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IMPACT OF SULPHUR FERTILIZATION ON GROWTH AND YIELD ATTRIBUTES OF CASTOR (*RICINUS COMMUNIS* L.) UNDER INTERCROPPING SYSTEMS IN SEMI-ARID REGION OF RAJASTHAN, INDIA

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ABSTRACT

An investigation was carried out during *Kharif* season of 2023 & 2024 at Instructional Farm, SKNCOA, Jobner, Rajasthan, to investigate, "Impact of Sulphur Fertilization on Growth and Yield Attributes of Castor (*Ricinus communis* L.) under Intercropping Systems in Semi-Arid Region of Rajasthan". The treatment comprised of five intercropping systems, viz., Sole castor, I_2: Castor + Mungbean, I_3: Castor + Cowpea, I_4: Castor + Clusterbean, I_5: Castor + Groundnut as main plots and four levels of sulphur viz., S_0: Control, S_1: 20 kg/ha, S_2: 40 kg/ha, S_3: 60 kg/ha as sub plots replicated thrice in a split plot design. Results revealed that among the intercropping system, maximum plant height, dry matter accumulation, number of spikes per plant and number of capsules per spike were observed under the sole castor treatment which was found significantly higher over rest of the treatments. Under different legume intercropping, castor + groundnut provided to be most compatible system, yielding superior growth and yield attributes compared to the other legume-based cropping system. In case of sulphur fertilization, application of sulphur at 60 kg/ha and 40 kg/ha resulted in statistically similar plant height, dry matter accumulation, number of spikes per plant and number of capsules per spike but found significantly higher over control with no sulphur application and 20 kg S/ha. Intercropping systems and sulphur fertilization failed to influence the number of seeds per capsule and the seed index of castor.

Key words: Intercropping, Sulphur, Cropping system, Legume, Capsule, Dry matter.

Introduction

Castor (*Ricinus communis* L.) is a non-edible oilseed crop belonging to family *Euphorbiaceae*. Castor seeds contain about 45–50% oil which is completely biodegradable and valued for its diverse industrial applications (Mansingh *et al.*, 2022). Castor oil is widely utilized as a lubricant, non-drying oil, medicinal ingredient and fuel for aero-engines and serve as a precursor in the synthesis of sebacic acid for nylon and fibre industries. It is used in the manufacture of perfume hair oils, dyes, printing inks and in leather processing industries. Castor stem pulp is used for paper production, while its leaves are used for rearing silkworm. Castor cake is rich in nitrogen (4.5%), phosphorus (2.6%) and potassium (1.0%) also serves as excellent organic manure although it is unsuitable for cattle feed due to the presence of toxic ricin (Ghilotia *et al.*, 2019).

Castor is predominantly cultivated in arid and semi-arid regions, with major producers being India, Mozambique, Brazil, China, Thailand and Myanmar. India, castor was cultivated over an area of 9.65 lakh hectare with a production of nearly 17.86 lakh tonnes and an average productivity of about 1852 kg ha^{-1} (Anonymous, 2024-25). During 2024–25, Gujarat accounts for the largest share in area (6.46 lakh ha) and production (13.61 lakh tonnes), followed by Rajasthan, Andhra Pradesh, Karnataka and Odisha. Its cultivation in Rajasthan is concentrated mainly in Sirohi, Jalore, Barmer, Pali, Hanumangarh, Bhilwara, Chittorgarh and Udaipur districts. In Rajasthan, castor is grown in an area of 2.55 lakh hectare with production and productivity of 3.91 lakh tonnes and 1535 kg/ha, respectively (Anonymous, 2024-25). Castor is predominantly cultivated under rainfed conditions on sandy and marginal soils, where its long duration, wider spacing and initial slow growth provide an excellent opportunity for intercropping with fast-growing and short-duration cereal, pulse and oilseed crops in suitable spatial arrangements to enhance overall productivity and economic returns per unit area. Although wider row spacing reduces plant population on an area basis, castor plants have the ability to compensate for this reduction by increasing their individual growth and yield potential (Dhimmer and Raj, 2009). Advantage of intercropping in castor can be increased by reorienting crop geometry for better availability of solar energy and putting suitable intercrops (Gangadhar *et al*., 2023).

Intercropping refers to growing of two or more crops simultaneously on the same field with definite row arrangement. The most common goal of intercropping is to produce a greater yield on a given piece of land by making use of resources or ecological processes that would otherwise not be utilized by a single crop. Recent evidence suggests that there are substantial advantages of legumes intercropping, which are achieved not by means of costly inputs, but by the simple expedient of growing crops together in an appropriate geometry. Intercropping of castor with legumes is the most dominant intercropping system of castor growing regions of India (Kumawat *et al*., 2016).

