The Bioscan 12(1): 643-646, 2017 (Supplement on Agronomy)
AN INTERNATIONAL QUARTERLY JOURNAL OF LIFE SCIENCES
www.thebioscan.com

# PRODUCTIVITY AND ENERGETICS OF CASTOR (*RICINUS COMMUNIS* L.) BASED INTERCROPPING SYSTEMS UNDER RAINFED CONDITION

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**KEYWORDS**
Castor
Energetics
Energy use efficiency
Intercropping
Production efficiency

**Received on :**
06.04.2016

**Accepted on :**
29.06.2016

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**ABSTRACT**

A field experiment was conducted to investigate the 'Performance of castor based intercropping systems' duringrainy season, 2013 on medium deep black soils under rainfed condition. There were 11 treatments consisting of sole castor and castor + intercrops *viz*., groundnut, sesame, pearlmillet, foxtailmillet and cluster bean each in 1:1 and 1:2 row proportions. Castor + groundnut (1:2) recorded significantly higher castor equivalent yield (1964 kg/ha) and production efficiency (16.36 kg/ha/day). The same intercropping system produced significantly higher yields of protein (517 kg/ha) and fat (915 kg/ha). While, the maximum carbohydrate yield (943 kg/ha) was observed with castor + pearlmillet (1:2) followed by castor + pearlmillet (1:1). Total output energy (96,300 MJ/ha) and net energy (82,370 MJ/ha) were maximum with castor + groundnut (1:2) intercropping system followed by castor + groundnut (1:1) intercropping system while, output/input ratio (7.86) and energy use efficiency (159.85 kg/ 1000MJ) were maximum with castor + groundnut (1:1) closely followed by castor + groundnut (1:2).

## INTRODUCTION

Castor (*Ricinus communis* L.) is one of the ancient and important non edible oilseeds and has immense industrial and medicinal value. In India, it is grown in about 1.23 million hectares with production of 1.96 million tonnes and productivity of 1592 kg/ha (www.indiastat.com, 2014). However, castor production alone is not economical and hence intercropping seems to be the only way to increase productivity and intensity land use (Mandal *et al*., 2014). In fact, it is possible too intensify as castor is planted using both wider inter and intra-row spacings. The space available between the rows provides initially an opportunity for introduction of an additional crop as intercrop during monsoon as moisture available then is more than adequate for castor due to seasonal concentration of rain. Further, by virtue of its drought tolerance, slow initial growth, perenniating nature, branching habit and indeterminate penology (Hegde and Sudhakara Babu, 2013) castor forms an ideal component in an intercropping system. Having accepted castor crop's suitability for intercropping system, the important point to ponder would be the choice of ideal intercrop with castor. Again, there is a wide range of choice amongst cereals, legumes and oilseeds, and even non-traditional crops like gum guar expands the options (Kalaghatagi and Guggari, 2010; Sharath Kumar *et al.,* 2010; Basith and Shaik Mohammad, 2013). Intercropping being the main stay of dry farming farmers efforts are needed to enhance production efficiency and economic sustainability of dryland crops through intercropping. Therefore, an investigation was envisised to identify suitable castor based intercropping system envisaged in production and energetics on medium deep black soils under rainfed condition in the North Eastern Dry Zone of Karnataka.

## MATERIALS AND METHODS

A field experiment was conducted during rainy season, 2013 at the Agricultural College Farm, Raichur falling under North Eastern Dry Zone of Karnataka state located at $60^{o}$ 15′ N latitude and 77 °20′ E longitude and at an altitude of 389 m above mean sea level. The soil of the experiment was medium deep black, clayey in texture, alkaline (8.3) in reaction, low in organic matter (2.4 g/kg), available nitrogen (226 kg/ha), medium in available phosphorus (12.8 kg/ha) and high in available potassium (278.3 kg/ha). The experiment was laid out in a Randomized Complete Block Design with 11 treatments replicated thrice.Treatments consisted of sole cas tor and castor (cv. DCH-177) + intercrops [groundnut (cv. R-2001-2), sesame (cv. DS-1), pearl millet (cv. ICPT-8203), foxtail millet (cv. HMT-100-1) and cluster bean (cv. HG-365)] at one or two row proportions (1:1 and 1:2). Castor was sown at a spacing of 90 cm x 60 cm in sole as well as intercropping systems and component crops were accommodated in between two rows of castor. The intercrops were in additive series and the populations of intercrops were 1,11,111 and 2,23,333, respectively in 1:1 and 1:2 row proportions for all intercrops except pearl millet which had 74,074 and 1,48,148, respectively at 1:1 and 1:2 row proportions. Castor and intercrops were hand dibbled simultaneously. Castor was fertilized with 40:40:20 kg N, $P_2O_5$, $K_2O$/ha. The fertilizer application to all intercrops was additional and in proportion to their sole optimum plant densities as per recommendation. All the recommended agronomical practices were followed and crops were raised completely as rainfed.

