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Evaluating the production potential and economic feasibility of castor (*Ricinus communis* L.) intercropping systems

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Abstract
The inter-cropping system based on castor cultivation creates a favorable microclimate for intercrops, leading to increased yields with a minimum investment. This system not only generates additional income per unit area but also offers ample opportunity for intercrops to thrive between castor rows, given castor's slow growth rate. Consequently, an experiment titled "Evaluating the production and economic feasibility of castor (*Ricinus communis* L.) intercropping systems" was led-out at the Regional Research Station, Bawal, CCSHAU during the 2020-21 *kharif* season. The primary objectives were to identify the most suitable intercrops for castor cultivation and to analyze the economic viability. The experiment followed a randomized block design and replicated thrice, comprising eleven treatments. These included sole crops of castor (DCH 177) at 150 and 200 cm row spacing, as well as green gram (MH 421), bajra (HHB 67 Imp.) and sesame (HT 2). Additionally, intercropping combinations of green gram, bajra and sesame with castor were tested in 2 and 4 row ratios. Results specified that significantly superior yields (both economic and biological) under castor sole system (200 cm), with yield values of 3,879 and 5,656 kg ha^{-1}, respectively. This performance was comparable to castor sole (150 cm) and the castor (150 cm) + green gram (2 rows) intercropping system. The highest system equivalent yield was recorded in the castor (200 cm) with green gram (4 rows) (4220 kg ha^{-1}) intercropping system. Economic assessment of the treatments found that the castor (200 cm) with green gram (4 rows) intercropping system yielded the higher net profit (Rs. 1,57,453 ha^{-1}) and with benefit-cost ratio of 3.78.

Keywords: Castor, green gram, bajra, sesame, intercropping, equivalent yield and net profit

Introduction
Castor is classified as an indeterminate, non-edible oilseed crop, belonging to the Euphorbiaceae family. Its origins trace back to Eastern Africa, with Ethiopia as its place of origin. Primarily cultivated in regions with low rainfall, particularly the semi-arid areas of India, due to its drought tolerance, India stands at the first in production of castor seed globally. Castor seeds boast an oil content ranging from 50-55%, marking it as the world's second major source of non-edible oil. The oil extracted from castor seeds finds extensive utility across a diverse spectrum of industries, including the production of hydraulic fluids, nylon fibres, cosmetics, jet engine lubricants and pharmaceuticals. Additionally, castor oil proves to be a viable candidate for biodiesel conversion. Furthermore, castor cake, a byproduct of oil extraction, serves as a valuable organic fertilizer, boasting high concentrations of nutrients. It contains approximately 4.5% nitrogen, 2.6% phosphorus and 1.2% potassium, alongside 22.37% protein and 45-46% carbohydrates, making it a potent organic supplement for soil enrichment.

Castor is typically cultivated as a long-term crop with wide spacing between plants. This allows for the possibility of intercropping with fast-growing, short-duration food grains, pulses and oilseed crops, arranged in a suitable pattern to enhance crop growth, yield production and productivity per unit time and land. Widening the row spacing for castor may reduce the plant density per acre, but the crop can compensate for yield loss by boosting the growth of plants and productivity of individual plants (Dhimmer *et al*., 2009) [1]. In castor intercropping system, by optimized or adjusting crop geometry will maximize the solar energy absorption (Willey, 1979) [9] and selecting appropriate intercrops.

Intercropping is familiar as a beneficial farming practice that can sustainably increase yields compared to monoculture practice. These advantages are particularly valuable as they are attained without requiring expensive inputs and they also contribute to improved crop growth. Intercropping offers insurance against complete crop failure and helps mitigate soil erosion, especially when subsidiary crops have trailing habits. Recognizing the promising potential of castor cultivation in the irrigated ecosystems of Southern-Western Haryana, efforts were made to maximize net returns. To optimize resource utilization, this study was designed to explore varied crop dimensions and incorporate short-duration intercrops in the underutilized inter-row spaces, leveraging the early slow growth phase of castor.

