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Productivity and economics of castor (*Ricinus communis*) – based intercropping systems under rainfed conditions

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Castor (*Ricinus communis* L.) is most important non-edible oilseed crop of India due to the fact that its oil has diversified uses and has great value in foreign trade. Unfortunately, in India, castor is raised under limited resource conditions leaving the crop thirsty and hungry and thereby poor yields. Plant geometry plays an important role in increasing the yield of a crop and for castor it needs optimization. Castor is a long duration widely spaced crop with comparatively thin plant population as compared to other field crops and has lot of vacant space in early months of cropping. There is tremendous scope for intercropping short duration crops particularly legumes to utilize the wider inter row space in castor crop. Therefore, five intercrops were tested in castor lines with the normal and paired row pattern of planting.

Experiments were conducted during *kharif* (2006-2009) to assess the productivity of castor in various plant geometries and to see the feasibility of various intercrops in the crop under rainfed conditions. The study was conducted at Dryland Agriculture Research Farm of Chaudhary Charan Singh Haryana Agricultural University, Hisar located in semi-arid climate. The soil of the experimental site was sandy loam in texture, low in available nitrogen (203 kg/ha), medium in available phosphorus (16.4 kg/ha), high in available potash content (387 kg/ha) and slightly alkaline in reaction (pH 8.0). Fourteen treatments consisting of castor sole at 75 cm and 90 cm, castor paired at 60:90 cm and 60:120 cm, intercropping of 1 row of greengram, moth bean, clusterbean, cowpea and pearl millet in castor paired row system of 60:90 cm and intercropping of 2 rows of greengram, moth bean, clusterbean, cowpea and pearl millet in castor paired row system of 60:120 cm were tested in randomized block design with 3 replications. A basal dose of 40 kg N + 20 kg P_2O_5/ha was applied in the form of urea and diammonium phosphate before sowing of the crops. All the crops were sown on 15 July 2006, 24 June 2007, 26 June 2008 and 17 July 2009 in the plot size of 9.0 m × 3.6 m. Two seeds of castor were dibbled at 60 cm spacing in the rows as per crop geometry treatments, whereas all the intercrops were sown continuously in the rows. In 1 row intercropping system, seed rate for legumes and pearl millet was used @ 5 kg/ha and 1.25 kg/ha while in 2 rows intercropping system, seed rate for legumes and pearl millet was used @ 8 kg/ha and 2 kg/ha, respectively. In all the intercrops plant to plant distance of 15 cm was maintained by thinning at 20 days after sowing. Likewise, one plant of castor was maintained at 60 cm distance in all the rows by pulling out the additional plant, if both seeds germinated at one spot. The cultivars DCH 7 of castor, Muskan of greengram, RMO 40 of moth bean, HG 563 of clusterbean, HC 98-46 of cowpea and HHB 67 of pearl millet were used in the experiment. Weed management was done with the help of wheel hand hoe three weeks after sowing of the crop. The crops were raised under rainfed conditions. Picking of castor was done 3 times at 120, 150 and 180 days after sowing. Intercrops, i e greengram, moth bean, clusterbean, cowpea and pearl millet were harvested at 88, 74, 112, 81 and 72 days after sowing. The total rainfall received during the crop growth season was 131, 249, 382 and 243 mm during 2006, 2007, 2008 and 2009, respectively. The number of dry spells of more than 10 days experienced by the crop was 2, 4, 4 and 3 during 2006, 2007, 2008 and 2009 seasons, respectively. The pooled grain yields of all the crops in sole as well as in intercropping systems were subjected to statistical analysis only after conversion into the castor equivalent yield taking into consideration the average market prices of 100 kg grain (castor ₹ 1 850, greengram ₹ 3 250, moth bean ₹ 2 875, clusterbean ₹ 1 775 and pearl millet ₹ 725) and straw (pearl millet ₹ 125, cluster bean ₹ 154 and others ₹ 42) during the study period. The sole planting of all the intercrops was also taken in the adjoining field. The four years mean yield of various intercrops in sole stands, viz. greengram 677 kg, clusterbean 1 353 kg, pearl millet 1 853 kg, moth bean 721 kg and cowpea 691 kg/ha was used for computation of competition functions by the following methods suggested by Willey

