



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
© Agronomy
NAAS Rating (2026): 5.20
www.agronomyjournals.com
2026; SP-9(7): 100-105
Received: 15-04-2026
Accepted: 19-05-2026

K Latha Sahithi Yadav
M.Sc. (Ag.) Research Scholar,
Department of Agronomy,
Agricultural College, Mahanandi,
Andhra Pradesh, India

Y Pavan Kumar Reddy
Assistant Professor, Department of
Agronomy, Agricultural College,
Mahanandi, Andhra Pradesh, India

C Prathyusha
Assistant Professor & Head,
Department of Agronomy,
Agricultural College, Pulivendula,
Andhra Pradesh, India

V Siva Jyothi
Assistant Professor, Department of
Soil Science, Agricultural College,
Mahanandi, Andhra Pradesh, India

A Subba Rami Reddy
Professor & Head, Department of
Agronomy, Agricultural College,
Mahanandi, Andhra Pradesh, India

M Vishnu Priya
Teaching Associate, Department of
Agronomy, Agricultural College,
Mahanandi, Andhra Pradesh, India

Chavan Syamaraj Naik
Associate Dean, Agricultural
College, Mahanandi, Andhra
Pradesh, India

Corresponding Author:
K Latha Sahithi Yadav
M.Sc. (Ag.) Research Scholar,
Department of Agronomy,
Agricultural College, Mahanandi,
Andhra Pradesh, India

Architectural plasticity and yield dynamics of castor under high-density planting

K Latha Sahithi Yadav, Y Pavan Kumar Reddy, C Prathyusha, V Siva Jyothi, A Subba Rami Reddy, M Vishnu Priya and Chavan Syamaraj Naik

DOI: <https://www.doi.org/10.33545/2618060X.2026.v9.i7Sb.5926>

Abstract

A field experiment was carried out in college farm, Agricultural College, Mahanandi, to study the effect of different castor hybrids and spacings on growth and yield parameters and energetics of castor. The experiment was laid out in a factorial randomized block design with three replications. Factor 1 comprised of three castor hybrids ICH-5 (H₁), ICH-6 (H₂) and PCH-111(H₃) and factor 2 comprised of five spacings 60 cm x 30 cm (S₁), 60 cm x 60 cm (S₂), 75 cm x 30 cm (S₃), 90 cm x 30 cm (S₄) and 90 cm x 45 cm (S₅). Among the hybrids ICH-5 (H₁) has significantly higher growth parameters viz., plant height (cm), dry matter production (kg ha⁻¹). Concerning the yield attributes highest spike length (cm) and no. of. capsules (59). seed yield was significantly higher in ICH-5 (H₁). Among different spacings 60 cm x 30 cm (S₁) significantly higher growth parameters viz., plant height (cm) and dry matter production (kg ha⁻¹) and yield attributes like spike length (cm) and no. of. capsules and seed yield recorded highest in 90 cm x 30 cm (S₄) which was statically on par with 90 cm x 45 cm (S₅). From this it is concluded that raising ICH-5 (H₁) castor hybrids combined with 90 cm x 30 cm (S₄) or 90 cm x 45 cm (S₅) recorded highest seed yield, net returns and benefit-cost ratio. Hence, adopting 90 cm x 30 cm (S₄) or 90 cm x 45 cm (S₅) enhances the yield and productivity of castor.

Keywords: Castor hybrids, spacings, growth parameters, yield, energetics

1. Introduction

Castor (*Ricinus communis* L.), a member of the Euphorbiaceae family, is a perennial crop values for its oilseed production. It is cultivated in warm tropical and temperate regions, contributing significantly to industrial purposes. Castor an important non edible oilseed crop which was drought tolerant crop that thrives in marginal soils with minimal input requirement, making it a valuable option for cultivation in semiarid regions. The major castor growing countries globally which includes India, China, Brazil, Russia, Thailand, Ethiopia, and the Philippines. Castor was cultivated globally with a mean productivity of 1.48 t ha⁻¹. India being the leading producer accounts nearly 85-90 cm% of global castor output, spanning an area of 0.75 cm-0.8 m ha with an average productivity of 1.9 to 2.0 t ha⁻¹(FAOSTAT 2022). One of the major constraints in castor cultivation is its prolonged crop duration, with most existing cultivars requiring 6–7 months to reach harvest. In addition, harvesting involves multiple pickings, including primary, secondary, and tertiary spike harvests, which substantially increase labour requirements and cultivation costs. These limitations often restrict the inclusion of castor in intensive cropping systems and reduce farm profitability.

