EFFECT OF DIFFERENT TILLAGE PRACTISES ON CASTOR (*RICINUS COMMUNIS* L.) CULTIVATION IN LEGUME-BASED INTERCROPPING SYSTEM

VEERAMANI, P.* – RAVICHANDRAN, V. – SARAVANAN, P. A. – MANICKAM, S. – VENKATACHALAM, S. R. – ARUTCHENTHIL, P. – VELMURUGAN, M.

Tapioca and Castor Research Station, Tamil Nadu Agricultural University, Yethapur 636119, Tamil Nadu, India

**Corresponding author*
e-mail: veeramani.p@tnau.ac.in; phone: +91-98-9426-6355

(Received 26th Jul 2023; accepted 9th Feb 2024)

Abstract. A drought-resistant plant with high adaptability to various climatic and soil conditions is castor (*Ricinus communis* L.). There is currently a significant expectation of increased castor oil demand on the global market. When it comes to crop development, there are a variety of factors to take into account for each growing region, especially when it is preferable to fit the castor crop to specific tillage practices and intercropping system. In this veneration, the current study's goal was to determine the effects of various tillage methods and legume crop-based intercropping system in rainfed regions. The field experiments were conducted in 2021-2022 and 2022-2023 at Tapioca and Castor Research Station, Tamil Nadu Agricultural University, Yethapur. The experimental treatments consisted of conventional tillage and minimum tillage as main plot and castor based inter cropping system @ 1:3 ratio *viz.*, Castor + Greengram, Castor + Cowpea, Castor + Groundnut and Sole Castor as subplot treatments and conducted in split plot design with three replications. The pooled results of a two-year study of different tillage practices in legume crop based intercropping systems in rainfed conditions showed no significant difference among tillage practices relevant to growth, yield attributing characters, seed yield and biomass yield, however higher values were registered under conventional tillage practices over minimum tillage. Higher seed yield of both base (1152 kg ha^{-1}) and inter crop (481 kg ha^{-1}) were documented in conventional tillage practices over minimum tillage. With respect to inter cropping, higher base crop (castor) yield of 1058 kg ha^{-1} was recorded under castor + groundnut inter cropping system, which was observed to be on par with sole castor (1020 kg ha^{-1}), and castor + greengram (907 kg ha^{-1}). Recorded highest Castor equivalent yield in castor + groundnut (1:3) intercropping, grown under a conventional tillage system. Moreover, the maximum benefit-cost ratio was recorded in castor + groundnut (1:3) intercropping, over sole castor cropping. The highest Castor Equivalent Yield (CEY) in a conventional tillage system was observed in a castor + groundnut (1:3) intercropping system.
Keywords: *intercrop, legume, no tillage, castor, groundnut*

Introduction

Castor, a tropical plant in the *Euphorbiaceae* family, is used as a non-edible oil seed crop all over the world. Through the export of oil and its derivatives, India makes roughly 2500 crores in foreign exchange each year (Ramanjaneyulu, 2014). However, compared to other field crops, castor is a long-lasting, widely spaced crop with a relatively low plant population, which offers plenty of space for growing intercrop to boost productivity from a given piece of land. Climate change is also a growing threat, largely due to its negative impacts on agricultural production and global food security (Wheeler and Von Braun, 2013). Different regions of the world have recorded an increase in yearly average surface temperature of about 0.5°C during the past 50 to 100 years (IPCC, 2014). Furthermore, climate modification affects the capability of environments to meritoriously capture carbon and maintain the equilibrium in the

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2202_11391148

nitrogen cycle (Fu et al., 2020). Maintaining output while preserving soil quality is a significant challenge for modern agriculture. Lowering tillage frequency and intensity is a method used to improve soil quality. However, reducing tillage has obvious drawbacks, such as encouraging the growth of undesirable weeds that can reduce crop output. There is no agreement on whether practices that minimize or stop (i.e., no tillage) tillage are a viable alternative to traditional agricultural practices because they have only lately been adopted in agriculture. In addition, there are clear advantages to reduced tillage in terms of reducing soil erosion and encouraging a more active microbial community in soil where symbiotic organisms predominate. There is evidence that conservation tillage (reduced tillage and no tillage) increases yields (Naab et al., 2017) and reduces soil degradation in conserved tillage practices, as well as the addition of plant waste to soil is one mechanism supporting the positive effects of these practices on soil health, soil organic carbon and yield. Cutting intercrops and putting them into the soil before planting the target crop has been suggested as a method to increase yields and soil health because of their high nitrogen and phosphorus content (Nziguheba et al., 2000).

