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Prospects of castor intercropping system on yield, intercropping indices and economics under semi-arid region of Haryana

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Abstract

A field experiment was conducted at Regional Research Station, Bawal, CCS HAU during the *kharif* season of 2020-21 in the loamy sand soils to study the performance of castor based intercropping system with different row proportion and planting geometry. The results showed that significantly higher yields (seed and stalk) were recorded with values of 3,879 kg ha⁻¹ and 5,656 kg ha⁻¹, respectively in the sole castor (200 cm) which was at par with castor sole (150 cm) and castor (150 cm) + mungbean (1:2) intercropping system. The various intercropping indices computed among these intercropping systems *viz.* LER, ATER, A, RCC and CR indicated that pearl millet was most competitive and mungbean was most complementary among intercrops for base crop. The highest castor equivalent yield (4220 kg ha⁻¹), net returns (1,57,453 Rs. ha⁻¹) and B:C (3.78) was exhibited in castor (200 cm) + mungbean (1:4) intercropping system.

Keywords: Intercropping, planting geometry, intercropping indices, yield, net returns

1. Introduction

Castor (*Ricinus communis* L.) is an indeterminate and non-edible oilseed crop. It belongs to the family *Euphorbiaceae*. It is native to Eastern Africa and originated in Ethiopia, which is cultivated in low rainfall regions (drought tolerant) of the semi-arid region of India. India is the largest producer of castor in the world. Castor seeds contain 50-55 percent oil and are the world's second-largest source of non-edible oil. Castor oil is mainly used for the manufacture of wide range of ever-expanding industrial products such as nylon fibres, jet engine lubricants, hydraulic fluids, cosmetics, pharmaceuticals. Castor oil is a good choice for converting oil in to bio-diesel. Castor cake provides highly concentrated organic manure with 4.5, 2.6 and 1.2 percent of nitrogen, phosphorous and potash, respectively and it also offers 22.37 percent protein and 45-46 percent of carbohydrates.

However, castor is a long-term, widely spaced crop with a comparatively thin population of plants, providing scope for intercropping with quick growing and short duration food grain (cereal), pulse and oilseed crops in appropriate geometry to increase growth, yield and economics per unit area. Growing castor at wider row spacing reduces the plant population on acreage basis but castor can compensate the yield loss by increasing growth and yield of individual plant (Dhimmer *et al.*, 2009) [9]. Advantage of intercropping in castor can be increased by reorienting crop geometry for better availability of solar energy and putting suitable intercrops. Intercropping has been recognized as a potentially beneficial system of crop production which can provide sustained yield advantages compared to sole cropping. These advantages are especially important because they are achieved not by means of costly inputs but the simple expedient of growing crop together. It provides an insurance against total crop failure and also reduces soil erosion if the plants of the subsidiary crops have trailing habit. The success of intercropping is mainly dictated by crop compatibility, suitable modification in planting patterns and careful selection of crops which could reduce mutual competition between main and intercrop to a considerable extent. By looking to good proposal of castor in irrigated ecosystem of Southern-Western Haryana this was conducted to realize higher net return. In order to have best utilization of available resources, present study was planned with crop geometry and short duration intercrop between underutilized inter row space on account of initial slow growth of castor.

2. Material and Methods

A field experiment was conducted during 2020-21 at Regional Research Station, Bawal (Rewari), CCS Haryana Agricultural University. The soil of the experimental field was loamy sand in texture and slightly alkaline in reaction (pH 8.5), low in organic carbon (0.21%) and nitrogen (125 kg ha⁻¹), medium in available phosphorus (16.2 kg ha⁻¹) and potassium (195.4 kg ha⁻¹). The experiment was conducted in randomized block design with three replications. The intercropping system comprising of sole castor, castor + greengram, castor + pearl millet and castor + sesame, under two level of row spacing of castor, viz., 150 and 200 cm and made eleven treatment combinations viz., Sole castor (150 cm), Sole castor (200 cm), Sole greengram, Sole pearl millet, Sole sesame, Castor (150 cm) + greengram (1:2), Castor (150 cm) + pearl millet (1:2), Castor (150 cm) + sesame (1:2), Castor (200 cm) + greengram (1:4) and Castor (200 cm) + pearl millet (1:4), Castor (200 cm) + sesamum (1:4).

