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Evaluation of castor (*Ricinus communis*) genotypes for productivity, economics, litter fall and changes in soil properties under different levels of inter-row spacing and nitrogen

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ABSTRACT

A fixed plot field experiment was conducted during the rainy (*kharif*) seasons of 2002 and 2003 at New Delhi, to find out the effect of 3 inter-row spacings (60, 75 and 90 cm) and 3 levels of N (0, 60 and 120 kg N/ha) on performance of 2 genotypes ('DCH 177' and 'DCS 9') of castor (*Ricinus communis* L.) and physico-chemical properties of soil. The mean performance indicated significant superiority of 'DCH 177' to 'DCS 9' in terms of yield attributes, seed yield (27.7 and 23.9 q/ha), harvest index (9.59 and 8.92%) and net return (Rs 24,072 and 20,656/ha). The optimum N dose was worked out to be 121.6 and 100.9 kg N/ha for 'DCH 177' and 'DCS 9' respectively. Castor genotypes responded to inter-row spacing significantly. The maximum seed yield (26.5 q/ha), harvest index (9.72%) and net return (Rs 23,420/ha) were recorded with 90 cm inter-row spacing. Low temperature during December to February induced considerable fruits drop. The treatments under test also caused perceptible variation in fruits drop. Mean litter fall of 9 to 10 tonnes/ha per season was recorded. Litter fall exhibited marked increase due to decrease in inter-row spacing and increase in N levels. At the end of 2 years experimentation on the same site, physico-chemical properties like bulk density and pH recorded perceptible decrease from initial values, while soil organic carbon content and available N exhibited marked improvement over initial values.

Key words : Castor, Productivity, Litter fall, Soil properties, Inter-row spacing, Nitrogen

Castor is an important non-edible oilseed crop grown during the monsoon season mainly for its seed, from which 40–50% oil is extracted. It does well both under dryland or rainfed farming and limited irrigation due to deep root-system. Its cultivation is becoming popular in north-western part of the country owing to its better performance under stress conditions and higher export potential.

Newly developed genotypes of castor are different from the traditional ones in terms of morphology, duration, growth response, and productivity (Kumar *et al.,* 2003; Raghavaiah *et al.,* 2003). They also respond differently to different agro-climatic conditions. In north-western part of the country, some of rainy-season sown castor genotypes continue to produce flowers and fruits till April-May. During this period, these genotypes produce considerable amount of litter in the form of leaves, flowers, pods and twigs resulting in significant contribution to soil organic carbon content and soil organic carbon content related changes in physico-chemical properties of soil. Plant density and N requirement of genotypes vary substantially with management practices and agro-climatic conditions.

Considering these factors, the present study was undertaken to evaluate the performance of 2 genotypes under different inter-row spacing and N levels in terms of productivity, economics and changes in soil physico-chemical properties over the experimental period.

MATERIALS AND METHODS

A fixed plot field investigation was conducted at New Delhi during the rainy seasons of 2002–03 and 2003–04 on sandy-loam soils, having 236, 12.5 and 172.3 kg/ha available N, P and K respectively. The initial soil organic carbon content, pH and bulk density were 0.38%, 7.86 and 1.51 Mg/m^3 respectively. Treatment combinations comprising 2 castor genotypes 'DCH 177' (Hybrid) and 'DCS 9' (Selection), 3 inter-row spacings (60, 75 and 90 cm with 45 cm uniform intra-row spacing) and 3 levels of N (0, 60 and 120 kg N/ha) were laid out in a 3 times replicated split-plot design, where genotypes and inter-row spacings were allotted to main plots and N levels to sub-plots. The crop was sown in the first week of July. The crop received 40 kg each of P_2O_5 and K_2O at the time of field preparation. Nitrogen dose as per treatment was given in 3 splits, i.e. one-third as basal, one-third after first picking and one-third after second picking of spikes. The crop received 2 weedings, at 20 and 40 days after planting, and there was no need of weeding the crop thereafter. Crop received 2 irrigations during each crop season. The crop was harvested by picking of matured spikes at different growth stages. The first harvesting of the crop was done in the third week of October, followed by second in December and final in April of preceding year. The oil content in seed was determined using nuclear magnetic resonance. Three plants were tagged randomly in the second row fixed for sampling in each plot at 50 days and were used for recording growth and yield attributes of the crop under different treatments. Economics such as net returns and benefit:cost ratio were worked out at the existing market rate. The experiment was conducted on the same site without any change in the layout plan. Bulk density, pH and soil organic carbon and available N content of soil were determined at the beginning of experient and at the end of 2 crop cycles. For this purpose, soil samples were drawn from each treatment and analysed for these physico-chemical properties by following standard procedures.