The fundamental idea behind intercropping systems is to grow two or more crops together, with the idea being that two crops can utilize the environment more effectively than one, leading to higher yields. This is because the component crops each use different amounts of resources, and by growing together, they complement one another and make better use of resources as a whole. This practice has some benefits, including the efficient use of land, insurance against extreme weather, larger yields and greater financial gains, the improvement or preservation of soil fertility, and the diversification of farm products. Because it reduces inter- or intra-specific competition and offers a significant yield gain over a single crop, intercropping.

Due to its significance, much study had already been conducted on various tillage techniques and intercropping systems, but it was still necessary to identify the most effective ones for sustaining castor crop output and soil reserves. The goal of this study was to identify the best tillage techniques and intercrops for the cultivation of castor crops. Therefore, the purpose of this experiment was to compare the crop production and financial viability of castor crop under rainfed circumstances using various tillage strategies and intercropping systems based on legumes.

Materials and methods

Experimental area

The field tests were carried out in 2021–2022, and 2022–2023, at the Tapioca and Castor Research Station (TCRS) farm, Tamil Nadu Agricultural University, Yethapur (11.66° N, 78.47° E), Tamil Nadu, and India. The testing site was located at an altitude of roughly 278 m above sea level. The test site was situated in an arid plain region that was fed by rainfall. A TCRS, Yethapur, was erected 200 m away from the experimental site, and it collected meteorological data for the course of the experiment. During the study period, seasonal rainfall (June-January) averaged 968 mm. During the trial period, the average annual maximum and lowest temperatures were 35°C and 21°C, respectively. Prior to the field-testing, soil samples were taken from each corresponding experimental unit at depths ranging from 0 to 15 cm, and they were carefully analyzed to ascertain the various physicochemical characteristics of the soil profile. The experimental field’s soil type was non-

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
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calcareous red soil, and according to the experimental site two-year average available nutrient status, it had high levels of P and K (26.0 kg ha^{-1} and 293 kg ha^{-1}) Available P, Low: < 11.0 kg ha^{-1}, Medium: 11–22 kg ha^{-1}, High: > 22 kg ha^{-1} and Available K, Low: < 110 kg ha^{-1}, Medium:110-280 kg ha^{-1}, High: > 280 kg ha^{-1} and low levels of N (216 kg ha^{-1}), Available N, Low: < 240 kg ha^{-1}, Medium: 240- 480 kg ha^{-1} and High: > 480 kg ha^{-1}. The soil had a low organic carbon content (0.23 percent), a pH of 7.01, and an EC of 0.37.

Experimental details

The trials were carried out using a split-plot design with three replications, a net plot measuring 12 m x 6 m, with plant rows spaced 1.2 m apart and 0.9 m apart. The plots each had a surface area of 72 m2, and there was a 0.5 m gap between them. The experiment used three replications (24 experimental units), two tillage systems (conventional tillage and minimal tillage), three legume intercrop patterns (castor + greengram, castor + cowpea, castor + groundnut, and sole castor). As test subjects, the cultivars of castor hybrid ICH 66, greengram CO 8, cowpea VBN 4, and groundnut VRI 8 were used. The sowing and harvesting dates were respectively in July and December every year for all crops, except for intercrops, which had a short growing period and were harvested in September of each year. Intercrops seeds were sown in rows at the recommended spacing of 30 cm between rows and 10 cm within rows. The arrangement of intercropping was 3:1 (one row of castor alternated by three rows of intercrop). Two seeds were sown per hill and later reduced to one per hill; gapping occurred ten days after emergence. In the two years preceding the current field experiment, minimum tillage plots were tilled twice with a cross plough, twice with a cultivator, and once with a planking (no disc plough). To prepare the experimental plots for the conventional tillage system, the disc plough was used for one deep tillage, two cultivator ploughings, and one planking followed by suitable planking to incorporate the intercrop residues into the soil.