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(1979). Land equivalent ratios (LER) = La+Lb, La=Yab/Yaa, Lb = Yba/Ybb where, La and Lb are land equivalent ratio of main and intercrops, respectively. Yaa and Yab are yields of main crop while Ybb and Yba are the yields of intercrops in sole stands and in intercropping, respectively. Area time equivalent ratio (ATER) = (LaTa+LbTb)/T where La and Lb, are partial LERs of main and intercrops, Ta and Tb are duration of main and intercrops and T is the total duration of the whole intercropping system. Income equivalent ratio (IER) = income from both main and intercrops in intercropping system/income from sole main crop. Monetary advantage index (MAI) = Net returns from combined produce (₹/ha) × (LER-1)/LER. Aggressivity of main crop (Aab) = {(Yab/Yaa × Zab) - (Yba/Ybb × Zba)} and of intercrop (Aba) = {(Yba/Ybb × Zba) - (Yab/Yaa × Zab)}. Relative crowding coefficient of main crop (Kab) = (Yab × Zba)/(Yaa-Yab) Zab and of intercrop (Kba) = (Yba × Zab)/(Ybb – Yba) Zba, and product of both (K) = Kab × Kba. Competitive ratio of main crop (Cra) = (LERa/LERb) (Zba/Zab) and of intercrop (Crb) = (LERb/LERa) (Zab/Zba) where Zab, proportion of intercrop area allocated to main crop and Zba, proportion of intercrop area allocated to intercrop.

The castor yield among all the four sole planting pattern, viz. 75 cm and 90 cm row spacing and 60:90 cm and 90:120 cm paired row with 60 cm plant to plant spacing did not differ significantly. However, paired row planting had slight advantage over single row planting pattern with yield gain of 5.2 to 6.8 per cent (Table 1). This may be due to more solar radiation interception in paired row planting as

Table 1 Effect of plant geometry and intercrops on grain yield of castor, castor equivalent yield and economics of castor intercropping system (pooled data of four years)

Planting system	Grain yield (tonnes/ha)					Castor equivalent yield (tonnes/ha)	Cost of cultivation (₹/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	B:C ratio
	2006	2007	2008	2009	Mean					
Castor at 75 cm	0.65	1.19	0.74	0.58	0.79	0.79	13 543	14 615	1 072	1.07
Castor at 60:90 cm	0.72	1.25	0.78	0.63	0.84	0.84	13 668	15 614	1 946	1.14
Castor at 60:90 cm + 1 row of greengram	0.67 (0.33)	1.18 (0.25)	0.70 (0.27)	0.54 (0.20)	0.77 (0.26)	1.28	15 144	23 643	8 499	1.56
Castor at 60:90 cm + 1 row of moth bean	(0.37) 0.69	1.15 (0.15)	0.68 (0.18)	0.51 (0.12)	0.76 (0.21)	1.11	15 122	20 479	5 357	1.35
Castor at 60:90 cm + 1 row of clusterbean	0.63 (0.26)	1.11 (0.33)	0.65 (0.31)	0.49 (0.25)	0.72 0.28)	1.04	15 063	19 295	4 232	1.28
Castor at 60:90 cm + 1 row of cowpea	0.65 (0.34)	0.99 (0.17)	0.58 (0.21)	0.43 (0.15)	0.66 0.22)	1.06	15 037	19 573	4 536	1.30
Castor at 60:90 cm + 1 row of pearl millet	0.62 (0.77)	0.73 (0.94)	0.43 (0.75)	0.28 (0.69)	0.51 (0.79)	0.95	14 995	17 649	2 654	1.18
Castor at 90 cm	0.67	1.17	0.73	0.57	0.78	0.78	13 460	14 522	1 062	1.08
Castor at 90:120 cm	0.73	1.21	0.76	0.60	0.83	0.83	13 509	15 281	1 772	1.13
Castor at 90:120 cm + 2 rows of greengram	0.55 (0.40)	1.07 (0.32)	0.63 (0.35)	0.46 (0.29)	0.68 (0.34)	1.35	15 245	24 919	9 674	1.63
Castor at 90:120 cm + 2 rows of moth bean	0.59 (0.43)	1.03 (0.17)	0.60 (0.22)	0.44 (0.16)	0.66 (0.25)	1.11	15 290	20 525	5 235	1.34
Castor at 90:120 cm + 2 rows of clusterbean	0.53 (0.39)	0.99 (0.42)	0.58 (0.41)	0.42 (0.35)	0.63 (0.39)	1.07	15 279	19 887	4 608	1.30
Castor at 90:120 cm + 2 rows of cowpea	0.54 (0.41)	0.86 (0.22)	0.50 (0.30)	0.34 0.34)	0.56 (0.29)	1.09	15 263	20 165	4 902	1.32
Castor at 90:120 cm + 2 rows of pearl millet	0.51 (1.04)	0.59 (1.19)	0.35 (0.92)	0.18 (0.86)	0.41 (1.00)	0.96	15 181	17 686	2 505	1.16
CD (P=0.05)	0.10	0.15	0.10	0.13	0.12	0.09		1442		