RESULTS AND DISCUSSION

Growth and yield attributes

Both the genotypes recorded marked variation in plant height, spikes/plant, capsules/plant, 1,000-seed weight and seed yield/plant. Hybrid 'DCH 177' recorded significantly higher values of these parameters than 'DCS 9'. With the decrease in inter-row spacing, declining trend was observed in seed yield/plant and capsules/plant. Reduction in inter-row spacing from 90 cm to 75 cm induced significant decrease only in seed yield/plant. Further, reduction in inter-row spacing from 75 to 60 cm caused marked decrease both in capsules/plant as well as yield/plant. Contrary to these parameters, plant height and plant population/ha exhibited marked increase with decrease in inter-row spacing from 90 to 60 cm. Spikes/plant did not show perceptible changes due to reduction in inter-row spacing from 90 to 60 cm.

With the successive increase in N level from 0 to 120 kg N/ha significant increase in plant height, capsules/plant and seed yield/plant was recorded. The magnitude of increase in these parameters was more between 0 and 60 kg N/ha compared to 60 and 120 kg N/ha. The spikes/plant showed significant increase only up to 60 kg N/ha. Application of N did not induce perceptible variation in the plant population/ha.

Seed and stover yield and harvest index

The genotype 'DCH 177' recorded significantly higher seed yield, stover yield and harvest index over 'DCS 9'. The 'DCH 177' recorded 15.8% increase in seed yield over 'DCS 9'. Against this increase in seed yield, the increase in stover yield was only 5.7%, which point towards higher partitioning coefficient of hybrid 'DCH 177' compared to selection 'DCS 9'. This also point towards sink limitation or poor translocation of assimilate from source to sink in selection or variety compared to hybrid, as evident from the variation in capsule numbers and other yield attributes between 'DCH 177' and 'DCS 9'. Lakshmamma and Prayaga (2001) also reported similar variations in seed yield, stover yield and partitioning coefficient between hybrid and non-hybrid. These findings also supported the view of Uprety *et al.* (1979) and Kumar *et al.* (2003), who reported that grain yield in cowpea and chickpea was not only influenced by total

Table 1. Effect of inter-row spacing and N level on the growth and yield attributes of castor genotypes

Treatment	Growth and yield attributes					
	Plant height (cm)	Plant population/ ha	Spikes/ plant	Seed yield/ plant (g)	100-seed weight (g)	Fruit drop/m^2 (g)
Genotype						
'DCH 177'	354	29,380	17.2	105.1	29.1	57.5
'DCS 9'	303	29,280	15.4	86.8	27.7	52.8
CD (P=0.05)	11	NS	0.4	5.7	1.1	3.1
Inter-row spacing (cm)						
60	342	35,970	15.7	71.8	27.7	58.3
75	330	28,800	16.6	92.6	28.5	55.0
90	312	23,220	16.8	123.3	28.8	51.8
CD (P=0.05)	14	620	NS	4.5	0.8	3.4
N (kg/ha)						
0	290	29,600	13.9	64.6	27.3	52.1
60	337	29,360	17.3	105.2	29.0	55.0
120	359	29,030	17.9	118.1	29.1	58.5
CD (P=0.05)	18	NS	1.8	9.9	1.3	3.8

Table 2. Effect of inter-row spacing and N level on the seed yield, harvest index, oil content and economics of production of castor genotypes