The suggested fertilizer dosage of 90:45:45 NPK kg ha^{-1} was adhered to; a full dose of phosphorus and 50% of the N and K were applied as a basal at the time of sowing, and the remaining N and K were applied in two equal splits at 30 and 60 days later. The fertilizer supplies were urea, di-ammonium phosphate (DAP), and muriate of potash (MOP). Five plants were picked at random from the net plot area and marked with tags. 90 and 135 day after sowing (DAS) phases, respectively, of growth were used to record biometric observations. The produce from the net plot area was weighed after being fully sun-dried to calculate the biological yield. Following threshing and winnowing, the weight of seed from main and intercrop crops was measured in kg $plot^{-1}$ and then converted to kg ha^{-1} for each net plot area. By deducting the biological yield from the stalk/straw yield, the stalk/straw yield (kg ha^{-1}) was calculated. Based on the total number of each distinct weed species per square meter, weed density was estimated. Using weed data, weed control efficiency was calculated as follows according to the conventional procedure:

$$WCE\ (\%) = \frac{DW_C - DW_T}{DW_C} \times 100$$

where DW_T, dry weight of weeds in treated plot; DW_C, dry weight of weeds in unweeded control plot.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
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Statistical analysis

The outcomes from the experiment were examined statistically as advised by Gomez and Gomez (1984). The cost economics of nerium was worked out for an area of one hectare (10,000 m^2) and expressed in USD. The ratio of gross income and gross cost is computed and expressed as BC ratio. In cases where there were significant treatment differences, the F test and crucial differences were calculated at the 5% level of probability, and values were calculated.

Measurements and analytical procedures

Five randomly selected groundnut, cowpea, and green gramme plants in each experimental unit had their pods counted and the mean number of pods per plant was calculated. Each experimental unit's green gramme, cowpea, and groundnut were picked and dried in the sun. Green gramme, cowpea, and groundnut harvest plants were threshed after being sun-dried, and the formula below was used to determine and convert the seed yield of each experimental unit into seed yield (kg ha^{-1}).

$$\text{Seed yield (kg ha}^{-1}) = \frac{\text{Seed yield (kg plot}^{-1})}{\text{Net plot area (m}^2)} \times 10{,}000\ \text{m}^2$$

To calculate the biomass, mature plants from a plot were gathered. The collected samples were sun-dried until the weight remained constant. The sample dry weights were then converted to biomass (kg ha^{-1}) using the conversion factor.

$$\text{Harvest index (\%)} = \frac{\text{Seed yield (kg ha}^{-1})}{\text{Biological yield (kg ha}^{-1})} \times 10{,}000\ \text{m}^2$$

On the basis of current market pricing (Rs kg^{-1}), the castor equivalent yield (CEY) was computed in terms of the castor yield of all intercropping regimes. The formula proposed by Lal and Ray (1976) was used to compute it.

$$\text{CEY (kg ha}^{-1}) = \frac{\text{Seed yield of intercrops (kg ha}^{-1}) \times \text{Price of intercrop (Rs kg}^{-1})}{\text{Price of castor (Rs kg}^{-1}) + \text{Seed yield of castor (kg ha}^{-1})}$$

Results and discussion

Phenological attributes

Figures 1 and *2* depict the effects of tillage practices on phenological traits such as No. of productive branches per plant, the length of the primary spike (cm), the number of productive spikes and pods per plant, and the number of capsules per spike. However, the effects of legume intercrops were significant for the number of productive branches/plant, length of the primary spike (cm), number of productive spikes and pods/plant, and number of capsules/spike. The interaction of the tillage practices and legume intercropping had no significant effect on these traits. The castor crop grown under CT, with legume residue incorporated, took more productive branches per plant (18.2), length of primary spike (68.2 cm), number of productive spikes (10.0), and capsules per spike (92.6) compared to MT.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
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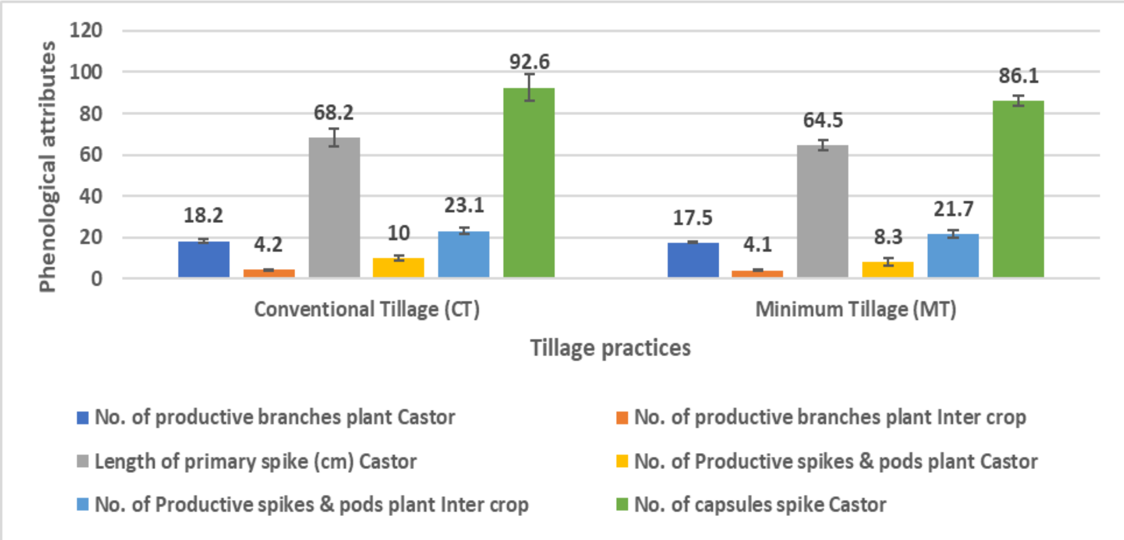