Materials and Methods

A research trail was led out from 2020 to 2021 at the RRS, Bawal (Rewari), under the auspices of CCSHAU, Hisar. The experimental site soil was characterized as loamy-sand with a slightly alkaline pH of 8.5. It exhibited low levels of organic carbon and nitrogen (0.21% and 125 kg ha^{-1}, respectively), with medium levels of phosphorus and potassium (16.2 and 195.4 kg ha^{-1}, respectively). The trial was organized using a randomized block design, encompassing eleven treatments involving both sole and diverse intercropping systems, with each treatment replicated thrice. DCH-177 was the castor hybrid, MH-421, HHB-67 Imp. and HT-2 were the varieties of green gram, bajra and sesame, respectively, were sown on July 10th, with intercrops spaced at 30 cm x 10 cm in rows. The duration of the crop season witnessed a total rainfall of 312.9 mm. Harvesting occurred at three intervals, namely 120, 180 and 240 days after sowing (DAS), respectively. All necessary intercultural management practices adhered to the prescribed package of practices recommended by CCSHAU.

Results and Discussion

The seed and stalk yield of castor exhibited significant differences as a result of varying intercropping methods within two distinct row spacings for castor cultivation

The findings from Table 1 suggest that the economic yield of castor increases with wider intercropping spacing of 200 cm compared to narrower spacing of 150 cm. Castor grown alone yields higher seed output than when intercropped, mainly due to competition from other crops for resources. Among the intercrops, castor demonstrates higher seed yield when intercropped with green gram. Both 150 cm and 200 cm row spacings for green gram show similar yields, outperforming intercropping with bajra at their respective spacings. This could be attributed to the nitrogen enrichment of the soil by legumes, facilitating castor growth post-legume harvest, a concept supported by Reddy *et al*. (2008) [6], who noted pulses' complementary effect and cereals' competitive effect when intercropped with castor. In three different 4 rows system, castor + bajra intercropping system at 200 cm spacing yields the lowest equated to other row ratios. Emphasizing that wider row system enhances yield of castor compared to narrower spacings (Rana *et al.* 2006) [5]. Additionally, studies by Narayan Mavarkar (2006) [4] and Leela Rani (2008) [2] suggest that intercropping with leguminous crops enhances yield of castor compared to non-leguminous ones, despite an overall decrease in seed yield under intercropping compared to monocropping.

The outcomes presented in Table 1 indicate that sole castor cultivation (200 cm) led to significantly higher economic and biological yields, likely due to the presence of a superior number of yield-contributing factors. This finding aligns with the observations of Mohsin *et al*. (2018) [3], who also noted comparable outcomes in intercropping involving castor. Notably, sole castor planting yielded higher stalks compared to various intercropping arrangements.

Aside from competitive effects, the predominant prices of economic yield serve as a supplementary factor in determining the components of an intercropping system. Consequently, the intercrops yield was converted into equivalent yield of castor and added to the castor yield. Equivalent yield (Table 2) of castor showed significant increases in castor (200 cm) + green gram (4 rows) and castor (150 cm) + green gram (2 rows) intercropping systems compared to sole systems and other intercropping systems. This could be attributed to both the higher price and yield of greengram, as well as the less decrease in main crop seed yield in this particular intercropping systems. These findings align with the observations of Narayan Mavarkar (2006) [4] and Thanunathan *et al*. (2006) [7]. The higher system equivalent yield was in the castor with greengram intercropping system by Mohsin *et al.* (2018) [3]. Conversely, a greater reduction in equivalent yield of system was observed in bajra and sesame intercropping systems, resulting in lesser castor equivalent yield. This corroborates the findings of Vaghela *et al.* (2019) [8], who similarly noted that intercropping of bajra and sesame under castor cropping system has shown lesser system equivalent yield equated to the green gram intercropping system.