The intercropping of castor with suitable crops has been found to be beneficial in fetching higher monetary returns. When legumes are grown in association with non-legumes, there is often advantage to the non-legumes from nitrogen fixed by the legumes (Sharma and Singh, 2014). Intercropping is an efficient strategy that can be followed with desirable outcome in the changing climatic scenario. Legumes enhance the soil by adding nitrogen, which benefits the crops grown alongside them in intercropping systems (Maitra *et al.*, 2019). Since legumes fix nitrogen from the air, they reduce competition for nitrogen from the soil, making this a highly efficient practice in mixed cropping setups. Compared to monocropping, using legumes in an intercropping system can lead to higher yields from the same area and greater resource efficiency. The synergy between legumes and non-leguminous plants often results in better yields because legumes enhance soil health through their relationship with rhizobia, which improves soil functions (Fustec *et al.*, 2010). Legume and oilseed intercropping, compared to growing these crops separately, enhances soil fertility, improves nutrient-use efficiency, and reduces the need for additional fertilizers, all while providing better yields and economic returns (Dowling *et al.*, 2021).

Sulphur plays a crucial role in enhancing productivity and quality of oilseed-based intercropping systems. Sulphur, considered the fourth major nutrient, and is essential for the synthesis of sulphur-containing amino acids (methionine, cysteine and cystine), vitamins (biotin, thiamine), chlorophyll and oils (Jamal *et al*., 2009). Its deficiency, reported widely in the soils of Rajasthan including Jaipur, Jodhpur and Udaipur (Tandon, 1986), results in poor growth, reduced branching, delayed maturity and low oil content in crops. In India, more than 41 per cent of the soils are deficient in sulphur (Singh, 2001). Adequate sulphur nutrition is therefore critical for improving seed yield, oil quality and overall system productivity in castor-based intercropping under rainfed conditions.

Sulphur Bentonite is a highly concentrated sulphur fertilizer containing 90% elemental sulphur blended with 10% bentonite clay, which functions as a binding and dispersing agent. After soil application, the bentonite absorbs moisture and swells, breaking the sulphur pastilles into microscopic particles. This fragmentation accelerates the microbial oxidation of sulphur into plant-available sulphate, thereby improving sulphur availability and ensuring its uniform distribution in the soil (Scherer, 2001). Given the ecological and economic significance of castor and the complementary benefits of legumes and sulphur nutrition, castor-based intercropping systems offer a promising strategy for improving resource-use efficiency, soil fertility and farmers' income in semi-arid regions. This necessitates systematic evaluation of suitable legume intercrops and optimum sulphur levels for enhancing growth, yield and profitability of castor under semi-arid region of Rajasthan.

Materials and Methods

The experiment was conducted during the *Kharif* seasons of 2022-23 and 2023-24 at Instructional Farm, S.K.N. College of Agriculture, Jobner, Jaipur which is located at latitude of 26^0 05' North, longitude of 75^0 28' East and at an altitude of 427 metre above mean sea level. This region falls under agro-climatic zone III-A (Semi-arid Eastern Plain Zone) of Rajasthan. The soil of experimental plot was sandy loam in texture, alkaline in

Table 1 : Experimental treatments.

Main plot (Intercropping)	Subplot (levels of sulphur)
I_1: Sole castor	S_0: Control
I_2: Castor + Mungbean	S_1: 20 kg/ha
I_3: Castor + Cowpea	S_2: 40 kg/ha
I_4: Castor + Clusterbean	S_3: 60 kg/ha
I_5: Castor + Groundnut	

reaction, poor in organic carbon with low available nitrogen and medium in available phosphorus and potassium. The soil of experiment field was also deficient in available sulphur. The experiment was laid out in the split plot design replicated three times.