Figure 1. *Phenological attributes of castor-based tillage practices*

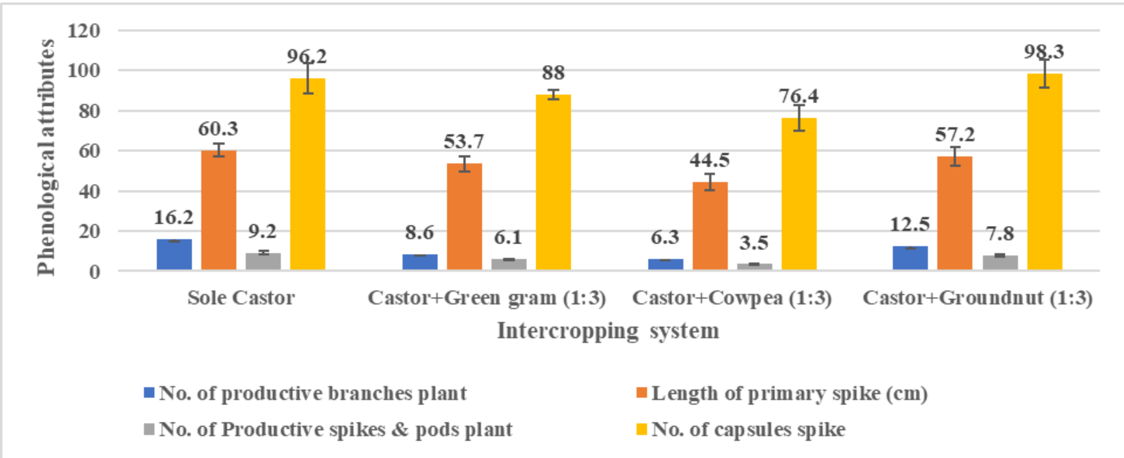

Figure 2. *Phenological attributes of castor based inter cropping system*

Yield and yield-related attributes of the castor crop

The results based on pooled data showed that the tillage practices did not show any significant effect on number of productive branches plant^{-1}, Length of primary spike (cm), number of productive spikes and pods plant^{-1} and number of capsules spike^{-1}. In castor numerically higher value of yield was found in conventional tillage. Highest castor seed yield and biomass yield were significantly highest with sole castor followed by castor + groundnut (1:3) and castor + greengram (1:3). This might be because solitary castor experiences less inter-row rivalry and makes better use of resources like water, nutrients, space, and sunlight, which leads to more spikes and capsules per plant and exhibits a positive link with seed yield. These results are very similar to those of Kumar et al. (2011) and Kumavat et al. (2016). Substantial yield reduction was noticed in castor + cowpea inter cropping system (837 kg ha^{-1}) due to severe competition between castor and cowpea particularly for space and nutrients which resulted in lower plant height of castor and reduction in No. of productive branches plant^{-1}. Chand and

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Sujatha (2000) reported similar result that castor + sesame intercropping recorded lower seed yield. Regarding biomass yield, higher biomass addition through inter crop was recorded in castor + groundnut inter cropping system (8083 kg ha^{-1}) which was followed by solo castor (7742 kg ha^{-1}). The lowest biomass addition of 6350 kg/ha was recorded under castor + greengram inter cropping. Legume crops may be a better alternative because of the advantageous impact of fixing atmospheric nitrogen; as a result, additional nitrogen may have become available for castor to use more effectively after 90 DAS before harvest.