Castor hybrid DCH-177, greengram var. MH-421, pearl millet hybrid. HHB-67 Imp. and sesamum var. HT-2 were sown on 10 July. All intercrops are sown at 30 cm x 10 cm row spacing. The recommended half dose of N (45 kg ha⁻¹), full dose of P₂O₅ (45 kg ha⁻¹) and K₂O (25 kg ha⁻¹) was applied to castor through UREA, DAP and MOP at the time of sowing by drilling in furrows 5-8 cm below the seeds. Remaining 50 per cent N (45 kg ha⁻¹) was top dressed in two equal splits at 20 days crop growth stage and 30 days thereafter. Recommended dose of fertilizer for intercrops applied as per the package of CCSHAU, Hisar. In all the intercrops nitrogen was applied as top dressing. Castor was weeded manually twice 20 and 40 DAS. During the crop season there was 312.9 mm rainfall. Castor spikes has harvested in 5 pickings viz., 120, 150, 180, 230 and 270 days after sowing, respectively. All other intercultural practices were done as per package of practices.

3. Results

3.1 Yield parameters

3.1.1 Number of branches per plant

The data from Table 1 revealed that sole castor was sown with 200 cm gave significantly higher number of branches (13.20) over 150 cm (12.80) row spacing and intercropping treatments. Among different intercropping systems in least number of branches per plant were recorded in castor (150 cm) + pearl millet (8.0) in 1:2 row ratio system.

3.1.2 Number of spikes per plant

An examination of data in Table 1 represents that the effect of different treatments was found significant for number of spikes plant⁻¹ in castor. Sole castor (200 cm) recorded significantly maximum number of spikes per plant (18.47) as compared to all other treatments. The lowest number of spikes plant⁻¹ in the castor crop were recorded in 150 cm row spacing sown with two rows of pearl millet (11.90).

3.1.3 Number of capsules per spike

It is evident from the data given in Table 1 that effect of different legume, cereal and oilseed intercrops on castor was found significant for number of capsules primary spike⁻¹. Sole castor (200 cm) recorded significantly higher number of capsules per primary spike (89.33) as compared to all other treatments. The maximum reduction in the number of

capsules primary spike⁻¹ was observed in castor (150 cm) + Pearl millet (71.56) with 1:2 row ratio treatment.

3.1.4 Length of primary spike

A perusal of data presented in Table 1 showed that different intercropping systems and row spacing of castor did not exhibit any significant effect on length of primary spike of castor, however, it ranged from 52.27 to 60.60 cm among different treatments.

3.1.5 Seed index

Data pertaining to seed index presented in Table 1 revealed no significant difference on castor based intercropping systems under different row spacing, i.e., test weight of castor was not affected by different intercropping systems and row spacing.

3.2 Yields

3.2.1 Castor yield

Effect of different legume, cereal and oilseed intercrops in the two different row spacings of castor furnished in Table 2 revealed that castor yield (seed, stalk and biological) differed significantly under among different based intercropping systems.

3.2.1.1 Seed yield

The highest castor seed yield (3,879 kg ha⁻¹) was realized when castor crop was sown as sole in 200 cm row spacing than all other treatments. Among different intercropping systems, higher seed yield of castor was observed in castor sown with 150 cm row spacing with two rows of mungbean, sesame and pearl millet (3,547, 3,443 and 3,020 kg ha⁻¹, respectively) than castor sown in 200 cm row spacing with four rows of mungbean, sesame and pearl millet (3,250, 3,195 and 2,410 kg ha⁻¹, respectively).

3.2.1.2 Stalk yield

The maximum stalk yield was obtained in castor sole 200 cm row spacing (5,656.42 kg ha⁻¹) than all other intercropping systems. Among different intercropping systems between different row spacing of castor, higher stalk yield of castor was recorded in castor (150 cm) with two rows of mungbean, sesame and pearl millet (5,248, 5,150 and 4,566 kg ha⁻¹, respectively) than castor sown with 200 cm row spacing with four rows of mungbean, sesame and pearl millet intercrops (4,792, 4,751 and 3,628 kg ha⁻¹, respectively).

3.2.1.3 Biological yield

Highest biological yield (9535 kg ha⁻¹) of castor was obtained in sole castor (200 cm) which was found significantly higher than all other treatments. Among intercropping systems with two different row spacing of castor, higher biological yield of castor was observed in castor (150 cm) with two rows of mungbean, sesame and pearl millet (8,795, 8,605 and 7,586 kg ha⁻¹, respectively) than castor sown with 200 cm row spacing with four rows of mungbean, sesame and pearl millet (8,042, 7,946 and 6,038 kg ha⁻¹, respectively).

3.2.1.4 Harvest index

The harvest index of castor was not significantly affected with legume, cereal and oilseed intercrops in two row spacings of castor, however, it ranged from 39.91 to 40.68

percent among different treatments. The highest harvest index was noticed in sole castor at 200 cm spacing (40.68%) and lowest in castor (200 cm) + pearl millet (39.91%) in 1:2 row ratio intercropping system.