Treatment	Seed yield (q/ha)	Stover yield (q/ha)	Harvest index (%)	Oil content (%)	Net return (Rs/ha)	Benefit: cost ratio
Genotype						
'DCH 177'	27.7	257	9.59	44.7	24,072	3.67
'DCS 9'	23.9	243	8.92	43.4	20,656	3.62
CD (P=0.05)	1.5	10	0.47	0.47		
Inter-row spacing (cm)						
60	24.6	254	8.71	43.9	20,656	3.42
75	26.3	252	9.33	44.1	22,964	3.6
90	26.5	245	9.72	44.2	23,420	3.81
CD (P=0.05)	1.6	NS	0.51	NS		
N (kg/ha)						
0	17.7	204	8.64	45.2	13,724	2.75
60	28.3	300	9.50	43.6	24,932	3.95
120	31.5	326	9.68	43.5	28,436	4.14
CD (P=0.05)	1.4	18	0.42	0.43		

dry-matter production, but also the manner in which the photosynthates were distributed within the plant. If, there would have been no sink limitation, the performance of 'DCS 9' in terms of seed yield would be on par with the hybrid 'DCH 177'. Higher numbers of capsules and seed yield/plant were responsible for higher yield in 'DCH 177'.

Reduction in inter-row spacing did not cause marked variation in the stover yield of castor. On the contrary, seed yield and harvest index exhibited marked variation due to inter-row spacing. With the decrease in inter-row spacing from 90 to 75 cm, there was no perceptible change in seed yield and harvest index, however, further reduction in spacing from 75 to 60 cm, caused statistically measurable depressive effect on seed yield and harvest index. With the decrease in spacing from 75 to 60 cm, 6.4 and 6.6% reduction in seed yield and harvest index was recorded. Decline in partitioning coefficient and more competition for nutrients, space and light under closer spacing might be the cause for reduction in seed yield and harvest index. Favourable effects of increasing levels of N on the growth and yield attributes of castor got translated on the seed and biological yields and harvest index. Application of 120 kg N/ha resulted in significantly highest seed yield (31.5 q/ha) and stover yield (326 q/ha). The seed yield with 120 kg N/ha was 93.8 and 11.3% higher than the control and 60 kg N/ha respectively. Contrary to seed and stover yield, the increase in harvest index owing to N application was significant only up to 60 kg N/ha. The results corroborate the findings of Raghavaiah *et al.* (2003).

Capsule drop

Besides the treatment effects, capsule drop/m^2 was affected by ambient temperature. Capsule drop was negligible in September, October, November, February and March and it was maximum in December, January and beginning of February and further at the end of April. It means very low and high temperature has marked effect on the capsule drop. The 'DCH 177' recorded significantly higher capsule drop/m^2 than 'DCS 9'. With the increase in inter-row spacing, there was a decrease in the capsule drop, which might be attributed to the expected variation in micro-climate, particularly temperature under different spacing. With the increase in N level, there was a marked increase in capsule drop/m^2, which may be attributed to expected micro-climatic variation due to canopy growth and capsules drop proportionate to capsules/plant.

Interaction effect

Hybrid 'DCH 177' recorded significant increase in seed and stover yields up to 120 kg N/ha, whereas 'DCS 9'

Table 3. Interaction effect between genotypes and N levels on seed yield, stover yield, and capsules/plant in castor

Genotype	N (kg/ha) 0	60	120
		Seed yield (q/ha)	
'DCH 177'	18.45	30.14	34.44
'DCS 9'	16.80	26.63	28.45
CD (P=0.05)		2.05	
		Stover yield (g/plant)	
'DCH 177'	706	1007	1136
'DCS 9'	664	976	988
CD (P=0.05)		44	
		Capsules/plant	
'DCH 177'	211	325	363
'DCS 9'	172	264	282
CD (P=0.05)		16	

responded to N level up to 60 kg N/ha (Table 3). 'DCH 177' and 'DCS 9' gave statistically comparable seed yield at control but at 60 and 120 kg N/ha, 'DCH 177' recorded significantly higher seed yield than 'DCH 9' and the margin between the 2 was more at 120 kg N/ha. Nitrogen and genotype interaction was also found significant for stover yield/plant and capsules/plant. 'DCH 177' recorded significant increase in stover yield/plant up to 120 kg N/ha, whereas 'DCS 9' recorded marked increase only up to 60 kg N/ha. Differential response of genotypes to N levels may be attributed to the variation in genetic potential of genotypes.

Response analysis

Response analysis of genotypes and N showed a quadratic nature for the seed yield:

Genotype	*Response equation*	*Optimum N dose (kg/ha)*
'DCH 177'	$Y = 18.45+0.2564x-0.00102x^2$	121.6
'DCS 9'	$Y = 16.78+0.2305x-0.0011x^2$	100.9

Application of N induced a linear increase in the beginning, but with further increase in levels of N, subsequent increase in yield was at decreasing rate, as a result of which, genotypes recorded quadratic response to N application. The N-use response was obviously better in hybrid 'DCH 177' than 'DCS 9' owing to higher yield potential and migration coefficient.

