



## Selective mechanization improves productivity, energy indices and profitability of rainfed castor (*Ricinus communis*) in India

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### ABSTRACT

A 4-year field study (2013–14 to 2016–17) was conducted at Palem, Telangana, to understand the impact of selective mechanization practices (SMPs), viz. motorized power spray, mechanical interculture, harvesting using secateurs and mechanical castor shelling, and conventional practices (CPs) like knapsack sprayer, bullock-drawn blade, manual harvesting and manual shelling with wooden sticks on the productivity and profitability of castor (*Ricinus communis* L.) cultivation on rainfed Alfisols. Results showed a 13.2% increment in seed and oil yield, a saving of 23-man days and 54 hours time/ha coupled with higher additional net returns (₹9,448/ha) owing to SMPs. Further, adoption of SMPs also resulted in improved infiltration rate, higher rainwater use efficiency, energy ratio, energy productivity, and net energy gain over CPs. Of the 4 agronomic operations under study, the maximum energy (683 and 419 MJ/ha) was consumed by plant protection. To upscale and outscale the technology, there is a need for breeding genotypes amenable for mechanization and establishment of custom-hiring centres with appropriate machinery, so that small-holder farmers in India will have access to machinery for undertaking timely operations and improve farm income.

**Key words:** Castor, Conventional practices, Energy, Productivity, Selective mechanization

Agricultural farm sector in India has been characterized by unskilled-labour intensive with less farm machinery. Generally, farmers have been performing all their agricultural operations through traditionally available resources. Sowing with labour aided by bullock-drawn implements, post-sowing operations like thinning, gap-filling, weeding, fertilizer application with hand-operated tools, spraying, irrigation with labour and manual harvesting etc. are being done in different crops. Furthermore, various post-harvesting operations, viz. threshing/ shelling/ hulling/ decortication, cleaning, grading, peeling, are also handled manually

especially by women. It is mainly because of large percentage of small and marginal farmers (85%) with small-land holdings (1.16 ha), availability of surplus labour at cheaper cost, lack of technical know-how and low level of penetration of mechanization in rural areas, low farm power (1.84 kW/ha), non-contiguous group of farms and low productivity (Singh, 2010; Singh *et al.*, 2011). However, non-completion of various agronomic operations in time, loss of energy and produce, low output per unit time, body discomfort, fatigue and health disorders are the consequences of heavy dependence on human labour. Further, agricultural labour is less productive by 4 and 6 times as compared to industry and service sectors, respectively (Goldman Sachs, 2014).

The level of farm mechanization is dismally low in India (40%) as compared to the United States (95%), Western Europe (95%), Russia (80%) and Brazil (75%) (Renpu, 2014). However, in the recent past, India started moving from human and draft animal power to mechanical power, thus, energy usage and intensity have increased in the agricultural sector. In future, the population of rural areas is expected to decline from 62.83% in 2025 to 44.83% by 2050, the percentage of agricultural workers to the total

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workers which has declined from 59.1% in 1991 to 54.6% in 2011 is expected to decline further to 25.7% by 2050 (FICCI, 2015). Hence, there is an urgent need of farm mechanization to sustain the productivity and profitability in India.

Mechanization enhanced work efficiency of farm labour, resource-use efficiency (Asewar *et al.*, 2020), cropping intensity by 5–20%, production and productivity by 10–15%, savings in seeds up to 15–20%, saving in fertilizer and chemicals by 15–30% and reduced the time and labour by 20–30% (GoI, 1996). A strong correlation was observed between increase in foodgrain productivity (0.71 to 2.21 t/ha) and farm power availability (0.296 to 2.02 kW/ha) in India (CIAE, 2014). Thus, mechanization has been identified as a means to improve productivity and profitability. It became more important in dryland agriculture where the length of growing season is short, hence, critical for completion of all important agricultural operations in time.