3.2.2 Studies on Intercrop

The legume, cereal and oilseed intercrops yield furnished in Table 2 exhibited that intercrop yield (seed, straw and biological) differed significantly among castor based intercropping system in both row spacings.

3.2.2.1 Seed yield of intercrops

The economic yields of all the intercrops i.e., mungbean, pearl millet and sesame differed significantly with castor based intercropping systems in 2 rows. All the three intercrops viz. mungbean, pearl millet and sesame produced higher seed yield in their respective sole stand i.e., 1,402, 3,002 and 556 kg ha⁻¹, respectively. Among intercropping system, higher yield of each intercrop was obtained in 200 cm castor row spacing with 4 rows of mungbean, pearl millet and sesame (970, 2,414 and 327 kg ha⁻¹, respectively) than 150 row spacing of castor with 2 rows ratio (551, 1,200 and 157 kg ha⁻¹, respectively).

3.2.2.2 Straw yield of intercrops

The data indicated that straw/stover yield of intercrops followed similar trend of economic (seed) yield. The maximum straw yield was recorded in the sole stands of mungbean, pearl millet and sesame (4,137, 6,504 and 1,631 kg ha⁻¹, respectively) and these were significantly superior over 1:4 row ratio (2,935, 5,233 and 960 kg ha⁻¹, respectively) and in 1:2 row ratio (1,681, 2846 and 463 kg ha⁻¹, respectively) in both 200 and 150 cm intercropping systems.

3.2.2.3 Biological yield of intercrops

The biological yield also followed the trend as of seed and straw yield. The biological yield was recorded significantly higher by their respective sole stands of mungbean, pearl millet and sesame (5,539, 9,506 and 2,187 kg ha⁻¹) which remained significantly superior in 1:4 row ratio (3,924, 7,647 and 1,287 kg ha⁻¹, respectively) and in 1:2 row ratio (2,232, 4,047 and 621 kg ha⁻¹, respectively) treatments of both intercropping systems.

3.2.2.4 Harvest index of intercrops

The data showed significant effect on harvest index of intercrops due to castor based intercropping systems and two different rows. Mungbean, pearl millet and sesame intercrops had higher harvest index (25.31, 31.58 and 25.43, respectively) in their respective sole stands, as compared to 1:4 row ratio (24.74, 31.57 and 25.42, respectively) and in 1:2 row ratio (24.68, 29.67 and 25.41, respectively) intercropping treatments.

3.3 Assessment of intercropping advantages/competitive indices

The various intercropping indices were calculated based on sole and intercrop yields of castor, mungbean, pearl millet and sesame crops represented in Table 2 and 3.

3.3.1 Castor equivalent ratio

The data presented in Table 2 indicated that the different treatments had significant influence on castor equivalent

yield among various castor based intercropping system. Castor grown in 200 cm row spacing with mungbean (4,220 kg ha⁻¹) in 1:4 row ratio recorded higher castor equivalent yield than all other treatments and the lowest was recorded under castor (200 cm) + pearl millet (3,516 kg ha⁻¹) in 1:4 row ratio intercropping systems.

3.3.2 Land equivalent ratio

The Land Equivalent Ratio (LER) among all the intercropping treatments was greater than sole thereby indicating that intercropping of castor with mungbean, pearl millet and sesame was found superior as compared to than sole crop stand (Table 3). Castor (200 cm) + mungbean (1.53) in 1:4 row ratio showed maximum LER and the lowest LER was found in the 1:2 row ratio of castor (150 cm) + sesame intercropping system (1.18).

3.3.3 Income equivalent ratio

Income equivalent ratio (IER) is conversion of land equivalent ratio (LER) into economic terms. The data related to IER in Table 3 revealed that it followed the trend of LER and maximum IER was noted in castor (200 cm) + mungbean (1.53) in 1:4 row ratio and minimum was observed in the 1:2 row ratio of castor (150 cm) + sesame (1.18) intercropping system.

3.3.4 Area time-equivalent ratio

Area time-equivalent ratio (ATER) evaluated crops yield on per day basis and values of ATER among different intercropping treatments have been shown in Table 3. The intercropping of castor (150 cm) + mungbean (1.01) in 1:2 row ratio had highest ATER and castor (200 cm) + pearl millet (0.81) in 1:4 row ratio system had lowest ATER.