Castor variety GCH 8 was sown with a seed rate of 5 kg/ ha at a spacing of 90 cm between the rows and 60 cm between the plants. The intercrop seeds were also dibbled as two rows in between two rows of castor at spacing of 30 cm between the rows and 10 cm between the plants. The intercropping was done using the additive series where castor + legumes had 100% castor population and 66% legumes population. Sulphur was applied through bentonite which containing 90% sulphur before sowing as per treatments and was incorporated well into the soil. The recommended dose of nitrogen for castor crop was 60 kg/ha. It was applied by farm yard manures (12 tonne ha^{-1}) to the experimental plots fifteen days prior to sowing. Plant height of castor was recorded from five randomly tagged plants in each plot by measuring from the base to the base of the top leaf at 60, 90, 120 DAS and at harvest, and the average was calculated. Dry matter accumulation was determined by uprooting three plants at 30, 60, 90, 120 DAS and at harvest, removing roots, air-drying followed by oven drying at 70°C for 72 hours to constant weight, and computing the average. Yield attributes were recorded by counting the number of spikes per plant, capsules per spike and seeds per capsule from tagged plants and averaging the values. The seed index was determined by counting and weighing 100 seeds using an electronic balance. The data underwent analysis of variance (ANOVA) in a split plot design and the results were presented at a significance level of 5% ($P = 0.05$) (Gomez and Gomez, 1984). Critical difference (CD) values were calculated to compare various treatment means accordingly.

Results and Discussion

Intercropping

Growth Parameters of Castor

The data pertaining to Table 2 and Fig. 1 revealed that sole castor recorded the maximum plant height at 60, 90, 120 DAS and at harvest and was significantly superior to all intercropping system, except castor + groundnut at 60 DAS. Pooled analysis indicates that sole castor increased plant height by 27.09, 15.70, 14.95 and 5.79 per cent at 60 DAS; 38.10, 20.09, 18.53 and 8.02 per cent at 90 DAS; 35.23, 20.52, 17.70 and 8.07 per cent at 120 DAS; and 35.63, 19.29, 17.93 and 7.83 per cent at harvest over castor + cowpea, castor + mungbean, castor + clusterbean and castor + groundnut intercropping system, respectively. The reduced plant height under intercropping may be due to early-stage competition from faster-growing intercrops and limited availability of resources such as light, water and nutrients. The reduction in castor height may be due to faster growth of intercrops in the initial stages suppressing the growth of main crop and castor being initially a slow grower. This competitive interaction negatively affected castor growth, particularly as it is a slow-growing crop initially. These findings are consistent with earlier studies reported by Patel *et al.* (2025), Sangeetha *et al.* (2023), Aruna and Chandrika (2023) and Keshavamurthy and Yadav (2019).

During both the years and on pooled data basis, intercropping systems did not show any significant effect on dry matter accumulation of castor at 30 DAS (Table 3). However, at later intervals of observation (60, 90, 120 DAS and at harvest), significant differences were observed among treatments. However, sole castor recorded the highest dry matter accumulation at all growth stages and was found significantly superior to all intercropping systems during both the years as well as in pooled analysis. Among the intercropping systems, castor + groundnut recorded significantly higher dry matter accumulation at all growth stages, whereas castor + clusterbean was found statistically at par with castor + mungbean during individual years and in pooled data. The lowest dry matter accumulation was recorded under castor + cowpea at all the intervals of observation. On the basis of pooled analysis, sole castor enhanced dry matter accumulation by 32.26, 20.62, 17.43 and 7.69 per cent at 90 DAS; 32.52, 20.86, 18.29 and 8.76 per cent at 120 DAS; and 29.62, 19.64, 18.00 and 8.55 per cent at harvest over castor + cowpea, castor + mungbean, castor + clusterbean and castor + groundnut intercropping systems, respectively. The higher dry matter accumulation in sole castor may be attributed to better availability and efficient utilization of growth resources such as light, water and nutrients, resulting in enhanced photosynthesis and translocation of assimilates from source to sink. In contrast, intercropping systems led to reduced dry matter accumulation due to interspecific competition, particularly during early growth stages when castor grows slowly

