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# Agro-economic Feasibility and Indices of Castor+Groundnut Intercropping System Under Irrigated Conditions During *Rabi* Season in Telangana

A. V. Ramanjaneyulu[1], K. Indudhar Reddy[2], M. V. Nagesh Kumar[3], A. Madhavi[4], M. Venkata Ramana[5], A. Srinivas[6] and G. Suresh[7]

[1]Agricultural Research Station, Tornala, Telangana (502 114), India
[2]Agroclimatic Research Center, [3]Maize Research Center, [4]AICRP on STCR scheme, [5]AICRP on Integrated Farming Systems, [6]Main Farm, ARI, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad, Telangana (500 030), India
[7]ICAR-Indian Institute of Oilseeds Research, Rajendranagar, Hyderabad, Telangana (500 030), India

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**Corresponding Author**

A. V. Ramanjaneyulu
*e-mail*: avr_agron@rediffmail.com

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***Data Availability Statement:*** Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

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## Abstract

An experiment was carried out for three consecutive years from 2014-15 to 2016-17 at Regional Agricultural Research Station (RARS), Palem, Professor Jayashankar Telangana State Agricultural University, Telangana, India to study and understand the agro-economic feasibility and various indices of castor+groundnut intercropping system under irrigated conditions during *rabi* season. There were six treatments viz., sole castor, sole groundnut, castor+groundnut (1:5) with RDF (recommended dose of fertilizer) to both the crops, castor+groundnut (1:7) with RDF to both the crops, castor+groundnut (1:5) with RDF to castor alone and castor+groundnut (1:7) with RDF to castor alone. The results indicated that sole groundnut with significantly higher castor equivalent yield (3960 kg ha$^{-1}$) gave a higher yield advantage by 12.5 to 25.8% over castor+groundnut intercropping and 102.5% over sole castor. Further, sole groundnut recorded higher water use efficiency (10.25 kg ha$^{-1}$ mm$^{-1}$) and net returns mm$^{-1}$ water used (₹ 243.65 mm$^{-1}$). The economics also indicated that sole groundnut was profitable in terms of gross (₹ 1,50,465 ha$^{-1}$) and net returns (₹ 94,150 ha$^{-1}$). However, higher benefit:cost ratio was observed with sole castor (2.76) followed by sole groundnut (2.67) and castor+groundnut intercropping (1:5) with RDF applied to both crops (2.57). Among various indices, the highest land equivalent ratio (1.13), area time equivalency ratio (1.00) and monetary advantage index (15072) were recorded with castor+groundnut (1:5) where RDF was applied to both the crops.

***Keywords:*** ATER, castor, groundnut, intercropping, LER, MAI, WUE

## 1. Introduction

Castor (*Ricinus communis* L.) is one of the most important oilseed crops in India. It's oil has diversified uses and plays a great role in country's economy due to earning of high foreign exchange. It is a commercial and non-edible oilseed crop (Anjani et al., 2018) having multifarious uses (Ramanjaneyulu et al., 2017). It's oil is known for its usage as lubricant in jet engines, manufacture of paints, varnishes, soaps, dyeing and preservation industry across the globe. Further, it is widely used in the production of unique fatty acid ricinoleic acid (Ombrello, 2009). Of late, it is also becoming popular as one of the biofuel crops for biodiesel production (Razzazi et al., 2015; Kumar et al., 2015). It is mostly grown

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under rainfed conditions during *kharif* season (June to September) in dry land tracts of South and Eastern India in general and in Telangana in particular. However, in view of incidence of *Botryotinia* gray mold, occurrence of frequent dry spells and less scope for life-saving irrigation due to meager water resources and consequent reduction in economic yields during *kharif* season in Telangana (Ramanjaneyulu et al., 2013), farmers are preferring to raise castor during *rabi* season (October to March) as an irrigated dry (ID) crop due to assured irrigation and higher yield thus better returns (Ramanjaneyulu et al., 2014). Further, groundnut is a popularly grown leguminous oilseed crop during *rabi* season in Telangana. It is a preferred source of edible oil due to monounsaturated fats which is good for heart patients. Groundnut is a rich source of protein, vitamin E, niacin, folate, protein, manganese and resveratrol flavonoid which provides numerous health benefits (Anonymous, 2021). Though both the crops are high-yielding and income fetching crops, flare-up of seasonal pests and diseases, fluctuations in irrigation water availability and market price are affecting their performance thereby economic loss to the growers. Furthermore, castor being a long duration (150-240 days) and wide-spaced (90-150 cm) indeterminate crop with sequential flowering and fruiting (Severino et al., 2012) and slow growth upto 45 days after sowing (Soratto et al., 2012), it offers an excellent opportunity for intercropping for efficient utilization of spatial and temporal variations. Groundnut can be a better choice for intercropping owing to its atmospheric nitrogen-fixing nature and completion of its life cycle before second picking of castor. This practice helps to improve soil fertility, diversification of farm produce, reduction in pest and disease incidence (Rao et al., 2012), better complementarity, minimal competition for natural resources (Natarajan and Willey, 1986). Besides, castor also acts a trap crop for the control of *Spodoptera litura,* a major pest on groundnut, thus this practice minimizes the cost of plant protection. Though several researchers reported higher productivity, resource use efficiency and economic returns in intercropping systems under rainfed conditions (Chaudhari et al., 2017), such studies are meager under irrigated conditions during *rabi* season. Hence, we thought of understanding the agro-economic feasibility and study competition and biological indices in castor+groundnut intercropping under irrigated conditions during *rabi* season in Telangana.