Castor equivalent yield for each intercropping system was calculated based on the yield of individual crops in each intercropping system and their market prices prevailing at the time of experimentation. Production efficiency (kg/ha/day) was calculated by using formula (total castor equivalent yield/ total duration of the system) given by Tomar and Tiwari (1990). The energetics of different crops and cropping systems were calculated using the nutritive values of protein, carbohydrate, fat and energy per 100 g of edible portion suggested as by Gopalan *et al*. (1978). Energy output and input (1000 MJ/ ha) were calculated by using the energy equivalents (MJ) for outputs and inputs (Mittal *et al*., 1985). Energy output/input is the ratio of energy produced in cropping system to energy consumed for the production of crop. Energy use efficiency was worked out in terms of kg castor equivalent yield (main crop) produced per 1000 MJ energy consumption in the cropping system (Padhi, 2001).

## RESULTS AND DISCUSSION

### Performance of castor

Growth and yield parameters of castor under sole cropping and different intercropping combinations were influenced significantly (Table 1). Interestingly, castor yield under intercropping with groundnut was almost similar to that of sole castor yield (Table 2). In other words, absolutely no reduction in castor yield was visible as was observed with other intercropping systems. From this, it is probable that the groundnut component was complementary than competitive. The comparable yields of castor with groundnut irrespective of the row proportion in comparison to sole castor could be attributed to comparable performance of yield components *viz*., seed yield/plant, test weight, number of capsules/spike and spikes/plant which were at par among the three systems (Table 1). These improved performances could be further traced back to comparable performances of growth components *viz*., dry matter production/plant, number of branches/plant and plant height (Table 2). On the other hand castor yield decreased drastically with all the remaining intercrops. The extent of reductions in seed yields of castor were 92.6, 88.7, 84.2, 60.5, 52.2, 37.4, 35.3 and 33.8%, respectively with pearl millet (1:2 and 1:1), foxtail millet (1:2 and 1:1), sesame (1:2 and 1:1), cluster bean (1:2 and 1:1) intercrops. Similar reductions in castor yield due to intercropping with pearl millet (Basith and Shaik Mohammad, 2013), foxtail millet and sesame (Kalaghatagi and Guggari, 2010) and cluster bean (Patel *et al*., 2007) were reported by earlier workers.Of all, pearl millet was the most aggressive intercrop found to inflict maximum damage to the castor crop. The soil was medium deep and fairly fertile and the rains received during July (15% higher than normal during 2013) were further helpful in promoting pearl millet growth. Similar to pearl millet, foxtail millet also suppressed the growth of castor, and consequently reduced the yield.

Intercropping of sesame and cluster bean (gum guar) with castor either in 1:1 or 1:2 row ratio was not compatible as the castor yields were declined. Sesame being a non legume, medium statured crop adversely affected the growth and yield of castor because during early phase both the crop components grew vertically and competed for light and space. Similar competitive nature of cluster bean was also visible in the present study. Yield reduction in intercropping systems was also due higher population load per unit area compared to pure stand. In present investigation, it was also observed that higher competition with millets (pearl millet and foxtail millet) compared to sesame and cluster bean due the higher population load per unit area *i.e.,* 100 + 100 and 100 + 50%, respectively with 1:2 and 1:1 row ratio of pearl millet and foxtail millet as against 100 + 66 and 100 + 33%, respectively with 1:2 and 1:1 row ratio of sesame and cluster bean.In all, only groundnut proved to be an efficient inter crop with castor probably due to its low canopy height, low