3.3.5 Aggressivity

The Aggressivity (A) values in Table 3 explain that highest aggressivity was recorded in intercropping system of castor with sesame in 1:4 row ratio (0.034). Positive values of aggressivity of castor among all the intercropping systems showed dominance of main crop in intercropping treatments. The intercrops had negative aggressivity thereby representing poor competitiveness of these crops when grown as intercrop with castor. Highest negative value of aggressivity was recorded in castor (200) + sesame (-0.034) in 1:4 row ratio intercropping system, indicating more dominance of sesame to the castor as compared to mungbean and pearl millet.

3.3.6 Relative crowding coefficient

The data in the Table 3 indicated that highest crowding coefficient of castor was recorded in 1:2 row ratio of castor (150 cm) with mungbean (24.24) and the least value was recorded in castor + pearl millet (6.56) with 1:4 row ratio intercropping system. Crowding coefficient among different intercrops varied from 0.20 to 1.03. All intercrops had less crowding coefficient than main crop (castor) which indicated that castor produced more yield than expected in the intercropping systems. Total crowding coefficient had greater than unity indicates yield advantage. The highest value of total crowding coefficient was noticed in castor (150 cm) + mungbean (24.56) in 1:2 row ratio and the least in castor (200 cm) + pearl millet (7.59) with row ratio of 1:4 intercropping system. Castor (200 cm) + pearl millet in 1:4 row ratio intercropping system was found as non-

advantageous intercropping system than all other intercropping systems.

3.3.7 Competitive ratio

The perusal data of in the Table 3 specified that the highest competitive ratio of castor was recorded in 1:2 row ratio castor (150 cm) + sesame cropping system (6.31). Higher competitive ratio indicated that the castor crop was more competitive in this system. The highest competitive ratio among intercrops was found in castor + pearl millet (0.32) with 1:4 row ratio indicated that pearl millet was more competitive the castor crop than sesame and mungbean.

3.3.8 Monetary advantage index

Maximum monetary advantage index (MAI) was found in mungbean intercropped with castor in 1:4 row ratio (Rs. 40,849 ha⁻¹), indicated most profitable and sustainable intercropping system whereas, sesame intercropped with castor in 1:2 row ratio intercropping system (Rs.3,795 ha⁻¹) recorded lowest MAI.

3.4, Economics

Gross returns, cost of cultivation, net returns and B:C presented in Table 4 were calculated based on sole and intercrop yields of castor, mungbean, pearl millet and sesame with respect to their prevailing market prices and input costs.

3.4.1 Gross returns

The perusal of data revealed that highest gross returns were found from castor (200 cm) + mungbean with 1:4 row ratio intercropping system (Rs. 2,14,055 ha⁻¹) and lowest gross income was obtained in castor (200 cm) + pearl millet (Rs. 1,17,962 ha⁻¹) in 1:4 row ratio.

3.4.2 Cost of cultivation

The data indicated that highest cost of cultivation was in the castor (150 cm) + mungbean (Rs. 57,362 ha⁻¹) with 1:2 row ratio intercropping system and cost of cultivation minimum in castor (200 cm) + sesame (Rs. 54,572 ha⁻¹) with 1:4 row intercropping system.

3.4.3 Net returns

The net returns (Rs. ha⁻¹) realized from different sole and different intercropping systems, which indicated that 200 cm row spaced castor with mungbean (Rs. 1,57,453 ha⁻¹) in 1:4 row ratio intercropping system recorded maximum net returns and least in the castor (200 cm) + pearl millet (Rs. 1,20,637 ha⁻¹) in 1:2 row ratio intercropping system.

3.4.4 Benefit cost ratio

The data reviewed and concluded that highest B: C was exhibited in 200 cm row spaced castor with mungbean in 1:4 row ratio (3.78) and lowest B: C ratio was reported in castor (150 cm) + pearl millet in 1:2 row ratio intercropping system (3.15).

4. Discussion

The present study entitled, "Prospects of castor intercropping system on yield, intercropping indices and economics under semi-arid region of Haryana" was conducted during *kharif* season of 2020-21 aimed to predict the best intercrop with suitable row ratio in castor whereby, a farmer will get full harvest of castor yield and possible

additional returns with different intercrops. Therefore, three intercrops *viz.*, mungbean, pearl millet and sesame were intercropped with castor at 1:2 and 1:4 row ratios within spacing of castor at 150 and 200 cm, respectively and were compared to the sole castor. In this chapter, it is intended to discuss the variations observed in phenological stages, growth parameters, yield attributes, yield, and competitive indices of intercrops under different treatments. This efficiency depends on all crop components and how those components interact with each other. In this chapter, the attempt has been made to discuss the cause and effect relationship behind those variations that occurred due to different intercropping treatments. The results of the study are discussed and described in light of available evidences and literature of all other workers in this area, from earlier findings. The complete discussion has been divided in following heading for better understanding.

