged from 33.3-41% and tomato yields increased by 23.75% compared to control plots.

Overall, the project demonstrated that integrating mechanized in-situ moisture conservation implements can significantly enhance resource-use efficiency, crop productivity and profitability in rainfed farming systems.

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