**Table 1: Growth parameters (plant height, number of branches and dry matter production) at harvest and yield components of castor as influenced by intercrops and row proportions**

| Treatment | Plant height (cm) | No. of branches/ plant | Dry matter (g/plant) production | No. of spikes / plant | No. of capsules/ spike | 100 seed weight (g) | Oil content (%) | Seed yield/ plant (g) |
|---|---|---|---|---|---|---|---|---|
| $T_1$- Sole castor | 204.98 | 4.37 | 376.79 | 4.49 | 23.77 | 25.15 | 46.27 | 59.20 |
| $T_2$- Castor + groundnut (1:1)* | 209.10 | 4.43 | 385.12 | 4.92 | 24.75 | 24.60 | 46.10 | 59.43 |
| $T_3$- Castor + groundnut (1:2) | 211.47 | 4.37 | 381.38 | 4.66 | 24.50 | 25.05 | 44.77 | 59.42 |
| $T_4$- Castor + sesame (1:1) | 155.98 | 2.87 | 209.35 | 3.21 | 19.78 | 22.75 | 45.67 | 40.69 |
| $T_5$- Castor + sesame (1:2) | 189.82 | 3.23 | 200.77 | 2.54 | 19.67 | 22.65 | 45.27 | 30.05 |
| $T_6$- Castor + pearl millet (1:1) | 114.63 | 1.70 | 62.09 | 1.14 | 14.89 | 19.65 | 44.07 | 7.15 |
| $T_7$- Castor + pearl millet (1:2) | 105.48 | 1.40 | 53.67 | 0.77 | 14.00 | 18.00 | 40.83 | 6.12 |
| $T_8$- Castor + foxtail millet (1:1) | 149.58 | 2.67 | 143.09 | 2.51 | 18.49 | 22.45 | 45.63 | 25.17 |
| $T_9$- Castor + foxtail millet (1:2) | 118.70 | 2.23 | 98.87 | 1.81 | 18.75 | 19.85 | 45.23 | 10.05 |
| $T_{10}$- Castor + cluster bean (1:1) | 175.70 | 3.63 | 269.32 | 3.56 | 20.98 | 20.70 | 45.70 | 39.14 |
| $T_{11}$- Castor + cluster bean (1:2) | 174.35 | 3.80 | 243.13 | 3.15 | 19.79 | 22.70 | 45.13 | 41.34 |
| S.Em± | 11.26 | 0.21 | 9.52 | 0.33 | 1.57 | 1.17 | 0.67 | 3.26 |
| CD (P=0.05) | 33.23 | 0.61 | 27.30 | 0.97 | 4.70 | 3.31 | 1.99 | 9.62 |

* Row proportion

**Table 2: Castor seed yield,castor equivalent intercrop yield, total castor equivalent yield, production efficiency and economics of castor based intercropping systems as influenced by intercrops and row proportions**