Castor equivalent yield (CEY)

The combined data (*Table 2*) showed that while there was a noticeable decrease in the seed yield of the base crop and intercrops in the various intercropping treatments, there was a higher recovery in the seed yield in treatments like castor + groundnut (1:3) and castor + greengram (1:3), which resulted in a higher castor equivalent yield than sole castor. Castor equivalent yield was significantly greater in castor + groundnut (1:3) and castor + greengram (1:3) than in single castor in intercropping systems, which may be because groundnut and greengram yields were higher and castor seed yields were not reduced as much in these intercropping systems. Sharma and Singh (2014) and Dhimmar (2009) reported similar findings. The higher equivalent yield under intercropping than solitary cropping demonstrated increased biomass production and efficient utilization of the growth resources available (Azevedo et al., 1997). The productivity of crops in intercropping systems and their corresponding market pricing were two additional factors contributing to the distinct behavior in crop equivalent yield. When castor and groundnut were intercropped earlier (Ganvir et al., 2004), a similar tendency was seen.

Weed flora and weed control efficiency

The predominant weed flora observed in the experimental site were grassy weeds viz., Dactyloctenium aegyptium, Brachiaria reptans, Chloris barbata, Cynodon dactylon Sedges such as Cyperus rotundus, Fimbristylis argentea and broad-leaved weeds viz., Boerhaavia diffusa, Borreria hispida, Commelina benghalensis, Cassia nigricans and Croton sparsiflorus. During different stages of crop growth weed density and dry weight were numerically higher under minimum tillage operation with sole castor cropping system. Though, there was statistically no significant difference among the main plot treatments (*Table 1*), the highest weed control efficiency of 71.4 and 44.7% was recorded in castor + cowpea at 30 and 60 DAS, respectively which was followed by castor + groundnut (63.5 & 40.4 per cent). This may be because there is more competition for growth resources due to an increase in total population per unit area, which limits the development of growth and yield qualities. This result and that of Kathmale et al. (2014) were connected. With an effective land use strategy, intercropping increased productivity over solitary cropping while also effectively utilizing growth resources and suppressing weeds (Azevedo et al., 1997). The intercropping’s spreading canopy coverage prevented the weeds from growing. The early establishment on the ground surface, which caused weeds to level out, may be to blame for the lowest weed DMP. Effective weed management may be due to agricultural competition and the increased population per unit area. According to Rajesh et al. (2014), intercropping significantly reduces the dry weight of weeds.

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Table 1. *Influence of tillage practices and intercropping on weed density, weed dry weight and weed control efficiency of legume-based castor inter cropping system (pooled mean of 2 years)*

Treatment	Weed density m²		Weed dry weight g m²		Weed Control Efficiency (%)	
	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS
Main plot: tillage practice						
M_1. Conventional Tillage	*5.24 (27.5)^a	3.49 (12.0)^a	34.43^a	20.2^a	63.0^a	40.1^a
M_2. Minimum Tillage	5.51 (30.5)^a	3.74 (13.83)^a	36.16^a	21.5^a	62.3^a	36.9^a
S.Em. ±	0.25	0.17	1.66	0.93	3.19	1.97
CD (p = 0.05)	NS	NS	NS	NS	NS	NS
Sub plot: intercropping						
S_1. Sole Castor	6.66 (43.9)^a	4.47 (19.5)^a	74.45^a	29.29^a	-	-
S_2. Castor + Green gram (1:3)	5.34 (28.0)^a	3.80 (14.0)^a	34.95^b	20.40^b	53.1^a	30.4^b
S_3. Castor + Cowpea (1:3)	4.61 (20.8)^b	3.11 (9.16)^b	21.30^c	16.20^c	71.4^a	44.7^a
S_4. Castor + Groundnut (1:3)	4.88 (23.3)^b	3.08 (9.0)^b	27.20^c	17.45^c	63.5^a	40.4^a
S.Em. ±	0.34	0.23	2.72	1.33	3.49	2.17
CD (p = 0.05)	1.00	0.68	8.00	3.92	10.28	6.40
Interaction (M at S)						
S.Em. ±	0.50	0.33	3.76	7.90	5.40	3.36
CD (p = 0.05)	1.46	0.98	11.07	5.60	15.9	9.90

Data subjected to $\sqrt{(x + 0.5)}$ transformation and figure in parenthesis are original value

Yield and yield-related attributes of leguminous intercrops

Table 2 displays the findings, which include the number of pods per plant, seed output, biological yield, and harvest index of legume intercrops. The main impact of tillage techniques and legume intercropping on them was significant. Under the groundnut intercropping method, CT outperformed MT in terms of number of pods per plant (35.2), seed production (975 kg ha^{-1}), biological yield (5023 kg ha^{-1}), and harvest index (18%). The intercropping of legume intercrops with tillage techniques, however, was found to be non-significant for these features. Groundnut intercropped with castor exhibited the highest pods per plant, seed output, biological, and harvest indices of all the intercropped crops.