Castor is an important rainfed, non-edible oilseed crop which has multiple uses. It is also recognized for its suitability for biodiesel production considering its distinct oil quality properties, positive energy production and high energy-use efficiency. This crop can tolerate drought and be grown successfully on diversified agro-climatic conditions ranging from less-fertile marginal soils to high-fertile soils and Mediterranean climate to arid, semi-arid, temperate, tropical and sub-tropical climates and low-rainfall to high-rainfall areas (Ramanjaneyulu *et al.*, 2013). It is being cultivated in 12 states in India and mostly under rainfed conditions in South, Central and East India, but, irrigated conditions in Western and North India. The mechanization in castor, its associated benefits, energy flow and management is less studied. Hence a field study was conducted for 4 consecutive years in order to quantify the impact of selective mechanization on the performance and energy budgeting of rainfed castor.

## MATERIALS AND METHODS

A field experiment was carried out four years consecutively (*kharif* 2013-14 to 2016-17) was carried out at Regional Agricultural Research Station, Professor Jayashankar Telangana State Agricultural University (PJTSAU), Palem, the zonal headquarters for Southern Telangana Zone (STZ), to quantify the impact of selective mechanization practices (SMPs) on the performance and energetics of rainfed castor in Alfisols soils of Southern India. The study site was located at 16°35' N, 78°1' E an altitude of 642 above mean sea-level. Soil had a pH of 5.6 with low available N (220 kg/ha), medium available P (12.44 kg P/ha) and high available K (375.2 kg K/ha).

The study was a large plot size experiment with 2 treat-

ments, viz. selective mechanization practices (SMPs) and conventional practices (CPs), each in 0.4 ha area. The area under a given treatment was divided into 10 equal subplots which in turn were considered as 10 replications for data recording, collecting samples and subjected to statistical analysis. A gap of 4 m was left between 2 treatments and deep buffer channels were made with the help of a disc plough to avoid lateral flow of rainwater and nutrients from 1 treatment to another. A fertilizer dose of 80 kg N + 17.5 kg P + 25 kg K/ha was applied with half N, total P and K were applied basal, while, remaining half N in 3 equal splits at 30, 60 and 90 days after sowing (DAS). The N in the form of urea, P in single superphosphate and K in muriate of potash form were applied. Crop received rainfall of 685 mm over 47 rainy days in 2013, 419 mm over 33 days in 2014, 300 mm over 22 days in 2015 and 482 mm over 27 days in 2016. It was 21.3% excess in the first year, but deficit by 25.8% in the second year, 52.6% in the third year and 14% in the fourth year of experimentation. The experiment was conducted under rainfed conditions; however, life-saving irrigations (5 cm depth per irrigation) were given during 2014 (1 in August and 2 in November) and 2015 (2 in November) were given by ridge and furrow method to overcome moisture stress due to deficit rainfall.

The basic differences between 2 treatments include spraying by motorized power sprayer for management of insect-pest and diseases, tractor-drawn blade for interculture operations, harvested with secateurs and threshing with mechanical castor sheller among SMPs and knapsack sprayer, bullock-drawn blade, breaking with hand and beating with wooden sticks by manual labour in CPs. Though we tried sowing with the help of seed-cum-ferti-drill in mechanization method, it could not be successful due to few inherent site problems, and hence, sowing was done manually by dibbling in both the treatments. A high-yielding fusarium-wilt resistant castor hybrid 'PCH 111' was used in all the years of experimentation which had a potential yield of 1.4–1.6 and 3.4–3.8 t/ha under optimum growing conditions during the monsoon and post-monsoon seasons respectively. The sowing was done in the second week of July every year. However, recommended spacing is 90 cm × 60 cm in the region but we used 120 cm × 45 cm spacing without affecting the plant population (18,518 plants/ha) to ease mechanized operations in the inter-row space. All the other best-management practices and need-based plant-protection measures were strictly followed to ensure successful crop growth. A total of 3 pickings were taken at monthly intervals, starting from the first week of November up to the end of January during all the years and seed yield from all the pickings was pooled for arriving at the final seed yield. The oil content of castor seed samples was determined using the NMR facility at

the ICAR-Indian Institute of Oilseeds Research, Hyderabad, India. The oil yield was computed as a function of oil content and castor seed yield.