## 2. Materials and Methods

### *2.1. Characterization of experimental site and treatmental details*

A field experiment was carried to study productivity, profitability, suitability and various indices of castor+groundnut intercropping system under irrigated conditions during *rabi* season (October to March) in Telangana for three consecutive years from *rabi* 2014-15 to 2016-17 at Regional Agricultural Research Station, (RARS) of the Professor Jayashankar Telangana State Agricultural University, Palem, Nagarkurnool district, Telangana state, India. The soil of the experimental site was sandy loam in texture with a pH of 5.6, organic carbon of 0.38%, available N of 220 kg $ha^{-1}$, phosphorus of 28.5 kg $ha^{-1}$ and potash of 452 kg $ha^{-1}$. The trial was laid out with six treatments and four replications in a randomized block design (RBD). The treatments include $T_1$: Sole castor, $T_2$: Sole groundnut, $T_3$: Castor+groundnut (1:5) with RDF applied to both the crops, $T_4$: Castor+groundnut (1:7) with RDF applied to both the crops, $T_5$: Castor+groundnut (1:5) with RDF to castor alone and $T_6$: Castor+groundnut (1:7) with RDF to castor alone.

A high yielding, fusarium wilt resistant and double bloom castor hybrid PCH-111 and a high yielding groundnut variety K-6 were used as test cultivars in the field investigation. A fertilizer schedule of 80-40-30 kg N, $P_2O_5$, $K_2O$ $ha^{-1}$ was followed for sole castor where in half dose of nitrogen, a full dose of phosphorus and potash were applied as basal and the remaining half of the N dose was applied in three equal splits at 30, 60 and 90 DAS (days after sowing). While, sole groundnut received a fertilizer dose of 30-40-50 kg N, $P_2O_5$, $K_2O$ $ha^{-1}$ with 20 kg N, full dose of phosphorus and potash as basal and remaining 10 kg N $ha^{-1}$ at 30 DAS. Urea, SSP and MOP were used as a source of N, $P_2O_5$ and $K_2O$, respectively. In case of intercropping, fertilizer schedule for both the component crops ($T_3$ and $T_4$ only) was followed considering the per cent population of respective sole crops. An amount of 300 mm during 2014-15 and 400 mm was given to sole groundnut in each year 2015-16 and 2016-17. On the otherhand, 550 mm irrigation water was applied either for sole castor or castor+groundnut intercropping in each year of the experimentation. The tikka leaf spot in groundnut was controlled by spraying Hexaconazole 5% SC @ 2 ml $l^{-1}$ twice and *Achaea janata* and *Spodoptera litura* on castor by spraying Novoluron 10% EC @ 1 ml $l^{-1}$, to raise healthy crops of castor and groundnut. The details of effective rainfall, irrigation water applied and total water used during three years of experimentation was furnished in Figure 1 a, b, c and d. This data was used for computing water use efficiency.

### *2.2. Planting pattern, plot size and statistical analysis*

In castor+groundnut intercropping, one row of castor was planted after every five rows of groundnut in case of 1:5 ratio, while, one castor row after every seven rows of groundnut in 1:7 ratio as shown in Figure 2 a and b. A uniform spacing of 0.30×0.10 $m^2$ was maintained for groundnut in both sole and intercropped situations. While, castor was planted at 0.90×0.60 $m^2$ spacing in sole crop and 1.8×0.6 $m^2$ in 1:5 ratio and 2.4×0.6 $m^2$ in 1:7 ratio of castor+groundnut intercropping treatments. Thus, the plant density of both the component crops is reduced in intercropping vis-à-vis respective sole cropping, thus, it is called as replacement series of intercropping. The gross plot size was 9.0×4.8 $m^2$ and the net plot size was 7.2×4.8 $m^2$. Both the component crops were planted on 13th October during 2014 and 2015 and 18th October during 2016. The groundnut was harvested during first week of February, while in case of castor, three