4.1 Influence of different sole and intercropping systems on yield attributes of castor

Length of primary spike, number of spikes plant⁻¹, number of branches plant⁻¹ and number of capsules primary spike⁻¹ were highest in sole castor at 200 cm as compared to other intercropping system (Table 1). This was due to increased amount of light interception, availability of more space, less competition for nutrients, water and light. Mohsin *et al.* (2018) [7] and Keshavamurthy and Yadav (2019) [5] in castor sole (240 cm) also recorded better yield attributes (Length of primary spike, number of spikes plant⁻¹, number of branches plant⁻¹ and number of capsules primary spike⁻¹). Daisy *et al.* (2013) [3] also reported that wider row spacing in castor recorded higher number of spikes plant⁻¹ and number of branches plant⁻¹. Among intercrops highest number of spikes plant⁻¹ and number of capsules primary spike⁻¹ was obtained when castor (200 cm) was intercropped with mungbean (1:4) and corroborated by Mohsin *et al.* (2018) [7] and Porwal *et al.* (2006) [9]. The data in Table 1 indicated that different treatments had no significant effect on seed index of castor. Sharma (1985) also reported that 100 seed weight of castor did not differ significantly due to altered crop geometry. Mohsin *et al.* (2018) [7], Keshavamurthy and Yadav (2019) [5], Kumar (2002) [17] and Patel *et al.* (2007) [8] also reported similar results.

4.2 Performance of castor as affected by different treatments

Seed, stalk and biological yield of castor showed significantly difference due to different intercropping's in two row spacing of castor except the harvest index. The data (Table 2) indicated that seed yield of castor increased in wider intercropping system of 200 cm over narrow row spacing of 150 cm. In row spacing of 150 cm, seed yield of castor decreased due to lesser yield attributes as compared to sole castor at 200 cm. Sole planted castor recorded higher seed yield than intercropping system due to competition offered by these intercrops for natural resources. Castor (200 cm) + pearl millet in 1:4 row ratio system recorded lowest yield among all intercropping system of 1:2 and 1:4 row ratio. Among different intercrops, higher seed yield in castor was obtained when castor was intercropped with mungbean. Intercropping of mungbean in two row spacing of 150 and 200 cm remained at par to each other but superior than intercropping with pearl millet in their respective row spacings. This might be due to the fact

that legume might have improved nitrogen status of the soil on account of atmospheric N-fixation which was utilized by castor after harvest of legumes. Rana *et al.* (2006) [10] also recorded similar results that wider row spacing (90 cm) produced high castor yield than castor spaced at 60 and 75 inter-row spacing.

The data (Table 2) showed that significantly higher stalk and biological yield were recorded under sole castor (200 cm) which could be attributed due to a greater number of yield attributing characters. Mohsin *et al.* (2018) [7] also reported similar results in castor-based intercropping. Castor sole planting obtained higher stalk and biological yield as compared to different intercropping systems.

The harvest index (Table 2) of castor (39.91 to 40.68%) showed no significant difference among castor based intercropping systems with mungbean, pearl millet and sesame over sole castor.

4.3 Influence of different treatments on yield of intercrops

The Table 2 indicated that seed, stover, biological yield and harvest index of mungbean, pearl millet and sesame were higher in 1:4 as compared to 1:2 row proportion due to their higher plant densities as intercrops. Sole planting of intercrop has recorded higher seed, stalk and biological yield. Among different intercropping system, higher seed yield was obtained in pearl millet, mungbean and sesame in 1:4 row ratio with castor (200 cm) intercropping system. Vaghela *et al.* (2019) [14] reported same results that pearl millet had recorded higher seed yield than mungbean and sesame. Between two different row ratio, lower yield was obtained in sesame compared to other intercrops. Agarwal (2005) [1] also obtained similar result that sesame recorded lowest yield than other intercrops of greengram, black gram and cluster bean. The straw and biological yields also followed the trend of seed yield.

The maximum value of harvest index was recorded in pearl millet (31.58%), sesame (25.43%) and mungbean (25.31%) in their sole stands whereas, in 1:2 row ratio was 29.67, 25.41 and 24.68 percent, respectively and in 1:4 row ratio exhibited 31.57, 25.43 and 24.74 percent, respectively with castor intercropping system.