| Treatment | Castor yield (kg/ha) | Castor equivalent intercrop yield (kg/ha) | Total castor equivalent yield (kg/ha) | Production efficiency (kg/ha/ day) | Gross return (Rs/ha) | B:C | Economic efficiency (Rs/ha/day) | Income equivalent ratio (IER) | Relative net returns (RNR) |
|---|---|---|---|---|---|---|---|---|---|
| $T_1$- Sole castor | 1095 | - | 1095 | 9.13 | 43,813 | 1.61 | 138.8 | - | |
| $T_2$- Castor + groundnut (1:1)* | 1100 | 632 (650) | 1669 | 13.91 | 68,211 | 2.01 | 285.3 | 1.54 | 2.15 |
| $T_3$- Castor + groundnut (1:2) | 1098 | 962 (989) | 1964 | 16.36 | 81,050 | 2.08 | 350.7 | 1.79 | 2.47 |
| $T_4$- Castor + sesame (1:1) | 686 | 260 (104) | 946 | 7.88 | 30,307 | 1.12 | 27.0 | 0.70 | 1.03 |
| $T_5$- Castor + sesame (1:2) | 524 | 350 (140) | 874 | 7.28 | 40,040 | 1.39 | 93.7 | 0.92 | 1.29 |
| $T_6$- Castor + pearl millet (1:1) | 124 | 432 (1036) | 513 | 4.27 | 23,386 | 0.90 | -20.7 | 0.47 | 0.67 |
| $T_7$- Castor + pearl millet (1:2) | 81 | 568 (1364) | 592 | 4.93 | 28,090 | 1.01 | 3.4 | 0.54 | 0.80 |
| $T_8$- Castor + foxtail millet (1:1) | 433 | 146 (292) | 564 | 4.70 | 23,458 | 0.92 | -17.1 | 0.52 | 0.75 |
| $T_9$- Castor + foxtail millet (1:2) | 173 | 235 (469) | 384 | 3.20 | 16,858 | 0.64 | -80.6 | 0.35 | 0.52 |
| $T_{10}$- Castor + cluster bean (1:1) | 725 | 416 (333) | 1100 | 9.16 | 43,985 | 1.55 | 129.5 | 1.01 | 1.36 |
| $T_{11}$- Castor + cluster bean (1:2) | 708 | 478 (382) | 1138 | 9.49 | 45,536 | 1.51 | 127.9 | 1.05 | 1.51 |
| SEm ± | 77 | 14 | 83 | 0.71 | 3,327 | 0.11 | 27.7 | 0.06 | 0.11 |
| CD (P=0.05) | 228 | 42 | 245 | 2.09 | 9,815 | 0.32 | 81.8 | 0.17 | 0.32 |

* Row proportion; Values in parenthesis are actual yield of intercrops; Selling price (Rs/ kg): Castor-36, groundnut-35, sesame-90, pearl millet-15, foxtail millet-18 and cluster bean-45

**Table 3: Energy budgeting of castor based intercropping systems as influenced by intercrops and row proportions**

| Treatment | Total output energy (1000 MJ/ha) | Input energy (1000 MJ/ha) | Net output energy (1000 MJ/ha) | Output : input | Energy use efficiency (kg/000 MJ) |
|---|---|---|---|---|---|
| $T_1$- Sole castor | 61.81 | 8.01 | 53.81 | 7.72 | 136.83 |
| $T_2$- Castor + groundnut (1:1)* | 85.18 | 10.84 | 74.35 | 7.86 | 159.85 |
| $T_3$- Castor + groundnut (1:2) | 96.30 | 13.93 | 82.37 | 6.91 | 147.87 |
| $T_4$- Castor + sesame (1:1) | 39.79 | 9.56 | 30.23 | 4.16 | 81.98 |
| $T_5$- Castor + sesame (1:2) | 57.48 | 10.90 | 46.58 | 5.27 | 95.06 |
| $T_6$- Castor + pearl millet (1:1) | 43.82 | 10.25 | 33.56 | 4.27 | 54.24 |
| $T_7$- Castor + pearl millet (1:2) | 56.01 | 12.77 | 43.24 | 4.39 | 50.83 |
| $T_8$- Castor + foxtail millet (1:1) | 34.58 | 9.16 | 25.42 | 3.78 | 63.22 |
| $T_9$- Castor + foxtail millet (1:2) | 28.86 | 10.10 | 18.76 | 2.86 | 40.37 |
| $T_{10}$- Castor + cluster bean (1:1) | 48.17 | 9.32 | 38.85 | 5.17 | 122.43 |
| $T_{11}$- Castor + cluster bean (1:2) | 55.97 | 10.14 | 45.83 | 5.52 | 116.97 |
| S. Em.± | 5.30 | - | 4.66 | 0.65 | 7.90 |
| CD (P=0.05) | 15.64 | - | 13.74 | 1.93 | 23.32 |

* Row proportion

vigour in comparison to minor millets and sesame and leaf shedding at physiological maturity thereby it was least competitive among all intercrops. Besides, being legume it might have transferred part of the fixed N to castor, complementing the possible N competition that might have prevailed with other systems. Similarly, Srilatha *et al*. (2002) reported that intercropped groundnut was less or not harmful to castor amongst legumes like greengram or blackgram.