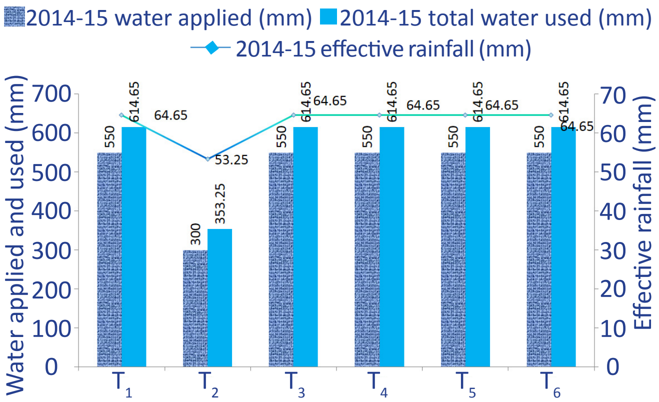


Figure 1a: Effective rainfall received, irrigation water applied and total water used during 2014-15

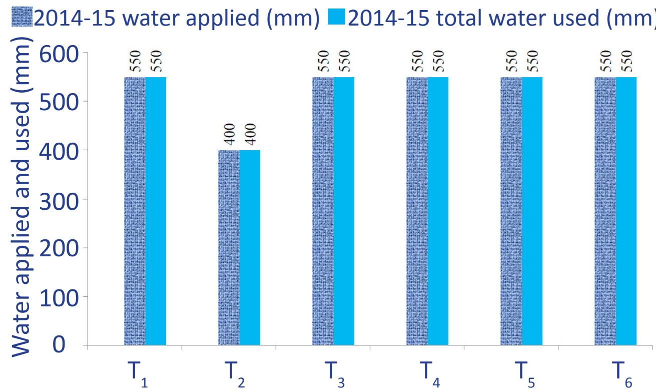


Figure 1b: Effective rainfall received, irrigation water applied and total water used during 2015-16

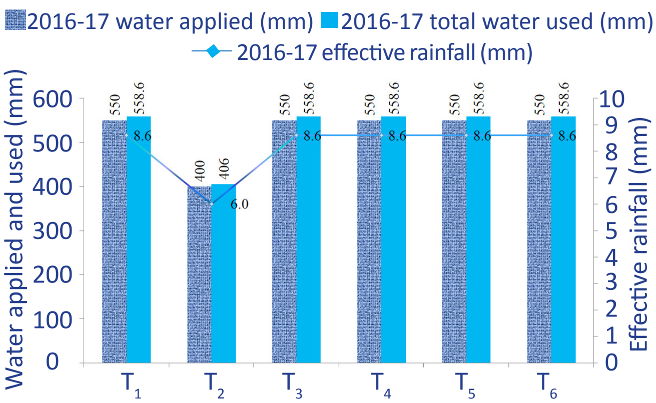


Figure 1c: Effective rainfall received, irrigation water applied and total water used during 2016-17

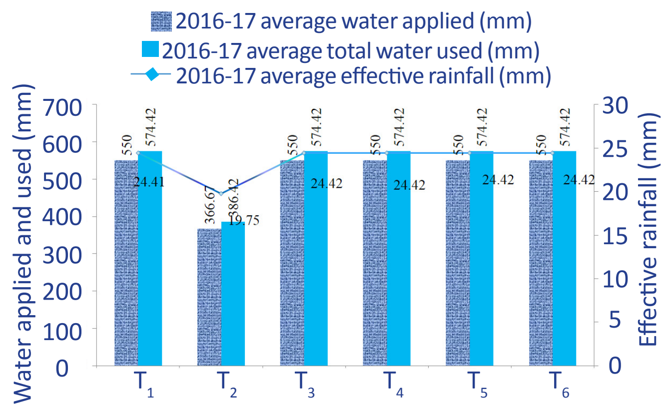


Figure 1d: Average effective rainfall received, irrigation water applied and total water used