4.4 Assessment of different intercropping systems based on various evaluation indices

The various intercropping advantages/competitive indices were calculated based on sole and intercrop yields of castor, mungbean, pearl millet and sesame crops are represented in Table 3.

Castor equivalent yield showed significantly difference due to different intercropping systems and row spacing of castor (Table 2). Apart from the competitive effects, prevailing prices of economic produce become an additional factor in choosing the components of intercropping system and so yield of intercrops were converted to castor equivalent yield and added to castor yield. Castor equivalent yield was significantly higher in castor (200 cm) + mungbean (1:4) and castor (150 cm) + mungbean (1:2) intercropping systems over sole castor and other intercropping systems which might be due to high price along with higher yield of greengram as well as less reduction of castor seed yield in this intercropping system. The results are accordance with those findings of Mohsin *et al.* (2018) [7], who reported higher castor equivalent yield in castor + greengram

intercropping system. The reduction of castor seed yield was recorded more in intercropping with pearl millet and sesame; therefore, lower castor equivalent yield was obtained. Vaghela *et al.* (2019) [14] reported similar results that castor intercropped with pearl millet and sesame recorded lower castor equivalent yield compared to mungbean intercropping system.

The land equivalent ratio (LER) signifies relative land area required under sole stand to produce equivalent yield in intercropping system under same management practices (Willey, 1979) [16]. In terms of LER, castor (200 cm) + mungbean (1:4) had maximum yield advantage. The LER value of 1.53 indicated that 53 percent more land area will be required by sole castor crop to produce equivalent yield of this system. The yield advantage indicated greater efficiency of intercropping systems and efficient use of resources per unit area (Varia and Sadhu, 2011) [15].

Similar trend was observed in income equivalent ratio (IER). Maximum IER (1.53) was observed in castor (200 cm) + mungbean intercropping system of 1:4 row ratio. Higher IER values (greater than one) among various intercropping systems depicted superiority of intercropping treatments over sole castor cultivation. Singh *et al.* (2005) [13] reported that intercropping of both pearl millet and green gram in cluster bean was compatible as witnessed by the biological parameters like land equivalent ratio, area time equivalent ratio, income equivalent ratio, monetary advantage index and crowding coefficient were more as compared to sole cluster bean.

ATER value indicates utilization of available land and space efficiently with respect to time. The value of ATER ranged from 0.81 to 1.01 in different intercropping systems. Maximum ATER value was observed in castor (150 cm) + mungbean in 1:2 row ratio (1.01) and followed by castor (200 cm) + mungbean with 1:4 row ratio (0.99), which indicated higher complementary effect of mungbean in 1:2 and 1:4 row ratio with castor and has least competition as compared to other intercropping treatments. Corroborative results were also reported by Baishya *et al.* (2014) [2] in maize who reported that intercropping system of cereals and legumes (maize-green gram) had higher area time equivalent ratio (1.19) in 1:1 row ratio.

The positive values of aggressivity of castor and negative values of intercrops mungbean, pearl millet and sesame indicated that castor was dominant component in intercropping system. The highest values of castor aggressivity was recorded in intercropping treatment of castor (200 cm) with sesame in 1:4 row ratio (0.034) followed by castor (200 cm) + mungbean in 1:4 row ratio (0.33) which showed that castor was more dominant in these intercropping systems. The higher value of intercrop aggressivity in castor (200 cm) + sesame (1:4) indicated that sesame was relatively more aggressive in comparison to mungbean and pearl millet.

Castor with higher values (6.56 to 24.24) of crowding coefficient than intercrops (0.20 to 1.03) indicated its dominance in the system. Highest value of castor crowding coefficient was recorded in castor (150 cm) + mungbean (24.24) with 1:2 row ratio intercropping system which was followed by castor (200 cm) + mungbean (20.67) in 1:4 row ratio system thereby, indicating that these were the most complementary combination among all cropping systems. Among the different intercrops, highest value of castor

crowding coefficient was recorded in castor (200 cm) + pearl millet (1.03) in 1:4 row ratio.

The castor competitive ratio was greater (3.09 to 6.31) than intercrops (0.16 to 0.32) indicated more competitiveness of castor over intercrops. Among different intercropping systems, castor (200 cm) + pearl millet (0.32) in 1:4 row ratio showed more competitive than other intercrops within same row ratio. Among different treatments highest competitive ratio of castor was observed in castor (150 cm) + sesame (6.31) intercropping system of 1:2 row ratio.