The infiltration rate from both the treatments was determined by using double ring infiltrometer. Rain water-use efficiency (RWUE) was calculated by dividing the seed yield with the amount of rainfall received during effective castor crop-growing period. However, the amount of irrigation water supplied to the crop in the form of life saving irrigation i.e., 150 mm during 2014 and 100 mm during 2015 was also considered, while calculating WUE for the respective years.

Energy equivalents for various renewable energy which includes seeds, yield, man and woman labour, irrigation water, while non-renewable energy which includes electricity, fertilizers, petrol/ diesel, machinery and chemicals were considered while calculating total input and output energy (Singh *et al.*, 2008; Devasenapathy *et al.*, 2009; Rafiee *et al.*, 2010; Lal *et al.*, 2015). Furthermore, the total labour and time requirement was calculated by summing up the requirements for each operation. Various energy indices were estimated using the following formulae as described and used by Rafiee *et al.* (2010).

Net energy gain = Energy output (MJ/ha) – Energy input (MJ/ha)

Energy ratio (energy-use efficiency) = Energy output (MJ/ha)/Energy input (MJ/ha)

Energy productivity = Castor seed yield (kg/ha)/Energy input (MJ/ha)

Specific energy (energy intensity) = Energy input (MJ/ha)/Castor seed yield (kg/ha)

Two-way factorial ANOVA was performed and pooled data were presented to understand the effect of method on the performance of castor and the treatments were compared using critical difference ( $CD=P<0.05$ ).

## RESULTS AND DISCUSSION

### Growth, productive traits and economic yield of castor

The performance of castor was significantly influenced

by conventional practices (CPs) and selective mechanization practices (SMPs). Though both the practices performed equally with regard to plant height, number of nodes up to primary raceme, number of branches/plant and 100-seed weight, SMPs resulted in significantly more number of total and effective spikes/plant and total and effective spike length over CPs (Table 1). Based on the pooled data, adoption of SMPs (1.49 t/ha) resulted in 13.2% higher seed yield over that of conventional practices (1.32 t/ha) (Table 1).

Though oil content was not significantly affected, the oil yield followed the similar trend of seed yield of castor (Table 1). The better performance of castor crop owing to SMPs over CPs could be because of mechanical interculture operations led to moisture conservation and uniform timely inputs application resulted better growth of plants. In case of SMP plot, the soil got well pulverized owing to interculture operations with tractor-drawn twin-blade implement which has gone nearly 15 cm deep into the soil, uprooted and exposed the weeds to the hot sun or incorporated *in-situ* which inturn might have added some organic matter too. This resulted in efficient weed control, earthing up, better aeration and conservation of soil moisture thus better root proliferation and yield. In the case of CP plot, bullock-drawn single blade, though disturbed the upper layer of 5.0–7.5 cm soil, uprooted the weeds partially, resulting in less weed control, minimum pulverisation of soil, less infiltration thus less soil-moisture conservation. Manual hand-weeding was uneconomical as compared to interculture operations with bullock-drawn blade, but mechanical interculture was beneficial and economical than the former practice. However, most importantly during a dryspell period, care must be taken to run the tractor-drawn interculture implements to a shallow depth, otherwise, this could lead to a loss of inherent soil moisture.

### Infiltration rate

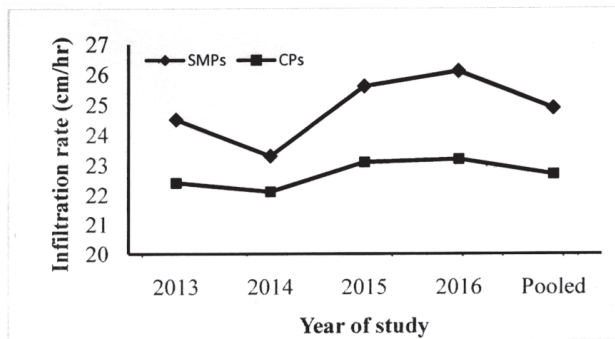
Studies on infiltration rate are important for understand-