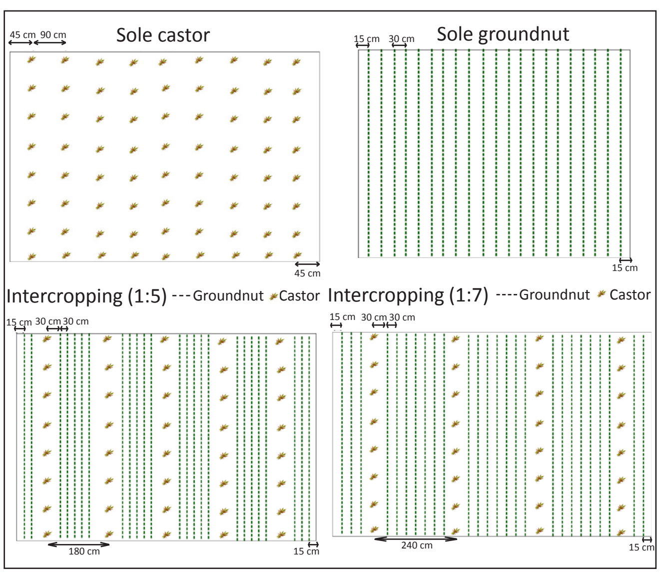


Figure 2: Planting pattern of sole cropping and intercropping

pickings were taken during second week of February and March during 2015, 2016 and 2017. The experimental data of various parameters were subjected to statistical analysis using Fisher's analysis of variance technique. Standard error of means (SEm ±) and least significant difference (LSD) at 5% probability ($p$=0.05) were worked out to understand and interpret the differences between treatment means (Panse and Sukhatme, 1985).

### *2.3. Computation of biological, competition and economic indices*

Biological indices include land equivalent ratio (LER), land equivalent co-efficient (LEC) and area time equivalency ratio (ATER), competition index such as relative crowding coefficient (RCC) and economic indices which includes net profit (NP), benefit: cost (B:C) ratio and monetary advantage index (MAI) were computed according to the formulae furnished below in Table 1.

## 3. Results and Discussion

### *3.1. Effect of sole and intercropping on plant density*

As shown in Figure 3 a and b, the theoritical plant density of castor declined from 18,518 ha$^{-1}$ (100%) in sole cropping to 9259 ha$^{-1}$ (50%) and 6944 (37.5%) due to its intercropping with groundnut in 1:5 and 1:7 ratio, respectively. Similarly, the plant density of groundnut which has to be 3,33,333 plants ha$^{-1}$ in sole cropping declined to 2,76,666 ha$^{-1}$ (83.3%) and 2,91,666 ha$^{-1}$ (87.5%) due to its intercropping with castor. The observed or recorded population was slightly less than the

Table 1: Formulae for computation of various indices

| Indices | Formula | Reference |
|---|---|---|
| CEY | (Ygc×Pg/Pcg)+Ycg | Willey and Osiru (1972) |
| WUE | CEY/water used<br>Water used: ER+IW | |
| LER | LERc+LERg=(Ycg/Ycc)+(Ygc/Ygg) | De Wit and Van den Berg (1965) |
| LEC | LERc×LERg | Adetiloye et al. (1983) |
| ATER | (LERc×Tc)+(LERg×Tg)/T | Hiebsch and McCollum (1987) |
| RCC | K=(Kc×Kg)<br>Kc={Ycg×Zgc}/{(Ycc-Ycg)×Zcg}<br>Kg={Ygc×Zcg}/{(Ygg-Ygc)×Zgc} | De Wit (1960) |
| MAI | Value of combined intercrops × (LER−1)/LER | Willey (1979); Ghosh (2004) |
| Net profit | Gross returns-Cost of cultivation | |
| B:C ratio | Gross returns/Cost of cultivation | |

Where: WUE: Water use efficiency (kg $ha^{-1}$ $mm^{-1}$); ER: Effective rainfall (mm); IW: Irrigation water applied (mm); CEY: Castor equivalent yield (kg $ha^{-1}$); Pg: Price of groundnut; LERc: LER of castor; LERg: LER of groundnut; Tc: Duration of castor; Tg: Duration of groundnut; T: Duration of cropping system; Kc: RCC of castor; Kg: RCC of groundnut; Zcg: sown proportion of castor in intercropping; Zgc: sown proportion of groundnut in intercropping; Ycg: yield of castor in intercropping; Ygc: yield of groundnut in intercropping; Ycc: yield of castor in sole cropping; Ygg: yield of groundnut in sole cropping

theoretical population due to loss of plants due to mechanical damage, pests and disease incidence. This plant density is very important for obtaining optimum yields and also analyzing the differential yields in sole and intercropping systems.

### *3.2. Effect of sole and intercropping on total system productivity and profitability*

CEY considers yield and market prices of component crops for arriving at the total productivity of the system. The experimental results indicated that significantly higher CEY was obtained from sole groundnut irrespective of year of experimentation (Table 2). The three years pooled data revealed that CEY realized from sole groundnut (3960 kg $ha^{-1}$) was higher by 12.5, 17.9, 15.8, 25.8, 102.5% than that of $T_3$ (3517 kg $ha^{-1}$), $T_4$ (3359 kg $ha^{-1}$), $T_5$ (3421 kg $ha^{-1}$), $T_6$ (3146 kg $ha^{-1}$) and $T_1$ (1956 kg $ha^{-1}$). It was mainly owing to the higher market price offered for groundnut (Rs. 50 $kg^{-1}$) than castor (Rs. 35 $kg^{-1}$). According to several earlier researchers, higher groundnut pod yield in sole cropping than under intercropping system with other crops was due to more no. of pods, kernels,