Conventionally, castor is cultivated under wider spacing to accommodate its branching growth habit. However, wider plant spacing results in lower plant population, delayed canopy closure, increased weed infestation and non-uniform flowering and maturity, ultimately limiting seed yield. High Density Planting (HDP) has emerged as a promising agronomic strategy to improve land-use efficiency, promote uniform canopy development, enhance crop synchronization and facilitate mechanized harvesting.

Despite its potential advantage, information on optimal plant densities and geometry for recently developed castor hybrids under mechanised harvesting systems remains limited. Therefore, the present study was undertaken to evaluate the effect of different planting spacings on growth,

yield, economics and energetics of castor and to identify suitable high-density planting dynamics for efficient mechanized harvesting.

2. Materials and Methods

The field experiment was carried out during the *kharif* season of 2025 at the College Farm, Agricultural College, Mahanandi, Acharya N.G. Ranga Agricultural University, Andhra Pradesh, India (15.51° N, 78.61° E; 233 m above mean sea level). The experimental soil was sandy loam in texture, slightly alkaline (pH 7.7) with an electrical conductivity of 0.35 dSm⁻¹, low organic carbon (0.35%) and available nitrogen (136.7 kg ha⁻¹), and high available phosphorus (38.9 kg ha⁻¹) and potassium (565 kg ha⁻¹). The experiment was arranged in a factorial randomized block design with three replications. The treatments consisted of three castor hybrids (ICH-5, ICH-6 and PCH-111) and five planting geometries (60 cm x 30 cm, 60 cm x 60 cm, 75 cm x 30 cm, 90 cm x 30 cm and 90 cm x 45 cm). Seeds were treated with imidacloprid (2.5 ml kg⁻¹ seed) before sowing. Fertilizers were applied at 60: 30: 30 kg N: P₂O₅: K₂O ha⁻¹ through urea, single superphosphate and murate of potash. Nitrogen was applied in four splits, whereas phosphorus and potassium were applied as basal. All other crop management and plant protection practices were followed uniformly for all treatments.

3. Statistical Analysis

Observations on growth, yield attributes, seed yield, quality parameters, economics, energetics and post-harvest soil properties were recorded using standard procedures. The experimental data were subjected to analysis of variance (ANOVA) appropriate for a factorial randomized block design, and treatment means were compared using the F-test at the 5% level of significance following Panse and Sukhatme (1985) [13].

4. Results and Discussion

The present investigation demonstrated that castor performance was significantly influenced by hybrid and plant spacing. Significant differences in growth, yield attributes, seed yield, economics, energetics and post-harvest soil nutrient status indicated that the expression of hybrid potential was largely dependent on the availability and utilization of growth resources under different spacing treatments.

4.1 Growth parameters

4.1.1 Plant height

Among the hybrids evaluated, significant differences in plant height were observed at all stages of crop growth. At 30 DAS, castor hybrid ICH-5 (H₁) recorded the highest plant height (30.09 cm), which was significantly superior to ICH-6 (H₂) (26.91cm) and PCH-111 (H₃) (25.97 cm). A similar trend was noticed at 60, 90, 120 DAS and at harvest.

Spacings significantly influenced the castor plant height at all stages of crop growth. The closer spacing of 60 cm x 30 cm (S₁) recorded significantly taller plants throughout the growth period viz., 30 DAS (31.07 cm), 60 DAS (79.18 cm), 90 DAS (172.84 cm), 120 DAS (189.80 cm) and at harvest (192.07 cm) than the other spacings adopted.

The interaction effect between hybrids and spacings was found to be non-significant at 30 DAS, but became significant from 60 DAS onwards up to harvest. At harvest, ICH-5 hybrid sown at a spacing of 60 cm x 30 cm (H₁S₁) recorded the highest plant height (210.54 cm) and was significantly superior over all other hybrid and spacing combinations. These results were in accordance with the findings of Severino *et al.* (2017) [17] and

Aruna and Sagar (2016) [1].