**Table 1.** Effect of selective mechanization practices (SMPs) and conventional practices (CPs) on growth and productive traits of castor under rainfed conditions (pooled data of 4 years)

Method	Plant height (cm)	Branches/ plant	Nodes up to primary spikes/plant	Spikes/ plant	Effective spikes/ plant	Total spike length (cm)	Effective spike length (cm)	100-seed weight (g)	Seed yield (t/ha)	Oil content (%)	Oil yield (t/ha)
SMPs	57.3	3.9	11.0	6.1	4.1	49.0	44.0	30.9	1.23	46.4	0.69
CPs	63.5	3.9	11.2	5.2	3.2	44.1	37.2	29.6	1.12	46.2	0.61
Mean	60.4	3.9	11.1	5.7	3.7	46.6	40.6	30.3	1.18	46.3	0.65
SEm±	0.9	0.1	0.2	0.1	0.1	1.0	0.9	0.2	0.02	2.1	0.04
CD (P=0.05)	2.7	NS	NS	0.4	0.3	2.9	2.6	NS	0.06	NS	NS

NS, Non-significant

ing problems like runoff, soil-moisture budgeting, irrigation scheduling, flooding, soil erosion and degree of pulverization. It is generally low in Alfisols, especially in semi-arid regions, as their non-stable and low soil structural stability encourages surface crust formation (Rao *et al.*, 1998), thus, crops often face moisture stress, and hence, proper agronomic interventions are required to reverse the situation. In the present study, the infiltration rate was higher in castor field with SMPs which led to better seed yield than that of CPs, irrespective of the year (Fig. 1). The main reason for this could be a possible break of hard pan, better pulverization and creation of loose soil due to mechanical interculture, which might have facilitated better infiltration thus storage of more moisture in the soil profile. Further, the values were higher in deficit-rainfall years, irrespective of the treatments, which could be due to the absorption of more moisture due to the dryness of the soil.



**Fig. 1.** Changes in infiltration rate due to selective mechanization practices (SMP) and conventional practices (CPs) in castor

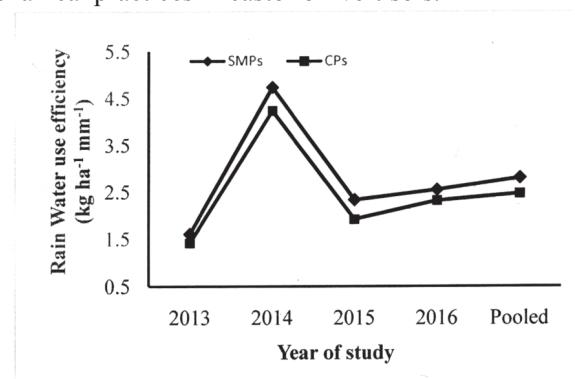
### Rain water-use efficiency

Rain water-use efficiency (RWUE) was significantly higher (2.81 kg/ha-mm) with SMPs than that of CPs (2.47 kg/ha-mm) (Fig. 2). This was mainly owing to the significantly higher seed yield obtained with SMPs.

### Operation-wise time and labour savings

Critical analysis of the data in Table 2 indicated that ir-

respective of the practices, 26–29% of the total time was incurred mainly in harvesting and threshing, followed by 22–32% time for weed management and 16–21% for fertilizer management. Similarly, 23–28% man-days were required for harvesting and threshing followed by 21–23% for fertilizer and 20–22% for weed management. Selective mechanization practices (SMPs) consumed only 116 man-days and 175 hours, whereas CPs incurred 139 man-days and 230 hours/ha, indicating saving of 23 man-days and 54 hours/ha with SMPs. The labour and time economized SMPs could be utilized in other farm activities by the farmers. Earlier, Naik *et al.* (2016) reported a total saving of 490 hr and 58 man-days/ha owing to the adoption of mechanical practices in castor on Vertisols.