The highest monetary advantage index (MAI) was noticed in castor (200 cm) + mungbean (Rs. 40,849 ha⁻¹) intercropping system with 1:4 row ratio which was followed by castor (200 cm) + pearl millet (Rs. 38,453.65 ha⁻¹) and castor (200 cm) + sesame (Rs. 16,580.46 ha⁻¹) in 1:4 row ratio. Renu (2016) found that the greater values of MAI observed in pearl millet and mungbean intercropping system, which also contributed by the greater LER and net returns as compared to other systems.

4.5 Economic evaluation of different treatments

The economic returns as clarified by gross and net returns were significantly higher in intercropping treatments as compared to sole castor (Table 4). Looking to the economics, castor (200 cm) + mungbean (1:4) and castor (150 cm) + mungbean (1:2) gave higher gross and net returns realization than other intercropping systems and sole castor. This could be due to higher yield of castor as well as intercrops in intercropping systems. Castor + mungbean

(1:4) intercropping system gave highest gross (Rs. 2,14,055 ha⁻¹) and net returns (Rs. 1,57,453 ha⁻¹) due to higher yield of mungbean as well as less reduction in seed yield of castor. Mohsin *et al.* (2018) [17] also found similar results that castor mungbean intercropping had recorded higher net returns. Castor intercropping with sesame and pearl millet reported lower seed yield of castor because of suppress in effect on castor growth and ultimately economic returns was decreased as compared to other intercropping systems and their sole crops. Corroborative results were also reported by Vaghela *et al.* (2019) [14] that castor + summer sesame and castor + summer pearl millet intercropping system gave less gross and net returns when compared with castor + summer mungbean intercropping system.

In terms of B:C, maximum value was recorded in castor (200 cm) + mungbean (3.78) with 1:4 row ratio. Mohsin *et al.* (2018) [7] reported that castor intercropped with mungbean at different row ratio has maximum B:C as compared to their respective sole cropping system. The range of B: C among treatments was between 1.75 to 3.78. Therefore, intercropping system of castor (200 cm) + mungbean in 1:4 row ratio was found more efficient in terms of gross and net returns as compared to sole crop in terms of benefit: cost. The least B: C was observed in castor (150 cm) + pearl millet (3.18) with 1:2 row ratio. Similar results were also reported by Vaghela *et al.* (2019) [14] that castor + summer sesame and castor + summer pearl millet intercropping system realized less B:C as compared to castor + summer mungbean intercropping system.

Table 1: Impact of different intercropping systems on castor yield attributes

Treatments		No. of branches plant ⁻¹	Length of primary spike (cm)	No. of spikes plant ⁻¹	No. of capsules primary spike ⁻¹	Seed index (g)
T ₁	Castor sole (150cm)	12.80	57.73	17.87	81.11	31.92
T ₂	Castor sole (200cm)	13.20	60.60	18.47	89.33	32.29
T ₃	Mungbean sole	-	-	-	-	-
T ₄	Pearl millet sole	-	-	-	-	-
T ₅	Sesame sole	-	-	-	-	-
T ₆	T1 + Mungbean (1:2)	10.73	56.87	14.53	72.78	31.12
T ₇	T1 + Pearl millet (1:2)	8.00	52.27	11.90	71.56	30.40
T ₈	T1 + Sesame (1:2)	9.87	56.07	13.27	72.67	30.67
T ₉	T2 + Mungbean (1:4)	12.47	54.80	17.80	80.50	31.50
T ₁₀	T2 + Pearl millet (1:4)	8.47	53.40	12.87	72.04	31.54
T ₁₁	T2 + Sesame (1:4)	10.61	52.60	14.80	74.44	31.87
	S.Em±	0.59	3.69	1.03	2.96	1.09
	C.D. (p=0.05)	1.81	N S	3.16	9.06	N S

Table 2: Influence of different intercropping systems on seed, stalk, biological yield and harvest index of castor crop