4.1.2 Days to 50% flowering

The results on days to 50% flowering of castor are presented in Table 1. The results indicated that different castor hybrids and spacing levels showed significance to attain 50% flowering whereas their interaction was non-significant.

Among the hybrids, ICH-5 (H₁) and ICH-6 (H₂) reached 50% flowering earlier (51 days) and were at par with each other. In contrast, PCH-111 (H₃) required significantly more time (61 days) to attain 50% flowering. The delayed flowering in PCH-111 (H₃) might be attributed to its inherent genetic character and longer vegetative phase. These results were in accordance with the findings of Murugan and Akhila (2020) [12].

Among the spacing treatments, the closer spacing of 60 cm x 30 cm (S₁) recorded the earliest flowering (51 days), which was comparable with 75 cm x 30 cm (S₃) (52 days). However, days to 50% flowering were delayed in wider spacing 60 cm x 60 cm (S₂) (59 days) and 90 cm x 45 cm (S₅) (57 days). The earliness under closer spacing might be due to increased plant density, which enhances competition for light and nutrients, thereby accelerating the transition from vegetative to reproductive phase. The present findings substantiate the results reported earlier by Anbarasu *et al.* (2018) [2].

4.1.3 No. of Capsules per spike⁻¹

The data pertaining to the number of capsules per spike as influenced by castor hybrids and spacings levels are presented in Table 1.

Castor hybrids showed a significant influence on the number of capsules per spike. Among the hybrids, ICH-5 (H₁) (59) recorded the highest number of capsules per spike, which was significantly superior to ICH-6 (H₂) (54) and PCH-111 (H₃), (55) which were statistically on par with each other. The superior performance of ICH-5 (H₁) might be attributed to its better genetic potential, more plant height, higher dry matter accumulation and a better source sink relationship established and efficient translocation of assimilates towards reproductive parts, which resulted in improved capsule filling and retention. Thereby increasing the total number of capsules per spike. The findings closely resemble those reported by Umesha *et al.* and Maheshwaran *et al.* Spacing levels also exerted a significant influence on capsules per spike. The highest number of capsules per spike was recorded under 90 cm x 45 cm (S₅) (62), which was significantly superior to all other treatments. This was followed by 90 cm x 30 cm (S₄) (58), 60 cm x 60 cm (S₂) (55) and 75 cm x 30 cm (S₃) (55), which were found to be statistically on par. The lowest number of capsules per spike was observed under 60 cm x 30 cm (S₁) (50). The findings are in line with the findings of Aruna and Sagar (2016) [1].

Although a spacing of 90 cm x 60 cm is generally recommended, the present investigation indicated that 90 cm x 30 cm (S₄) and 90 cm x 45 cm (S₅) were more optimal under the given conditions, as they maintained a better balance between plant population and resource availability, ultimately enhancing capsule filling and increasing the number of capsules per spike. The similar coincidence was reported by Reager *et al.* (2016) [16].

4.1.4 Dry matter production

Dry matter production increased progressively with growth from 30 DAS to harvest and was significantly influenced by hybrids and spacings at all growth stages.

At 30 DAS, among hybrids, ICH-6 (H₂) recorded highest dry

matter production (332 kg ha^{-1}), which is significantly superior than ICH-5 (H_1) (284 kg ha^{-1}) and PCH-111 (H_3) (194 kg ha^{-1}). The lowest dry matter production is observed in PCH-111 (H_3) (194 kg ha^{-1}).

Among different spacings, high density spacing $60 \text{ cm} \times 30 \text{ cm}$ (S_1) recorded significantly higher dry matter (395 kg ha^{-1}), which is significantly superior than other treatments. The lowest dry matter dry matter is recorded with $90 \text{ cm} \times 45 \text{ cm}$ (S_5) ($175 \text{ cm kg ha}^{-1}$). The superiority of $60 \text{ cm} \times 30 \text{ cm}$ spacing in terms of dry matter production can be attributed to the maintenance of a higher plant population ($55,555 \text{ plants ha}^{-1}$), which enhanced ground coverage, light interception and cumulative photosynthetic activity per unit area. Although individual plants grown under wider spacings exhibited greater growth, the reduced plant population limited total biomass production on a hectare basis. Similar findings have been reported by Moshkin (1986) ^[11] and Severino *et al.* (2012) ^[17].