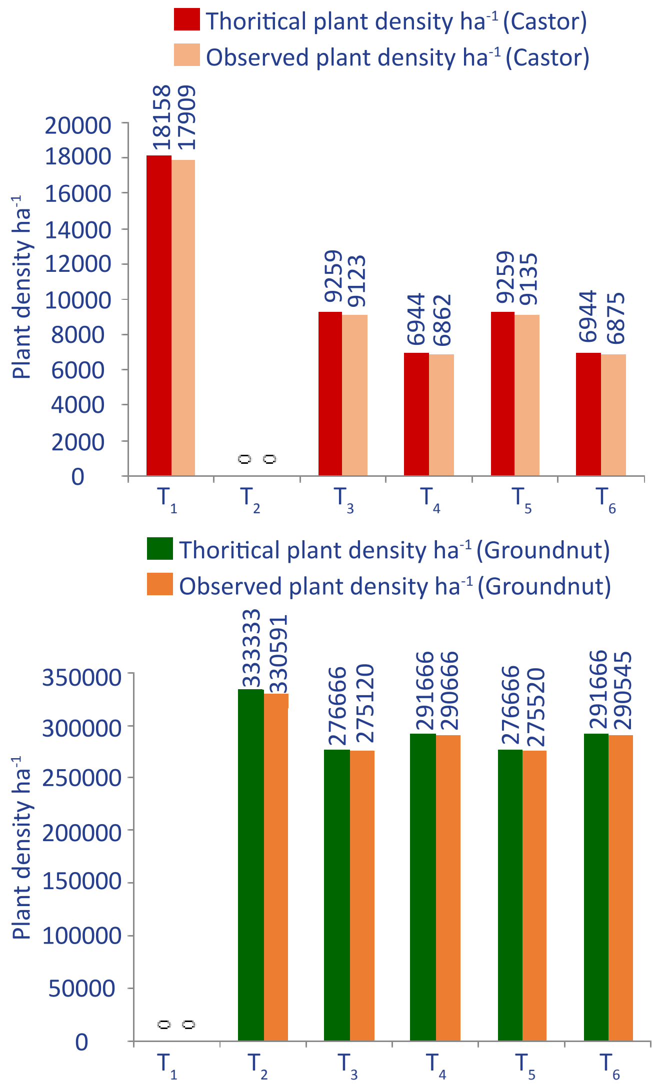


Figure 3: Changes in plant density of castor and groundnut

biomass and harvest index compared to that of intercropping system (Sarkar and Pal, 2004; Alom et al., 2010). Further, the gross (₹ 1,50,465 $ha^{-1}$) and net returns (₹ 94,150 $ha^{-1}$) were also higher with sole groundnut as compared to sole castor and castor+groundnut intercropping system. Additional net returns of ₹ 15,227 to 22,212 $ha^{-1}$ over castor+groundnut intercropping and ₹ 50,475 $ha^{-1}$ over sole castor were accrued from sole groundnut. Ganvir et al. (2006) stated that castor+groundnut (1:2) intercropping resulted in higher castor and intercrop yield, total productivity and gross monetary returns. However, higher B:C ratio was observed with sole castor (2.76) followed by sole groundnut (2.67) and castor+groundnut (1:5) with RDF applied to both the crops (2.57) in the current study. It was due to the lower cost of cultivation in sole castor (₹ 24,801 $ha^{-1}$) than sole groundnut (₹ 56,314 $ha^{-1}$) and intercropping (₹ 48,200 to 53,070 $ha^{-1}$).

As shown in Table 2, the yield of castor was high (1956 kg $ha^{-1}$), but, declined drastically due to intercropping with groundnut (1:5 or 7) due to reduction in its' plant stand

Table 2: Effect of castor+groundnut intercropping on castor equivalent yield, WUE and economics (Pooled data of three years rabi 2014-15 to 2016-17)