Intercropping treatments demonstrated significantly higher economic returns, in-terms of both gross and net returns, correlated to castor monoculture cropping, as illustrated in Table 3. Amid different intercropping systems, combinations such as castor (200 cm) with green gram (4 rows) and castor (150 cm) with green gram (2 rows) intercropping systems yielded the highest net returns, surpassing both sole cropping and intercropping systems cultivation. This superior economic performance could be attributed due to the higher yields obtained from both main crop and intercrops within these systems. Notably, the castor with green gram (4 rows) intercropping system stood out with a remarkable net return of Rs. 1,57,453 ha^{-1} and a B:C ratio of 3.78. This result was mainly due to the high yield of green gram and the relatively minor reduction in castor economic yield of within this intercropping arrangement. Similar findings were observed by Mohsin *et al.* (2018) [3], who also noted elevated net profit and B:C ratios in castor-green gram intercropping setups. However, intercropping castor with bajra and sesame led to a decrease in castor economic yield due to a suppressive effect on castor crop growth. Consequently, economic returns were diminished equated to sole cropping and other intercropping systems cultivation. This observation aligns with previous studies by Vaghela *et al.* (2019) [8], who found that intercropping castor with summer sesame or summer bajra resulted in lower gross and net returns compared to intercropping with summer green gram.

Table 1: Yield variation in castor and various intercrops under different intercropping systems

Treatments		Yield (kg ha^{-1})			
		Economic		Biological	
		Castor	Inter-crop	Castor	Inter-crop
T_1	Sole castor (150 cm)	3,840	-	5,648	-
T_2	Sole castor (200 cm)	3,879	-	5,656	-
T_3	Sole green gram	-	1,402	-	4,137
T_4	Sole bajra	-	3,002	-	6,504
T_5	Sole sesame	-	556	-	1,631
T_6	T_1 + green gram (2 rows)	3,547	551	5,248	1,681
T_7	T_1 + bajra (2 rows)	3,020	1,200	4,566	2,846
T_8	T_1 + sesame (2 rows)	3,443	157	5,150	463
T_9	T_2 + green gram (4 rows)	3,250	970	4,792	2,953
T_{10}	T_2 + bajra (4 rows)	2,410	2,414	3,628	5,233
T_{11}	T_2 + sesame (4 rows)	3,195	327	4,751	960
	SEm±	110	61	164	154
	CD at 5%	339	185	504	467

Table 2: Impact of various intercropping methods on equivalent yield of castor

	Treatments	CEY (kg ha^{-1})
T_1		
T_2	Sole castor (200 cm)	3,879
T_3	Sole green gram	-
T_4	Sole bajra	-
T_5	Sole sesame	-
T_6	T_1 + green gram (2 rows)	4,098
T_7	T_1 + bajra (2 rows)	3,570
T_8	T_1 + sesame (2 rows)	3,680
T_9	T_2 + green gram (4 rows)	4,220
T_{10}	T_2 + bajra (4 rows)	3,516
T_{11}	T_2 + sesame (4 rows)	3,686
	SEm±	120
	CD at 5%	367

Table 3: Economic comparison of castor based intercropping treatments

Treatments		Gross returns (Rs. ha^{-1})	Cost of cultivation (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C
T_1	Sole castor (150 cm)	1,88,011	53,612	1,34,399	3.51
T_2	Sole castor (200 cm)	1,89,801	51,742	1,38,059	3.67
T_3	Sole green gram	70,439	30,458	39,981	2.31
T_4	Sole bajra	72,688	41,434	31,254	1.75
T_5	Sole sesame	69,527	24,643	44,884	2.82
T_6	T_1 + green gram (2 rows)	2,02,643	57,362	1,45,281	3.53
T_7	T_1 + bajra (2 rows)	1,76,729	56,092	1,20,637	3.15
T_8	T_1 + sesame (2 rows)	1,97,397	56,072	1,41,325	3.52
T_9	T_2 + green gram (4 rows)	2,14,055	56,602	1,57,453	3.78
T_{10}	T_2 + bajra (4 rows)	1,76,441	54,682	1,21,759	3.23
T_{11}	T_2 + sesame (4 rows)	2,02,493	54,572	1,47,921	3.71