Figures in parenthesis indicates the grain yield of intercrops compared to sole planting. Similar results were also reported by Kumar (2002). In 60:90 cm paired row system, intercropping of 1 row of clusterbean, cowpea and pearl millet decreased the yield of main crop castor significantly, whereas, in 90:120 cm paired row planting, intercropping of 2 rows of all intercrops decreased castor yield significantly. However, it was interesting to note that productivity of the castor based intercropping systems in terms of total as well as castor equivalent yield was higher than sole castor planting patterns.

In respect of castor equivalent yield, intercropping of 2 rows of green gram in 90:120 cm paired row and 1 row of greengram in 60:90 cm paired row of castor were significantly at par but both these systems were superior to all other intercropping systems in both the paired row system of castor. Porwal *et al.* (2006) and Srilatha *et al.* (2002) also reported similar findings. Intercropping 1 row of green gram in 60:90 cm and its 2 rows in 90:120 cm increased castor equivalent yield by 61.8 and 71.6 per cent over sole castor planting at 75 cm and 90 cm and 51.4 and 63.1 per cent over 60:90 cm and 90:120 cm paired row planting patterns, respectively. Also intercropping of moth bean, cowpea and clusterbean either 1 row in 60:90 cm and 2 rows in 90:120 cm paired row of castor were significantly at par to each other but superior than intercropping of pearl millet in castor and pure planting patterns of castor. Legume intercrops might have improved nitrogen status of the soil on account of atmospheric N-fixation which was utilized by castor after harvest of legumes. However, even intercropping of 1 and 2 rows of pearl millet was significantly better than sole planting of castor in both single and paired row planting of castor. Though the castor + pearl millet intercropping system was most productive in terms of total yield but it had the lowest castor equivalent yield owing to low price of pearl millet grain, i e ₹ 725 /100 kg.

Castor planting in 60:90 cm and 90:120 cm paired row had significantly higher net returns to the extent of ₹ 874 and ₹ 710 as compared to 75 cm and 90 cm row to row planting of castor (Table 1). All the intercrops in both the paired row planting pattern of castor were more economical than sole planting of castor. Intercropping of 2 rows of green gram in 90:120 cm castor paired row system gave significantly higher net returns (₹ 9 674/ha) and B: C ratio (1.63) as compared to all other intercrops in both the planting pattern of castor as observed by Dhimmar (2009) and Prasad *et al.* (2011). Also, intercropping of 1 row of green gram in 60:90 cm paired row planting of castor was found significantly more economical (₹ 8 499/ha) as compared to remaining intercrops in both the planting pattern of castor. Among all the intercrops, the pearl millet intercrop was found least economical in both the planting pattern owing to lower market price of the pearl millet grain. Highest monetary advantage index (2 345) and income equivalent ratio (1.71) were obtained with intercropping of 2 rows of green gram in 90:120 cm castor paired row system followed by intercropping of 1 row of green gram in 60:90 cm paired row planting of castor with monetary advantage index of 1961 and income equivalent ratio of 1.61 (Table 2).

Land equivalent ratio (LER) of various intercropping systems varied from 1.03 to 1.32 (Table 2) but area time equivalent ratio (ATER) was greater than unity only when either 1 or 2 rows of green gram were taken in castor paired

Table 2 Biological parameters in different castor based intercropping systems (mean of four years)