| Treatments | Yield (kg ha$^{-1}$) | | Castor equivalent yield (kg ha$^{-1}$) | | | | WUE* | NRUWU | GR | CR | NR | ANR** | B:C ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | C | G | 2014-15 | 2015-16 | 2016-17 | Pooled | | | | | | | |
| $T_1$: SC | 1956 | 0 | 2368 | 1636 | 1865 | 1956 | 3.41 | 76.34 | 68476 | 24801 | 43675 | 50475 | 2.76 |
| $T_2$: SG | 0 | 2772 | 3948 | 3388 | 4546 | 3960 | 10.25 | 243.65 | 150465 | 56314 | 94150 | - | 2.67 |
| $T_3$: C+G (1:5) with RDF to both | 929 | 1811 | 3373 | 3133 | 4045 | 3517 | 6.12 | 139.28 | 131096 | 51092 | 80004 | 14146 | 2.57 |
| $T_4$: C+G (1:7) with RDF to both | 921 | 1707 | 3299 | 2920 | 3859 | 3359 | 5.85 | 125.24 | 125008 | 53070 | 71938 | 22212 | 2.36 |
| $T_5$: C+G (1:5) with RDF to castor | 996 | 1698 | 3375 | 3094 | 3795 | 3421 | 5.96 | 137.31 | 127073 | 48200 | 78873 | 15277 | 2.64 |
| $T_6$: C+G (1:7) with RDF to castor | 962 | 1529 | 3462 | 2534 | 3442 | 3146 | 5.48 | 116.35 | 116871 | 50038 | 66834 | 27316 | 2.34 |
| SEm± | | | 209 | 180 | 167 | 92 | 0.16 | 5.98 | | | | | |
| LSD ($p$=0.05) | | | 659 | 567 | 528 | 291 | 0.52 | 10.09 | | | | | |

C: Castor (seed); G: Groundnut (pod); WUE: WUE (kg ha$^{-1}$ mm$^{-1}$)*; NRUWU: Net returns per unit water used (₹ mm$^{-1}$); GR: Gross returns (₹ ha$^{-1}$); CR: Cost of cultivation (₹ ha$^{-1}$); NR: Net returns (₹ ha$^{-1}$); ANR: Additional net returns (₹ ha$^{-1}$)**; SC: Sole castor; SG: Sole groundnut; C+G: Castor+Grounndut; RDF for castor: 80-40-30 kg N, $P_2O_5$, $K_2O$ ha$^{-1}$; RDF for groundnut: 30-40-50 kg N, $P_2O_5$, $K_2O$ ha$^{-1}$; Market price: Castor seed: ₹ 35 kg$^{-1}$; Groundnut pods: ₹ 50 kg$^{-1}$ Groundnut haulms: ₹ 3 kg$^{-1}$; **: Additional net returns from $T_2$ (Sole groundnut) over other treatments; *: WUE is based on CEY

(Figure 3) and also competition offered and dominance of groundnut grown in the intercropping. Srilatha et al. (2002) noticed a significant reduction in the yield traits of castor such as number of capsules per plant, spike length and number of capsules per spike under intercropping with groundnut and soybean compared to sole castor. Though, castor grew taller in castor+groundnut intercropping system compared to sole castor, but, capsules per plant, seed weight per plant and test weight were higher in sole castor. Further, Dhimmar and Raj (2009) also confirmed reduced castor growth and yield due to intercropping with legumes. However, according to Dutra et al. (2015) intercropping was more advantageous to castor bean when groundnut was sown by 15 and 20 days late.

### *3.3. Effect of sole and intercropping on various biological, competition and economic indices*

LER indicates relative land area required under sole crop to produce the same yields obtained in intercropping. LER > 1 denotes the advantageous nature of intercropping, while, LER <1 is disadvantageous because of antagonism following stronger interspecific competition (Zhang et al., 2011). In the present experiment, the LER of intercropping treatments (1.05 to 1.13) was found to be more than that of sole crops (1.00). Further, among four intercropping treatments, it was significantly higher (1.13) with castor+groundnut (1:5) with or without RDF application to both the crops (Figure 4a) which means intercropping is 13% more productive than sole cropping. Furthermore, the 1:5 ratio is more productive than the 1:7 ratio. LEC *or* productivity index (PI) determines the strength of the intercropping interaction. It is a superior index for measuring the productivity of a cropping system. LEC followed a similar trend of LER among intercropping treatments (Figure 4b). Values of LER greater than 1.00 have also been reported for sorghum-bottle gourd intercropping (Chimonyo et al., 2016) and cassava-maize-egusi melon intercropping (Ijoyah et al., 2012). Few authors reported yield advantage in crop mixtures than equivalent sole crops on the same land area. However, this varies with the species combination and seeding ratio. Dhima et al. (2007) reported that higher LER is closely related to higher MAI values which emphasize the economic benefits from intercropping.