4.1.5 Primary Spike Length

Primary spike length was significantly influenced by both hybrids and spacing, and their interaction was also significant. Among the hybrids, ICH-5 produced the longest primary spike, followed by PCH-111, while ICH-6 recorded the shortest spike length. The superior performance of ICH-5 may be attributed to its better genetic potential for spike development, greater female flower retention, and efficient utilization of available resources. Among spacing treatments, $90 \text{ cm} \times 45 \text{ cm}$ recorded the highest primary spike length, followed by $75 \text{ cm} \times 30 \text{ cm}$ and $90 \text{ cm} \times 30 \text{ cm}$, whereas $60 \text{ cm} \times 30 \text{ cm}$ produced the lowest values. Wider spacing likely improved light interception, aeration, and nutrient availability, promoting better spike elongation, while closer spacing increased inter-plant competition, restricting spike growth. The interaction effect revealed that ICH-5 at $75 \text{ cm} \times 30 \text{ cm}$ recorded the maximum primary spike length, whereas PCH-111 at $60 \text{ cm} \times 30 \text{ cm}$ recorded the minimum. These findings agree with the reports of Severino *et al.* (2012) ^[17], Lavanya *et al.* (2012) ^[7], Ramesh *et al.* (2017), Meluca *et al.* (2022), and Pisal *et al.* (2018) ^[15].

4.1.6 Primary Effective Spike Length

Primary effective spike length was significantly affected by hybrids, spacing, and their interaction. ICH-5 recorded the highest primary effective spike length, followed by PCH-111, while ICH-6 recorded the lowest. This superiority may be due to enhanced retention of female flowers and efficient conversion of flowers into capsules, resulting in a longer effective fruiting zone. Among spacing treatments, $90 \text{ cm} \times 45 \text{ cm}$ produced the longest effective spike length, followed by $90 \text{ cm} \times 30 \text{ cm}$ and $75 \text{ cm} \times 30 \text{ cm}$, whereas $60 \text{ cm} \times 30 \text{ cm}$ recorded the shortest. The significant interaction indicated that ICH-5 planted at $75 \text{ cm} \times 30 \text{ cm}$ produced the highest primary effective spike length, while ICH-6 at $60 \text{ cm} \times 30 \text{ cm}$ recorded the lowest value. Improved spike development under optimum spacing was attributed to better availability of light, nutrients, moisture, and aeration, whereas closer spacing reduced effective spike length because of increased competition among plants. These findings are in agreement with Severino *et al.* (2012) ^[17], Lavanya *et al.* (2012) ^[7], Kumar and Venkatachalam (2017) ^[6].

4.2 Yield and yield attributes

4.2.1 Seed yield (kg ha^{-1})

Among hybrids, ICH-5 (H_1) recorded significantly higher seed yield (2666 kg ha^{-1}) followed by PCH-111 (H_3) (2455 kg ha^{-1}) and ICH-6 (H_2) (2179 kg ha^{-1}). The highest seed yield with ICH-

5 (H_1) might be due to better growth and yield attributes, such as higher dry matter production, spike length and number of capsules per spike⁻¹, which have a positive correlation with seed yield of castor. The lowest yield recorded in ICH-6 (H_2) (2179 kg ha^{-1}) might be due to poor source sink relationship and lower yield attributes. The findings are in line with Mishra and Tewari (2014) ^[10].

Among the spacings, $90 \text{ cm} \times 30 \text{ cm}$ (S_4) (3050 kg ha^{-1}) recorded significantly higher seed yield and was statistically on par with $90 \text{ cm} \times 45 \text{ cm}$ (S_5) (3001 kg ha^{-1}). The lowest seed yield was recorded with $60 \text{ cm} \times 30 \text{ cm}$ (S_1) (1395 kg ha^{-1}). Higher seed yield under $90 \text{ cm} \times 30 \text{ cm}$ (S_4) spacing might be attributed to optimum plant population coupled with better availability of growth resources such as light, moisture and nutrients, which favoured better development of yield attributes. Lower seed yield under high density might be due to severe competition with in the crop plants for available resources which resulted in decreased seed yield. Although the spacing ($90 \text{ cm} \times 45 \text{ cm}$) produced heavier seeds, the reduced plant population marginally limited yield realization on a hectare basis. On the other hand, the closer spacing of $60 \text{ cm} \times 30 \text{ cm}$ maintained a higher plant population but suffered from severe inter-plant competition, leading to reduced seed size and lower yield per plant, which ultimately decreased seed yield per unit area. Similar observations on the influence of hybrid and plant density interactions on castor productivity were reported by Moshkin (1986) ^[11], Severino *et al.* (2012) ^[17] and Lavanya *et al.* (2012) ^[7].