Fig 1: Overview of experimental site

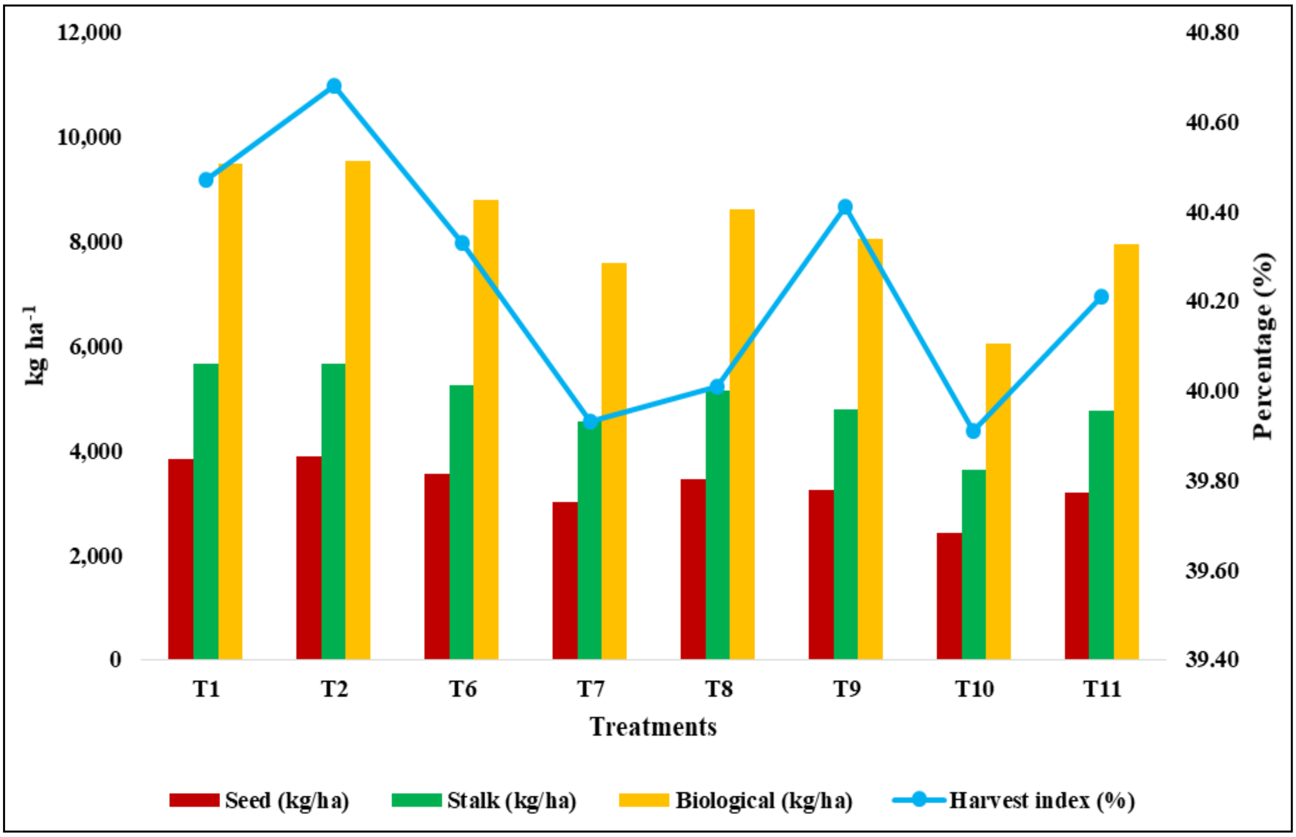

Fig 2: Comparative analysis of treatments on castor crop yield and harvest index

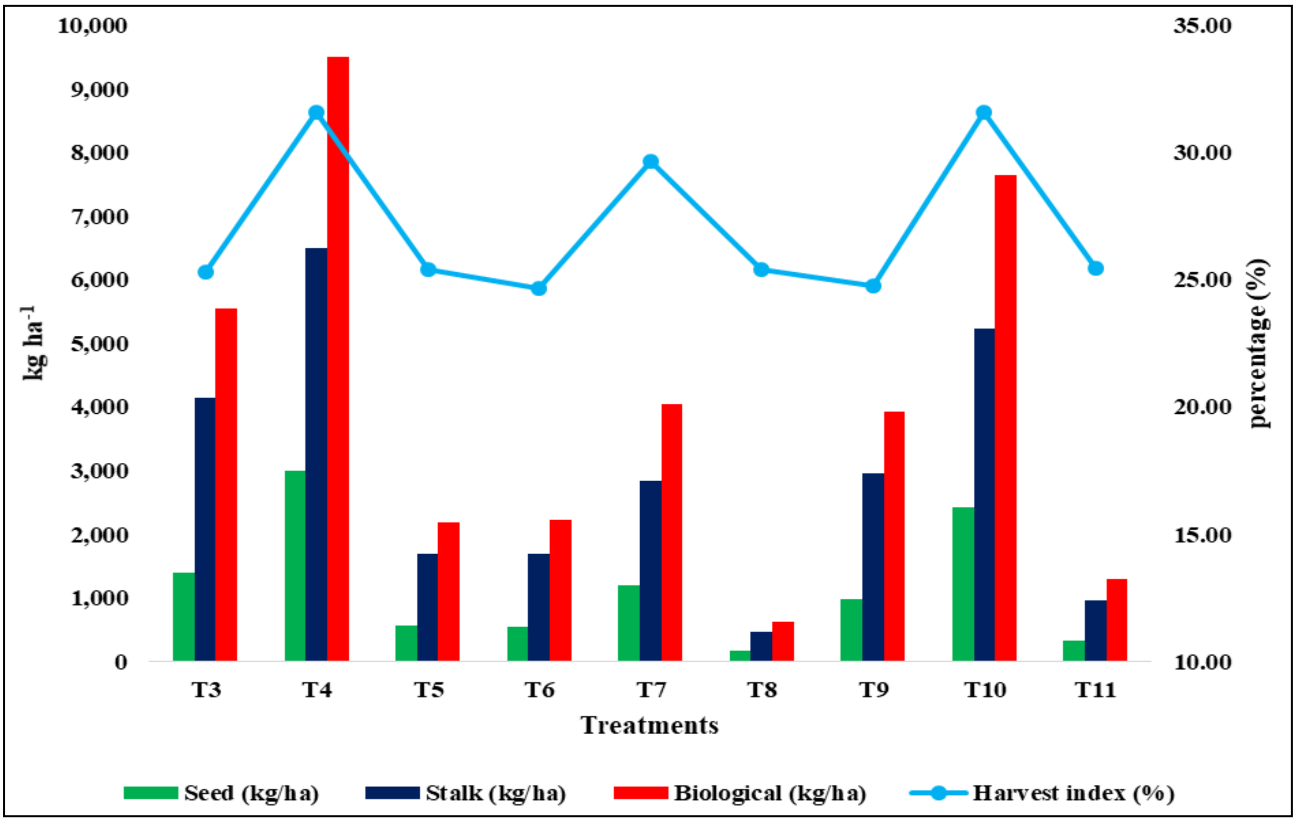

Fig 3: Evaluation of treatment variability on intercrop yield and harvest efficiency

Conclusion

This study reveals that incorporating legume intercropping with wider spacing leads to significant advantages, including increased castor yield, castor equivalent yield, net returns and B:C ratio compared to other intercropping and sole cropping systems. Specifically, the combination of castor (200 cm) and green gram in a 1:4 row ratio demonstrated superior performance over all other treatments. Consequently, intercropping systems prove to be higher sustainable and profitable than sole castor cultivation, offering greater remuneration to farmers of Haryana.

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