**Performance of intercrops**

Groundnut in two rows was most productive (962 kg/ha) followed by groundnut in single row (Table 2). The next higher productivity was visible in pearl millet in 1:2 row proportion followed by 1:1 row proportion (1364 and 1036 kg/ha, respectively). Cluster bean yield levels were also comparable to that of pearl millet. Groundnut and cluster bean owing to their better market prices fared better in comparison to pearl millet. Among the row proportions castor equivalent yield of intercrops was higher in 1:2 row proportion. This was on the expected line because the population of the intercrops was double in two rows compared to inclusion of one row. However, the yield differences were not exactly in tune with population levels. This indicated inter and intra crop interactions of differential magnitude.

**System productivity**

Among the castor based intercropping systems, the castor crop equivalent yield (CEY) was significantly higher (1964 kg/ha) when two rows of groundnut were introduced in between rows of castor (Table 2). It was followed by intercropping of castor with groundnut in 1:1 row ratio (1669 kg/ha) and sole crop of castor (1095 kg/ha). The CEY was higher to the tune of 79.4 and 52.2% over sole castor respectively with 1:2 and 1:1 row proportions of castor + groundnut. CEY obtained from castor + cluster bean in both (1:1 and 1:2 row proportions) intercropping systems were numerically higher but statistically comparable to sole crop of castor. Other intercropping systems fared poorly. Similar was the trend in production efficiency.

**Energetics of the systems**

Besides CEY, it would also be pragmatic to evaluate different intercropping systems and sole crop through their energetics which is more stable and meaningful as it indicates the energy yield from the systems which does not fluctuate with the market

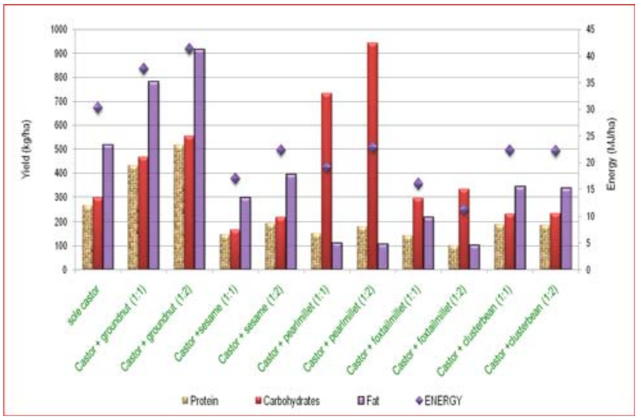


**Figure 1: Energetics: yield of protein, carbohydrates, fat and energy in seed as influenced by intercrops and row proportions**

prices since it is based on the nutritional value of the system. Higher protein, fat and energy were obtained from castor + groundnut (1:2) intercropping system followed by the same intercropping system with 1:1 row ratio (Fig. 1). While, significantly higher carbohydrate yield was obtained from castor + pearl millet (1:2) intercropping system. Higher protein and fat contents in both castor and groundnut along with higher yield resulted in higher energetics compared to other treatments. Nevertheless, pearl millet produced higher carbohydrate yield due to higher grain yield (1036 and 1364 kg/ha); being cereal the seeds are rich in carbohydrates.

### Energy budgeting

Energy relationship in a cropping system vary and constitute a dependent function of the crops knitted in a system, yield level, nature of power use, soil type, energy input and agro climate. Higher output energy was obtained under castor + groundnut (1:2) intercropping system due to higher biomass production and higher energy content, since both were oilseeds and which contain more energy than cereals and pulses (Table 3). Net energy obtained from the latter system was highest compared to other systems and it was comparable with the same crop combination in 1:1 row ratio. The demand of input energy was higher for cereals compared to legumes and oilseeds due to higher nutrient requirement especially nitrogen which has higher amount of energy. The lower input requirement and higher total yield increased the energy use efficiency and output/input energy ratio under castor + groundnut (1:1) intercropping system. The higher out/input ratio indicated that, the system is efficient in producing higher energy through photosynthesis by using lower input energy.

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