4.3 Economics

4.3.1 Gross Returns (₹ ha^{-1})

Among hybrids, the higher gross returns were realized in ICH-5 (H_1) ($1,46,619 \text{ ₹ ha}^{-1}$) which was significantly superior than other tested hybrids and lower gross returns ($1,19,845 \text{ ₹ ha}^{-1}$) was recorded with ICH-6 (H_2). The highest gross returns with ICH-5 (H_1) were mainly due to its higher seed yield. These results were in accordance with the findings of Jat and Patel (2023).

Among the different spacing treatments, significantly higher gross returns were realized with $90 \text{ cm} \times 30 \text{ cm}$ (S_4) ($₹1,67,75 \text{ cm}^0 \text{ ha}^{-1}$), which was on par with $90 \text{ cm} \times 45 \text{ cm}$ (S_5) ($₹1,64,468 \text{ ha}^{-1}$), while the lowest gross returns were recorded with $60 \text{ cm} \times 30 \text{ cm}$ (S_1) ($₹76,743 \text{ ha}^{-1}$). The higher gross returns obtained under these wider spacing treatments might be attributed to improved plant growth, enhanced availability of light, moisture and nutrients per plant, leading to higher seed yield and ultimately greater gross monetary returns (Dodiya *et al.* (2016) ^[4] and Paslawar *et al.* (2019) ^[14]).

With respect to the interaction combinations, ICH-5 grown at $90 \text{ cm} \times 45 \text{ cm}$ (H_1S_5) recorded the highest gross returns ($₹1,79,135 \text{ ha}^{-1}$), which was statistically on par with PCH-111 at $90 \text{ cm} \times 45 \text{ cm}$ (H_3S_5) ($₹1,78,585 \text{ ha}^{-1}$), ICH-5 at $90 \text{ cm} \times 30 \text{ cm}$ (H_1S_4) ($₹1,72,920 \text{ ha}^{-1}$), ICH-6 at $90 \text{ cm} \times 30 \text{ cm}$ (H_2S_4) ($₹1,66,375 \text{ cm ha}^{-1}$) and PCH-111 at $90 \text{ cm} \times 30 \text{ cm}$ (H_3S_4) ($₹1,63,955 \text{ ha}^{-1}$). The lowest gross returns were recorded by ICH-6 at $60 \text{ cm} \times 30 \text{ cm}$ (H_2S_1) ($₹63,360 \text{ cm ha}^{-1}$). These findings are in close agreement with those reported by Jat and Desai (2020) and Patel and Jat (2023).

4.3.2 Net Returns (₹ ha^{-1})

With respect to castor hybrids, significantly higher net returns were realized with ICH-5 (H_1) ($₹1,05,889 \text{ ha}^{-1}$), which was superior to the other tested hybrids, whereas the lowest net returns ($₹79,115 \text{ ha}^{-1}$) were recorded with the least-performing

hybrid ICH-6 (H₂).

The higher net returns obtained with ICH-5 (H₁) might be attributed to its superior seed yield, which resulted in higher income and greater net profit after meeting the cost of cultivation. These findings are in conformity with those reported by Jat and Desai (2020) and Patel and Jat (2023).

Among the spacing treatments, significantly higher net returns were recorded with 90 cm x 30 cm (S₄) (₹1,26,637 ha⁻¹), which was on par with 90 cm x 45 cm (S₅) (₹1,24,205 ha⁻¹). The lowest net returns were realized with 60 cm x 30 cm (S₁) (₹35,418 ha⁻¹). The higher net returns under these wider spacing treatments might be attributed to enhanced yield, which ultimately resulted in higher profitability. These findings are in conformity with those reported by Reager *et al.* (2016) [16].