**Fig. 2.** Changes in RWUE due to selective mechanization practices (SMP) and conventional practices (CPs) in castor

On an average, 6.8 labour and 35 hours time/ha could be economized because of mechanical intercultivation (SMPs) as compared to that of CPs. The saving in terms of labour is not high as expected which might be due to less weed menace in the experimental years (2014–16) which was in turn could be due to low rainfall.

Conventionally, castor growers are spraying plant-protection chemicals with the help of hand-operated knapsack sprayer which requires 7.5 to 8.0 hours/ha. The introduction of petrol-operated power sprayer as a part of the mechanization package could save 9.4 hours/ha in the cur-

**Table 2.** Effect of selective mechanization practices (SMPs) and conventional practices (CPs) on growth and productive traits of castor under rainfed conditions (Average data of four years)

Method	Time period (hours/ha)		Man-days (Nos./ha)	
	SMPs	CPs	SMPs	CPs
Land preparation and preparation of seed-bed	13.8	13.8	7.5	7.5
Seed, sowing, thinning, gap-filling and seed treatment	25.0	25.0	7.5	7.5
Manure and fertilizer management	37.5	37.5	26.9	30.0
Weed management and inter-cultivation	40.0	75.0	23.8	30.6
Irrigation	4.4	4.4	5.0	5.0
Plant protection	4.7	14.1	18.8	18.8
Harvesting, threshing and marketing	50.0	60.0	26.9	39.4
Total	175.3	229.7	116.3	138.8

rent experiment. In castor, seed/kernel/bean is the economic part that can be obtained by shelling the 3 locule capsules/fruit which are formed on primary/secondary/tertiary spikes. In general, the harvested spikes are sun-dried for about a week, depending on the seed-moisture content and sunlight and then subjected to threshing. Conventionally, harvesting of spikes is done by breaking with hand and threshed using wooden sticks by castor growers. In this process, 15% of the total yield is lost (Sanglikar *et al.*, 2017) in the field. Manual harvesting is laborious. Moreover, lack of availability during peak season and low efficiency of the labour lead to less yield. Further, harvesting of spikes during the post-noon is difficult, as spines on the fully dried capsules damage the palms of workers. Hence we introduced secateurs which could help in easy and safe harvesting and bagging without loss of yield. This also reduced the time by 30%.

Manual shelling by beating with wooden mallets or sticks is laborious, time-consuming and costly, as it accounts for 20–30% of production cost. Further, it causes strain and fatigue in workers, deteriorates the quality and affects the storage period of seed. Hence, we have introduced a mechanical castor sheller fitted with a 6 HP electric motor with a decorticating capacity of 0.6 t/hour. On an average, 10 hr (16.7%) and 12.5 man-days/ha (31.7%) could be saved due to mechanized harvesting and threshing (Table 2). The ICAR-Central Research Institute for Dryland Agriculture, Hyderabad, India also developed a power-operated castor sheller with 3 HP electric motor and an output of 0.7 t/hour and reported 25% yield improvement and returns over investment by 6,670/ha owing to selective mechanization in rainfed castor (Reddy *et al.*, 2015). However, some researchers felt that use of large power-operated shellers is economical only on large farms, hence, these machines have to be modified to suit to small castor farms to make them economical for small and marginal farmers in developing countries. Sanglikar *et al.* (2017) designed a pedal-operated light-weight castor

sheller with a shelling capacity of 49.3 kg capsules and 29 kg kernels/hour and low-operational cost (69.78/100 kg seeds) and was found suitable for small and medium farmers. Similarly, Razzazi *et al.* (2017) used a peeling machine with a capacity of 50 kg seed/hour and power consumption of 493 watts/hour in Iran. Further, Mrunalini (2015) who worked on ergonomic evaluation reported 33% saving in time and 50% more production per unit time, besides decline in average working heartbeat, physiological and muscular stress owing to use of manually hand-operated multipurpose castor sheller over conventional method.