ATER is a mathematically sound as well as biologically logical approach for comparing productivities among cropping systems taking into consideration area occupied and time required for completion of the life cycle. It is the ratio of area×time required in monoculture to area×time used by the intercrop in producing the same quantities of all component

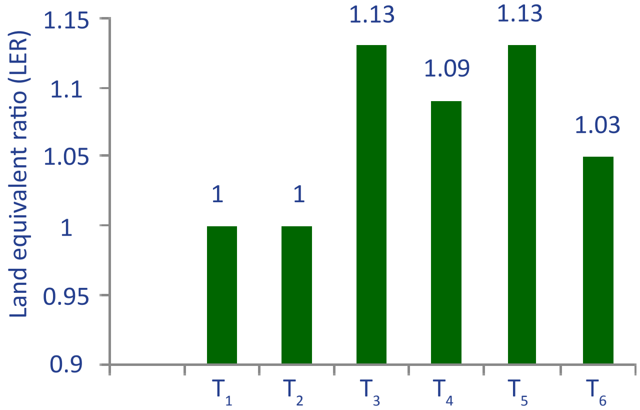


Figure 4a: Land equivalent ratio (LER)

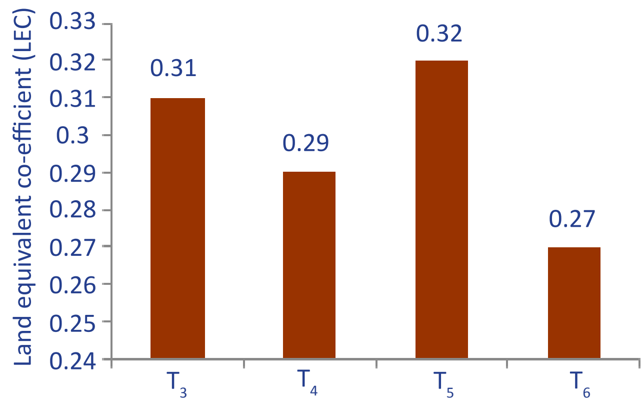


Figure 4b: Land equivalent co-efficient (LEC)

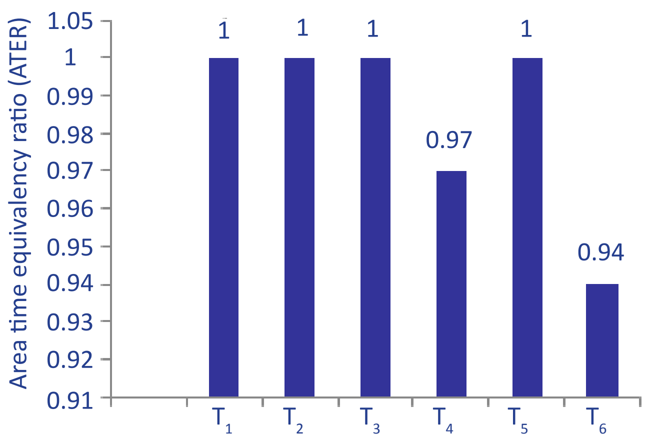


Figure 4c: Area time equivalency ratio (ATER)

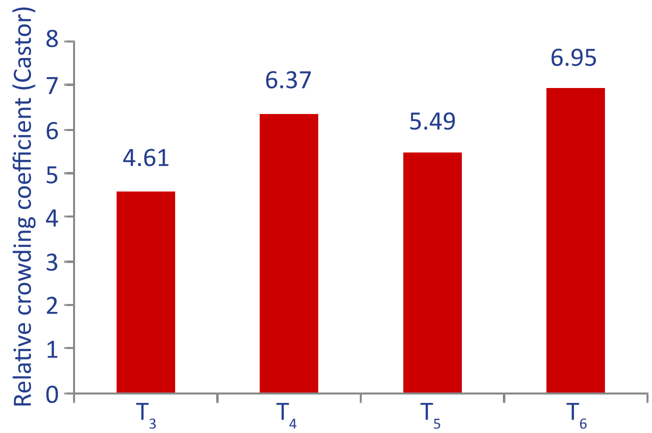


Figure 4d: Relative crowding coefficient (Castor)

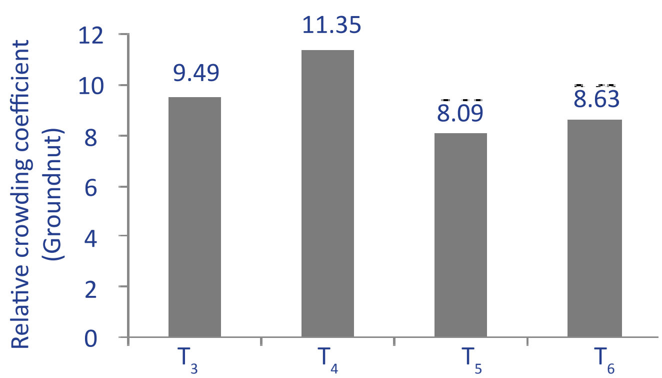


Figure 4e: Relative crowding coefficient (Groundnut)