The interaction effect of hybrids and spacings on net returns was found to be significant (Table 2). Among the treatment combinations, ICH-5 grown at 90 cm x 45 cm (H₁S₅) recorded the highest net returns (₹1,38,872 ha⁻¹), which was statistically on par with PCH-111 at 90 cm x 45 cm (H₃S₅) (₹1,38,322 ha⁻¹), ICH-5 at 90 cm x 30 cm (H₁S₄) (₹1,31,807 ha⁻¹), ICH-6 at 90 cm x 30 cm (H₂S₄) (₹1,25,262 ha⁻¹) and PCH-111 at 90 cm x 30 cm (H₃S₄) (₹122,842 ha⁻¹). The lowest net returns were recorded with ICH-6 at 60 cm x 30 cm (H₂S₁) (₹22,035 ha⁻¹).

The trend in net returns closely mirrored that of seed yield and gross returns, indicating that higher productivity was the primary factor contributing to increased profitability. The spacings of 90 cm x 30 cm and 90 cm x 45 cm provided favourable growing conditions, resulting in higher seed yields and consequently greater net returns. Among the hybrids, ICH-5 and PCH-111

performed better under wider planting geometries, translating their superior yield potential into higher economic gains.

In contrast, the lower net returns recorded under the closer spacing of 60 cm x 30 cm were mainly due to poor yield performance arising from increased inter-plant competition for growth resources. Similar findings were reported by Similar findings were reported by Paslawar *et al.* (2019) [14] and Patel and Jat (2023), who observed that improvements in seed yield through appropriate genotype selection and optimum plant spacing directly enhance farm profitability.

4.3.3 Benefit Cost Ratio

The benefit-cost ratio of castor was significantly influenced by different hybrids and spacings treatments. Among castor hybrids, the higher benefit cost ratio was realized in ICH-5 (H₁) (3.61) which was significantly superior than other tested hybrids and the lowest benefit cost ratio (2.94) was recorded with ICH-6 (H₂). The highest benefit cost ratio with ICH-5 (H₁) was mainly due to its higher seed yield. Jat and Desai 2020 reported similar result in their findings.

Among the different spacings treatments, a higher benefit cost ratio was realized with 90 cm x 30 cm (S₄) (4.09), which was on par with 90 cm x 45 cm (S₅) (4.08) and the lowest benefit cost ratio was realized in 60 cm x 30 cm (S₁) (1.86). Higher productivity and relatively lower cost of cultivation obtained under these resulted in an enhanced benefit cost ratio. These results were in accordance with the findings with Reager *et al.* (2016) [16].

Table 1: Growth parameters of castor as influenced by different castor hybrids and spacings during *kharif*, 2025

Treatments	Plant height (cm)					Dry matter production (kg ha ⁻¹)				
	30 DAS	60 DAS	90 DAS	120 DAS	At harvest	30 DAS	60 DAS	90 DAS	120 DAS	At harvest
Hybrids										
H ₁ : ICH-5	30.09	71.82	161.72	185.98	188.48	284	752	1823	1900	2300
H ₂ : ICH-6	26.91	64.61	159.77	176.93	179.27	332	691	1410	1649	1847
H ₃ : PCH-111	25.97	64.17	152.24	174.24	175.54	192	677	1108	1375	1496
SEm ±	0.72	1.1	1.34	1.75	1.28	6.93	16.61	30.01	44.3	46.7
CD (P=0.05)	2.09	3.20	3.90	5.09	3.72	20.2	48.4	87.4	129.1	136.1
Spacings										
S ₁ : 60 cm x 30 cm (55,555 plants ha ⁻¹)	31.07	79.18	172.84	189.80	192.07	395	1003	2026	2414	2758
S ₂ : 60 cm x 60 cm (27,777 plants ha ⁻¹)	24.20	57.37	145.57	169.50	172.11	199	556	1244	1246	1379
S ₃ : 75 cm x 30 cm (44,444 plants ha ⁻¹)	29.55	68.16	164.74	178.48	181.63	313	787	1593	1921	2206
S ₄ : 90 cm x 30 cm (37,037 plants ha ⁻¹)	28.27	68.77	154.15	177.69	180.11	261	683	1348	1640	1838
S ₅ : 90 cm x 45 cm (24,691 plants ha ⁻¹)	25.21	60.86	152.26	176.00	177.89	175	503	1040	1136	1225
SEm ±	0.93	1.42	1.73	2.26	1.65	8.95	21.4	38.7	57.2	60.3
CD (P=0.05)	2.69	4.14	5.03	6.57	4.80	26.1	62.4	112.8	166.6	175.7
Interaction (H X S)										
SEm ±	1.60	2.46	2.99	3.91	2.85	15.49	37.14	67.11	99.12	104.51
CD (P=0.05)	NS	7.17	8.71	11.38	8.31	45.1	108.1	195.4	288.6	NS