#### Economics of castor production

Adoption of SMPs incurred total cost of ₹23,945/ha which resulted in gross returns of ₹52,145/ha with net returns of ₹28,200/ha and benefit: cost (B:C) ratio of 2.18. It was mainly because of reduction in the cost by ₹3,375/ha and increase in gross returns by ₹6,073/ha with net returns of ₹9,448/ha besides higher B : C ratio over CPs (Table 3). Reduction in the cost of production was mainly owing to saving of 23 man-days with SMPs (Table 2). In a similar way, SMPs helped to reduce the cost by ₹5,341/ha and increased net returns by ₹17,783/ha because of a 17.6% improvement in seed yield of castor (Naik *et al.*, 2016) and ₹6,670/ha higher net income (Reddy *et al.*, 2015) over traditional castor-farming practices in South India.

#### Energy budgeting

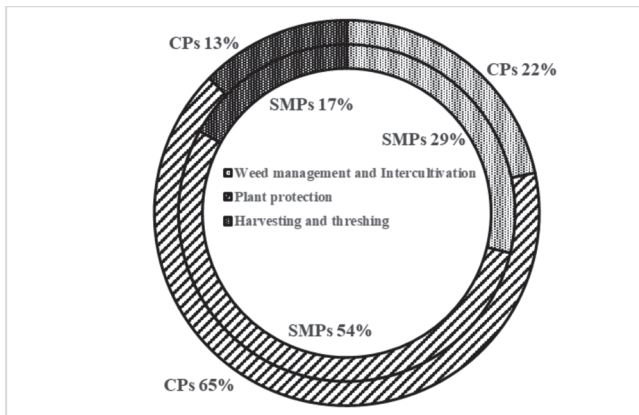
Among agronomic operations, the highest energy was used in plant-protection operations (SMPs: 683 and CPs: 419 MJ/ha) followed by weed management and interculture (363 and 138 MJ/ha) and the lowest energy for harvesting and threshing (213 and 81 MJ/ha) irrespective of year of study and practices (Fig. 3). But, SMPs were far superior to CPs. Energy output, net energy gain, energy ratio and energy productivity were significantly higher with SMPs as compared to that of CPs (Table 3). However, re-

**Table 3.** Effect of selective mechanization practices (SMPs) and conventional practices (CPs) on economics and energy budgeting in castor under rainfed conditions (Pooled data of four years)

Method	Total cost (× 10 <sup>3</sup> ₹/ha)	Net returns (× 10 <sup>3</sup> ₹/ha)	Benefit: cost ratio	Energy input (× 10 <sup>3</sup> MJ/ha)	Energy output (× 10 <sup>3</sup> MJ/ha)	Net energy gain (× 10 <sup>3</sup> MJ/ha)	Energy ratio	Energy productivity (kg/MJ)	Specific energy (MJ/kg)
SMPs	23.4	28.2	2.18	10.14	21.90	11.76	2.15	0.15	6.81
CPs	26.0	18.8	1.69	9.52	19.35	9.83	2.02	0.14	7.23
Mean	24.7	23.5	1.94	9.83	20.63	10.80	2.09	0.15	7.02
SEm ±					0.27	0.27	0.03	0.002	0.008
CD (P=0.05)					0.84	0.84	0.09	0.006	0.240

Market rate for castor seed: Rs. 35000/t

SMPs: Selective mechanization practices; CPs: Conventional practices



**Fig. 3.** Percentage of energy of various operations under selective mechanization practices (SMP) and conventional practices (CPs) in castor (average of 4 years)

verse was true in case of specific energy as SMPs recorded less value (6.81 MJ/kg) and CPs higher value (7.23 MJ/kg). It means less energy was used for producing a kilogram seed under SMPs (Table 3).

Thus, selective mechanization could be a better option in rainfed castor, as it required less labour and time but more intensive, effective input application, higher rain water-use efficiency and more moisture conservation in the root zone resulting in higher productivity and profitability over conventional practices. Further analysis also indicated that adoption selective mechanization practices enhanced net energy returns, energy ratio and energy productivity as compared to conventional practices.

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