Intercropping system	LER	ATER	MAI	IER	A_C	A_i	CR_C	CRi	K_C	K_i	K
Castor at 60:90 cm + 1 row of greengram	1.30	1.10	1961	1.61	0.52	–0.52	1.02	0.98	4.59	1.46	6.70
Castor at 60:90 cm + 1 row of moth bean	1.18	1.00	817	1.40	0.54	–0.54	1.34	0.74	3.73	0.94	3.50
Castor at 60:90 cm + 1 row of clusterbean	1.06	0.98	240	1.32	0.55	–0.55	1.74	0.57	2.44	0.62	1.51
Castor at 60:90 cm + 1 row of cowpea	1.11	0.93	409	1.34	0.46	–0.46	1.06	0.94	1.59	1.09	1.73
Castor at 60:90 cm + 1 row of pearl millet	1.03	0.77	77	1.20	0.30	–0.30	0.61	1.63	0.66	1.72	1.14
Castor at 90:120 cm + 2 rows of greengram	1.32	1.06	2345	1.71	0.25	–0.25	1.23	0.81	3.41	1.33	4.53
Castor at 90:120 cm + 2 rows of moth bean	1.15	0.94	683	1.41	0.31	–0.31	1.75	0.57	3.07	0.70	2.15
Castor at 90:120 cm + 2 rows of clusterbean	1.06	0.95	261	1.37	0.31	–0.31	1.98	0.50	2.47	0.54	1.33
Castor at 90:120 cm + 2 rows of cowpea	1.10	0.87	446	1.38	0.21	–0.21	1.20	0.83	1.60	0.97	1.55
Castor at 90:120 cm + 2 rows of pearl millet	1.04	0.71	96	1.21	0.05	–0.05	0.69	1.45	0.74	1.57	1.16

LER, Land equivalent ratio; ATER, area time equivalent ratio; A, aggressivity; CR, competitive ratio; K, relative crowding co-efficient; c, castor; i, intercrops; PR, paired row; r, row; GG, greengram; MB, moth bean; CB, clusterbean; CP, cowpea; PM, pearl millet row planting at 60:90 cm or 90:120 cm. In all other intercropping systems, ATER values were less or equal to unity (0.71 to 1.0) indicating that except green gram the other intercrops, viz. moth bean, clusterbean, cowpea and pearl millet could not utilize available land and space properly with respect to time in association with castor crop. Higher values of LER and ATER in castor + greengram intercropping systems reflect development of complimentarily with least competition in these systems. All the castor based intercropping systems were advantageous than sole castor planting systems because the product of relative crowding coefficient of main and intercrops was more than one due to their complimentary relationship (Table 2). The higher values of relative crowding coefficient of castor obtained from intercropping of greengram either 1 row in 60:90 cm (4.59) or 2 rows (3.41) in 60:120 cm paired rows of castor indicated greater advantage from these intercropping combinations which was further evident from their respective higher values of product crowding coefficient of 6.70 and 4.53 as reported by Tuti *et al.* (2012).

Higher values of competitive ratio of pearl millet in both 1 and 2 rows of its intercropping with castor indicated that it was most competitive to castor than other crops because it had relatively rapid initial growth leading to competition for resources with castor. Clusterbean and moth bean were less competitive to castor because of their initial slow growth which is further evident from the fact that main crop castor had higher values of competitive ratio in association with these crops. The negative values of aggressivity for all the intercrops indicated their poor competitiveness than the main crop castor, which has positive aggressivity in both 1 and 2 rows of intercropping systems. The higher values of aggressivity of castor in 1 row intercropping system showed its greater dominance over castor intercropped with two rows. Castor had lower value of aggressivity when intercropped with pearl millet and cowpea indicating their greater dominance over castor as compared to all other intercrops.

SUMMARY

A field experiment was conducted during rainy season of 2006 to 2009 at Dryland Research Farm of Chaudhary Charan Singh Haryana Agricultural University, Hisar with the objective to assess the productivity of castor (*Ricinus communis* L.) in various plant geometries and to see the feasibility of growing various intercrops in castor under rainfed conditions. Fourteen treatments consisting of castor sole at 75 cm and 90 cm, castor paired at 60:90 cm and 60:120 cm, intercropping of 1 row of greengram, moth bean, clusterbean, cowpea and pearl millet in castor paired row system of 60:90 cm and intercropping of 2 rows of greengram, moth bean, clusterbean, cowpea and pearl millet in castor paired row system of 60:120 cm were tested in randomized block design with three replications. Intercropping of 2 rows of greengram in 60:120 cm castor paired row system gave significantly higher castor equivalent yield (1.35 tonnes/ha), net returns (Rs 9 674/ha), benefit: cost ratio (1.63), monetary advantage index (2 345) and income equivalent ratio (1.71). Also, intercropping of 1 row of greengram in 60:90 cm castor paired row system was found to be more productive and remunerative than moth bean, clusterbean, cowpea and pearl millet intercropping systems. Intercropping of green gram in paired row planting system of castor either in 1 or 2 rows was found superior than other intercrops in terms of biological parameters like land equivalent ratio, area time equivalent ratio and relative crowding co-efficient.

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