Economics

Economic analysis revealed that 'DCH 177' recorded higher net realization (Rs 24,075) and benefit: cost ratio (Rs 3.67) than 'DCS 9'. With the change in low-monetary input, inter-row spacing from 60 to 75 cm, there was perceptible increase in net return and benefit:cost ratio. On an average, increase in net return was Rs 2,308/ha. Further increase in inter-row spacing from 75 to 90 cm, improved the net return and benefit:cost ratio further, but the change was not perceptible. The net return and benefit:cost ratio increased progressively with the increase in N levels from 0 to 120 kg N/ha; however, the magnitude of increase in both the parameters was more between 0 and 60 kg N/ha than 60 and 120 kg N/ha.

Litter fall

Litter fall from castor plants as recorded at different growth stages of plant from demarcated unit area and presented in Table 4 indicated that castor crop has high potential of making contribution of 8–10 tonnes organic residue/ha in the form of litter fall. This organic residue in the form of litter fall is easily decomposable. Both the genotypes recorded litter fall of same statistical order. With the increase in plant density/ha, there was a perceptible increase in litter fall/ha. With successive increase in N levels from 0 to 120 kg/ha, marked increase in litter fall was recorded. Successive increase in N level caused significant increase in biological yield, which further resulted in successive increase in litter fall/ha with increasing levels of N.

Physico-chemical properties of soil

Bulk density, pH, organic carbon and available N showed marked variation at the end of 2 years compared to initial values of these parameters (Table 4). On an average, bulk density and soil pH showed decreasing trend, while soil organic carbon content and available N revealed

Table 4. Effect of castor genotype, inter-row spacing and N level on the litter fall and physico-chemical properties of soil after 2 season experimentation

Treatment	Litter fall (q/ha)	Bulk density (Mg/m^3)	Soil organic carbon content (%)	Soil pH	Available N (kg/ha)
Genotype					
'DCH 177'	94.0	1.43	0.45	7.73	252
'DCS 9'	93.1	1.43	0.46	7.74	255
CD (P=0.05)	NS				
Inter-row spacing (cm)					
60	100.0	1.42	0.47	7.72	248
75	92.2	1.43	0.45	7.74	253
90	88.5	1.44	0.45	7.75	259
CD (P= 0.05)	3.6				
N (kg/ha)					
0	82.9	1.42	0.45	7.75	221
60	96.4	1.43	0.46	7.73	268
120	101.4	1.44	0.46	7.72	272
CD (P=0.05)	3.2	-	-	-	-
Initial value		1.51	0.38	7.86	236

positive balance over 2 years experimental period. Among the treatments, genotypes produced marked changes in the bulk density, pH, organic carbon and available N content of soil over initial values, but both the genotypes recorded similar values of these parameters. With the decrease in inter-row spacing, decreasing trend in bulk density, pH and available N was observed, while soil organic carbon content recorded improvement. Successive increase in N levels caused decrease in soil pH, whereas bulk density, organic carbon and available N exhibited marginal increase. These changes in physico-chemical properties of the soil might be attributed to the addition of organic residues to the tune of 8–10 tonnes/ha/annum in the form of easily decomposable litter fall. In addition to this, root biomass also contributed significantly towards the improvement of soil organic carbon. Soil organic carbon plays pivotal role in soil particle granulation, granular/crumby structure formation, soil aeration, microbial population build up, changing the proportion of macro- and micro-pores, thereby resulting a decrease in bulk density. The slight decrease in soil pH may also be attributed to decomposition of added organic material in the form of litter fall and roots resulting in production of organic acid and improvement in cation-exchange capacity of soil as reported by Tan (1992). Presumably increased microbial activities due to addition of large quantity of organic matter might have lead to minerlization, consequently improvement in available N in plough layer. Besides this, recycling of N from lower layer of soil profile due to deep root system of castor might have contributed for maintaining or increasing the available N content compared to initial status. Vani and Bheemaiah (2003) reported similar changes in soil physico-chemical properties of the soil mainly due to addition of large quantity of litter fall.

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