The results about soil health indicators, i.e., pH, soil organic matter (SOM), and soil available N, P, and K, were significantly influenced by different tillage systems and intercrops. CT improved SOM (0.31%), soil available N (252.1 kg ha^{-1}), P (11.1 kg ha^{-1}) and K (387.6 kg ha^{-1}) all of which were measured. Similarly, the inclusion of intercrops improved SOM and soil availability of N, P, and K. The highest SOM (0.32%), soil available N (267.1 kg ha^{-1}), P (13.2 kg ha^{-1}), and K (361.7 kg ha^{-1}) were recorded in the groundnut intercropping systems (Paslawar et al., 2007). The pH of the soil was 6.90, which was a little lower than the soil's initial pH of 7.01. Castor and groundnut had the lowest soil pH under CT. It can be as a result of the biomass mulch addition. According to Rao and Janwade (2009), the application of FYM, crop wastes, and green manure resulted in a small drop in pH and EC.

There remained no significant difference among the main and sub plot treatment on oil content (*Table 2*). With respect to oil yield, though main plot treatment did not show any important influence on oil yield, numerically higher oil yield was noticed under conventional tillage (526 kg ha^{-1}). With respect to sub plot treatments, castor + groundnut recorded significantly higher oil yield of 463 kg/ha which was on par with

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
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sole castor (436 kg ha^{-1}) and castor + greengram (381 kg ha^{-1}). Agarwal (2005), who noted that among the several intercropping systems, the one based on legumes yielded the highest amount of oil, made similar findings.

Table 2. *Influence of tillage practices and intercropping on yield attributes and yield of castor based inter cropping system (pooled mean of 2 years)*

Treatment	Seed/pod yield (kg ha^{-1})		Biomass yield (kg ha^{-1})		CEY (kg ha^{-1})	Oil yield (kg ha^{-1})	Gross returns (USD ha^{-1})	Net returns (USD ha^{-1})	BCR
	Castor	Intercrops	Castor	Intercrops					
Main plot: tillage practice									
M_1. Conventional tillage	1152^a	481^a	8951^a	3620^a	1633^a	526^a	746.4	392.5	2.10
M_2. Minimum tillage	1013^b	436^a	8463^a	3391^a	1449^a	472^a	656.3	329.5	2.00
S.Em. ±	51.5	31.1	316	320	89.2	25.3	-	-	-
CD (p = 0.05)	110.7	NS	NS	NS	NS	NS	-	-	-
Sub plot: intercropping									
S_1. Sole castor	1089^a	-	7742^a	-	1089^d	436^a	705.6	383.5	2.19
S_2. Castor + green gram (1:3)	916^c	447^c	7120^a	3420^c	1404^b	381^b	921.4	543.4	2.44
S_3. Castor + cowpea (1:3)	837^b	562^b	6350^b	4110^b	1399^c	350^b	920.2	533.9	2.38
S_4. Castor + groundnut (1:3)	1018^a	975^a	8083^a	5023^a	1993^a	463^a	1315.1	819.5	2.65
S.Em. ±	56.2	30.1	392	310	110.4	21.1	-	-	-
CD (p = 0.05)	181	93.0	908	968	118.7	52.6	-	-	-
Interaction (M at S)									
S.Em. ±	103.0	60.1	496.1	452.7	196.1	47.2	-	-	-
CD (p = 0.05)	198.2	117.4	768.9	704.1	402.1	91.0	-	-	-

$1 USD = ₹81.80 as on 24.07.2023
CEY: castor equivalent yield

Conclusion

The results of a two-year study on different tillage practices in castor-based legume intercropping systems in a rainfed region show that conventional soil tillage outperforms minimum tillage. With greater net returns of USD 1513 ha^{-1} and a benefit cost ratio of 2.65, intercropping castor + groundnut at a 1:3 row ratio was clearly superior than solitary castor and proved to be more lucrative. Under single castor, the lowest net returns were obtained at USD 705.6 ha^{-1} and a benefit cost ratio of 2.19. The physical, chemical, and biological qualities of the soil can be greatly enhanced by planting groundnut intercrops with minimal tillage. It consequently leads to an improvement in soil quality and an increase in production.

Acknowledgments. This project study was supported by all researchers and funding from All India Coordinated Research Project, IIOR, Hyderabad.

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