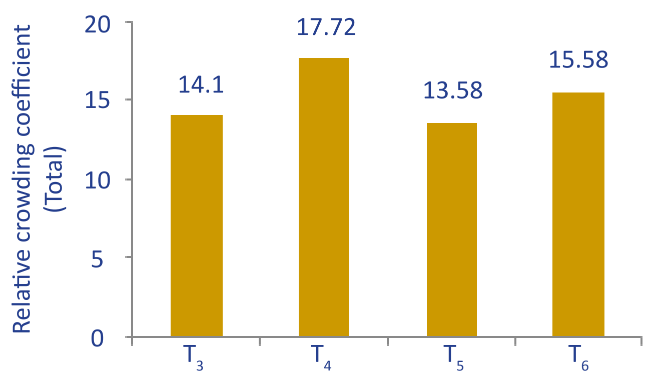


Figure 4f: Relative crowding coefficient (Total)

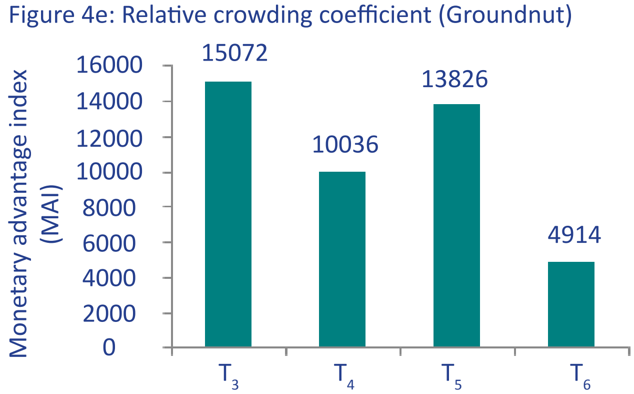


Figure 4g: Monetary advantage index (MAI)

crops. It is analogous to LER, but, it is very important when the duration of component crops is different. In the current experiment, though castor (180 days) and groundnut (120 days) differed in their duration, ATER didn't vary significantly among all the six treatments (Figure 4c) which might be due to utilization of land area and time (area*time) by all the treatments at about the same efficiency.

RCC shows the relative dominance of one species over the other in multiple cropping (Banik et al., 2006). The component crop with a higher RCC value is said to be more dominant (De Wit, 1960). RCC of either component crops or total was found to be higher with 1:7 ratio than 1:5 ratio of intercropping

(Figure 4 d,e and f) in the present field trial, which could be due to more plant density of groundnut and less of castor in a hectare area. Furthermore, groundnut was found to be more dominant and competitive as its RCC value (8.09 to 11.35) was higher than that of castor (5.49 to 6.95). This might be due to distant differences in rooting pattern, growth habit and maturity periods and contrast nature of utilizing natural resources efficiently. The results were in accordance with the findings of Dutta and Bandyopadhyay (2006). In fact, castor, being a long duration crop with slow initial growth habit, could offer a potential scope for shorter duration and quick-growing crop like groundnut to take advantage of the land resources more efficiently. MAI measures the economic viability of an intercropping system (Willey, 1979). The higher the MAI value, the more profitable is the cropping system (Dhima et al., 2007). As shown in Figure 4g, Castor+groundnut system (1:5) which received RDF for both the crops, had a higher MAI value (15072), hence, found to be a better option among intercropping systems.

### *3.4. Effect of sole and intercropping on water use efficiency*

WUE indicates yield of a crop or cropping system obtained per unit amount of water used. In other words, how efficiently a crop(s) consumed water to produce higher yield. It differed significantly among treatments. Sole groundnut recorded higher WUE of 10.25 kg $ha^{-1}$ $mm^{-1}$ followed by castor+groundnut (1:5) (6.12 kg $ha^{-1}$ $mm^{-1}$) which received RDF for both the crops (Table 2). On the otherhand, significantly lower WUE was observed in sole castor (3.41 kg $ha^{-1}$ $mm^{-1}$). This might be due to short duration (110 days), less water requirement and higher yield of groundnut per unit amount of water. On the contrary, castor due to its longer duration (>150 days) required more water but produced less yield $unit^{-1}$ amount of water. The highest net returns per mm water used were also recorded from sole groundnut (₹ 243.65 $mm^{-1}$) and least was realized from sole castor (₹ 76.34 $mm^{-1}$). The speculation by previous researchers about enhanced WUE in intercropping is partly due to improved water sharing and water compensation between the two intercrops (Fan et al., 2013).

## 4. Conclusion

Sole groundnut was found profitable as it gave maximum CEY as well as economic returns. It can be preferred under the conditions of limited water, requirement of fodder for cattle and need for improving the soil fertility. Further, sole castor can be promoted among economically poor farmers and also to overcome wild boar menace. Intercropping is preferred to overcome the price instability, pest and disease problems and wild boar, as castor acts as trap and repellent crop, respectively.

## 5. Future Research

The future research must be prioritized on finding suitable selective broad spectrum post-emergence herbicides for castor+groundnut intercropping system.

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