Table 2: Different growth parameters as influenced by different castor hybrids and spacings

Treatments	Days to 50% flowering	Primary spike length	Primary effective spike length	No. of capsules spike ⁻¹
Hybrids				
H ₁ : ICH-5	51	35.40	27.40	59
H ₂ : ICH-6	51	28.81	21.63	54
H ₃ : PCH-111	61	30.18	24.35	55
SEm ±	1.89	0.77	0.66	0.74
CD (P=0.05)	3.46	2.24	1.93	2.16
Spacings				
S ₁ : 60 cm x 30 cm (55,555 plants ha ⁻¹)	51	28.86	20.42	50
S ₂ : 60 cm x 60 cm (27,777 plants ha ⁻¹)	59	28.98	21.82	55
S ₃ : 75 cm x 30 cm (44,444 plants ha ⁻¹)	52	32.98	25.50	55
S ₄ : 90 cm x 30 cm (37,037 plants ha ⁻¹)	54	31.98	25.81	58
S ₅ : 90 cm x 45 cm (24,691 plants ha ⁻¹)	57	34.51	28.76	62
SEm ±	1.53	0.99	0.85	0.96
CD (P=0.05)	4.47	2.90 cm	2.49	2.79
Interaction				
SEm ±	2.66	1.72	1.48	1.66
CD (P=0.05)	NS	5.02	4.31	4.83

Table 3: Yield and yield attributes, economics of castor as influenced by different hybrids and spacings during, *kharif*, 2025.

Treatments	Seed yield	Gross returns	Net returns	Benefit -cost ratio
Hybrids				
H ₁ : ICH-5	2666	146619	105889	3.61
H ₂ : ICH-6	2179	119845	79115	2.94
H ₃ : PCH-111	2455	134728	93998	3.31
SEm ±	46.58	413.27	413.27	0.01
CD (P=0.05)	135.64	1203.38	1203.38	0.03
Spacings				
S ₁ : 60 cm x 30 cm (55,555 plants ha ⁻¹)	1395	35418	1.86	35418
S ₂ : 60 cm x 60 cm (27,777 plants ha ⁻¹)	2118	76209	2.89	76209
S ₃ : 75 cm x 30 cm (44,444 plants ha ⁻¹)	260 cm ⁴	102532	3.52	102532
S ₄ : 90 cm x 30 cm (37,037 plants ha ⁻¹)	3050	126637	4.09	126637
S ₅ : 90 cm x 45 cm (24,691 plants ha ⁻¹)	3001	124205	4.08	124205
SEm ±	60 cm.14	533.53	0.01	533.53
CD (P=0.05)	175 cm.11	1553.55	0.04	1553.55
Interaction (HXS)				
SEm ±	104.16	924.10	0.02	924.10
CD (P=0.05)	303.31	2690 cm.83	0.07	2690 cm.83

5. Conclusion

Overall, ICH-5 exhibited superior performance over the other hybrids with respect to growth, yield attributes, seed yield, economics and energetics. Among the spacing treatments, 90 cm x 30 cm and 90 cm x 45 cm were statistically comparable for seed yield, indicating that both spacing levels provided a favourable balance between plant population and individual plant performance. The enhanced productivity under these spacing treatments was associated with improved resource utilization, efficient assimilate partitioning and better expression of yield-contributing traits. Therefore, ICH-5 planted at either 90 cm x 30 cm or 90 cm x 45 cm may be recommended for achieving higher productivity, profitability and energy-use efficiency under mechanized castor cultivation.

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