Treatments	Seed Yield (kg ha ⁻¹)		Stalk Yield (kg ha ⁻¹)		Biological Yield (kg ha ⁻¹)		Harvest index (%)		CEY (kg ha ⁻¹)	
	Castor	Intercrop	Castor	Intercrop	Castor	Intercrop	Castor	Intercrop		
T ₁	Castor sole (150cm)	3,840	-	5,648	-	9,488	-	40.47	-	3,840
T ₂	Castor sole (200cm)	3,879	-	5,656	-	9,535	-	40.68	-	3,879
T ₃	Mungbean sole	-	1,402	-	4,137	-	5,539	-	25.31	-
T ₄	Pearl millet sole	-	3,002	-	6,504	-	9,506	-	31.58	-
T ₅	Sesame sole	-	556	-	1,631	-	2,187	-	25.43	-
T ₆	T1 + Mungbean (1:2)	3,547	551	5,248	1,681	8,795	2,232	40.33	24.68	4,098
T ₇	T1 + Pearl millet (1:2)	3,020	1,200	4,566	2,846	7,586	4,047	39.93	29.67	3,570
T ₈	T1 + Sesame (1:2)	3,443	157	5,150	463	8,605	621	40.01	25.41	3,680
T ₉	T2 + Mungbean (1:4)	3,250	970	4,792	2,953	8,042	3,924	40.41	24.74	4,220
T ₁₀	T2 + Pearl millet (1:4)	2,410	2,414	3,628	5,233	6,038	7,647	39.91	31.57	3,516
T ₁₁	T2 + Sesame (1:4)	3,195	327	4,751	960	7,946	1,287	40.21	25.42	3,686
	S.Em±	110	61	164	154	275	215	1.54	1.42	120
	C.D. (p=0.05)	339	185	504	467	844	651	N S	4.29	367

Table 3: Intercropping indices as affected by different intercropping systems

Treatments	LER	IER (Rs. ha ⁻¹)	ATER	Aggressivity		Crowding coefficient			Competitive ratio		MAI (Rs. ha ⁻¹)
				Castor	Intercrop	Castor	Intercrop	Total	Castor	Intercrop	
T ₆ T1 + Mungbean (1:2)	1.32	1.33	1.01	0.022	-0.022	24.24	0.32	24.56	4.70	0.21	14,740
T ₇ T1 + Pearl millet (1:2)	1.19	1.19	0.88	0.018	-0.018	7.37	0.33	7.70	3.93	0.25	9,080
T ₈ T1 + Sesame (1:2)	1.18	1.18	0.95	0.023	-0.023	17.35	0.20	17.55	6.31	0.16	3,795
T ₉ T2 + Mungbean (1:4)	1.53	1.53	0.99	0.033	-0.033	20.67	0.56	21.23	4.84	0.21	40,849
T ₁₀ T2 + Pearl millet (1:4)	1.43	1.43	0.81	0.021	-0.021	6.56	1.03	7.59	3.09	0.32	38,453
T ₁₁ T2 + Sesame (1:4)	1.41	1.41	0.93	0.034	-0.034	18.70	0.36	19.05	5.60	0.18	16,580

Table 4: Economic evaluation of different treatments

Treatments	Gross returns (Rs. ha ⁻¹)	Cost of cultivation (Rs. ha ⁻¹)	Net returns (Rs. ha ⁻¹)	B:C
T ₁ Castor sole (150cm)	1,88,011	53,612	1,34,399	3.51
T ₂ Castor sole (200cm)	1,89,801	51,742	1,38,059	3.67
T ₃ Mungbean sole	70,439	30,458	39,981	2.31
T ₄ Pearl millet sole	72,688	41,434	31,254	1.75
T ₅ Sesame sole	69,527	24,643	44,884	2.82
T ₆ T1 + Mungbean (1:2)	2,02,643	57,362	1,45,281	3.53
T ₇ T1 + Pearl millet (1:2)	1,76,729	56,092	1,20,637	3.15
T ₈ T1 + Sesame (1:2)	1,97,397	56,072	1,41,325	3.52
T ₉ T2 + Mungbean (1:4)	2,14,055	56,602	1,57,453	3.78
T ₁₀ T2 + Pearl millet (1:4)	1,76,441	54,682	1,21,759	3.23
T ₁₁ T2 + Sesame (1:4)	2,02,493	54,572	1,47,921	3.71



Fig 1: Field view of Experimentation area



Fig 2: Castor (200 cm) + mungbean (1:4)



Fig 2: Castor (200 cm) + pearl millet (1:4)

5, Conclusion

Intercropping studies carried out in castor crop with legume, cereal and oilseeds exhibited the superiority of treatments castor (200 cm) + mungbean in 1:4 row ratio in terms of castor equivalent yield, gross returns, net returns and benefit: cost over sole castor crop. Assessment of yield advantages through various indices also revealed the higher values of Land Equivalent Ratio (LER), Income Equivalent Ratio (IER), Area Time Equivalent Ratio (ATER) and Monetary Advantage Index (MAI) of this treatment. Hence intercropping system marked superior over sole castor and found more profitable and sustainable as compared with sole castor on sandy loam soils of South-Western regions of Haryana.

Authorship Contribution Statement

Dr. J. S. Yadav

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Appendix

Price of Outputs		
Sr. No.	Particulars	Price (₹ kg ⁻¹)
1	Castor seed	48
2	Mung bean	48
3	Pearl millet seed	22
4	Sesame	72