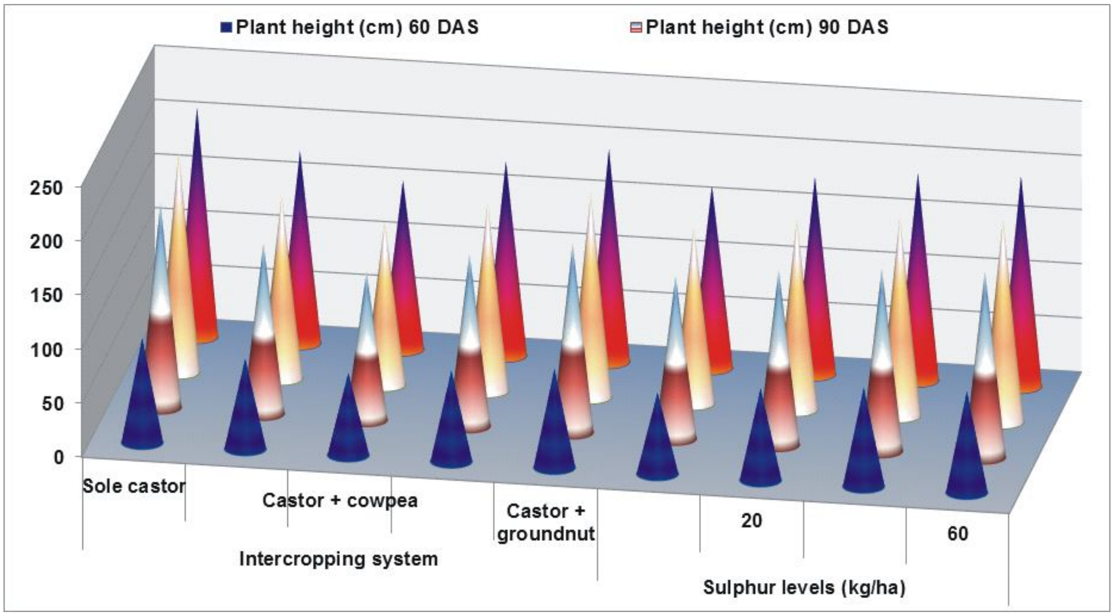

Fig. 1 : Effect of castor + legume intercropping systems and sulphur fertilization on plant height of castor.

Table 2 : Effect of castor + legume intercropping systems and sulphur fertilization on plant height of castor.

Treatments	Plant height (cm)											
	60 DAS			90 DAS			120 DAS			Harvest		
	2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled
Intercropping												
I_1	97.17	95.82	96.49	185.70	191.95	188.82	203.93	203.99	203.96	209.88	213.04	211.46
I_2	83.92	82.87	83.40	156.63	157.81	157.22	169.46	169.00	169.23	174.92	179.60	177.26
I_3	76.26	75.58	75.92	138.02	135.44	136.73	148.16	153.48	150.82	153.19	158.61	155.90
I_4	84.05	83.84	83.94	159.20	159.39	159.29	172.50	174.05	173.28	178.02	180.57	179.30
I_5	91.81	90.60	91.20	173.18	176.40	174.79	188.33	189.13	188.73	194.16	198.04	196.10
S.Em.±	2.13	2.02	1.47	3.53	3.49	2.48	4.48	4.11	3.04	4.63	4.20	3.12
CD (P = 0.05)	6.95	6.58	4.40	11.53	11.37	7.44	14.61	13.42	9.12	15.09	13.69	9.36
CV (%)	8.52	8.15	8.34	7.53	7.35	7.44	8.79	8.01	8.41	8.81	7.82	8.32
Sulphur levels (kg/ha)												
S_0	75.63	74.69	75.16	150.62	150.26	150.44	161.40	162.07	161.74	166.65	169.80	168.22
S_1	85.31	84.23	84.77	161.35	162.74	162.04	174.68	175.81	175.25	180.20	183.81	182.01
S_2	91.32	91.12	91.22	167.43	170.56	169.00	183.27	185.43	184.35	188.97	193.63	191.30
S_3	94.30	92.92	93.61	170.79	173.23	172.01	186.56	188.40	187.48	192.32	196.65	194.49
S.Em.±	1.58	1.76	1.18	2.82	2.51	1.89	4.00	3.52	2.66	3.88	3.59	2.65
CD (P = 0.05)	4.55	5.09	3.35	8.13	7.26	5.34	11.55	10.17	7.54	11.22	10.38	7.48
CV (%)	7.04	7.97	7.52	6.71	5.93	6.33	8.78	7.67	8.24	8.26	7.48	7.87

Note: I_1: Sole castor; I_2: Castor + mungbean; I_3: Castor + cowpea; I_4: Castor + clusterbean; I_5: Castor + groundnut; S_0: Control; S_1: 20 kg ha^{-1} S_2: 40 kg ha^{-1}; S_3: 60 kg ha^{-1}.

and intercrops establish rapidly. The relatively higher dry matter accumulation under castor + groundnut may be due to improved nutrient availability and reduced competition, while the lowest values under castor + cowpea might be due to its aggressive growth habit causing intense competition for both above- and below-ground resources. It is well established that crop combination and spatial arrangement in intercropping systems play a vital role in efficient utilization of growth resources and minimizing competition. These findings are in close agreement with the results reported by Keshavamurthy and Yadav (2019), Mohsin *et al*. (2018), Ghilotia *et al.* (2019) and Sangeetha *et al.* (2023).

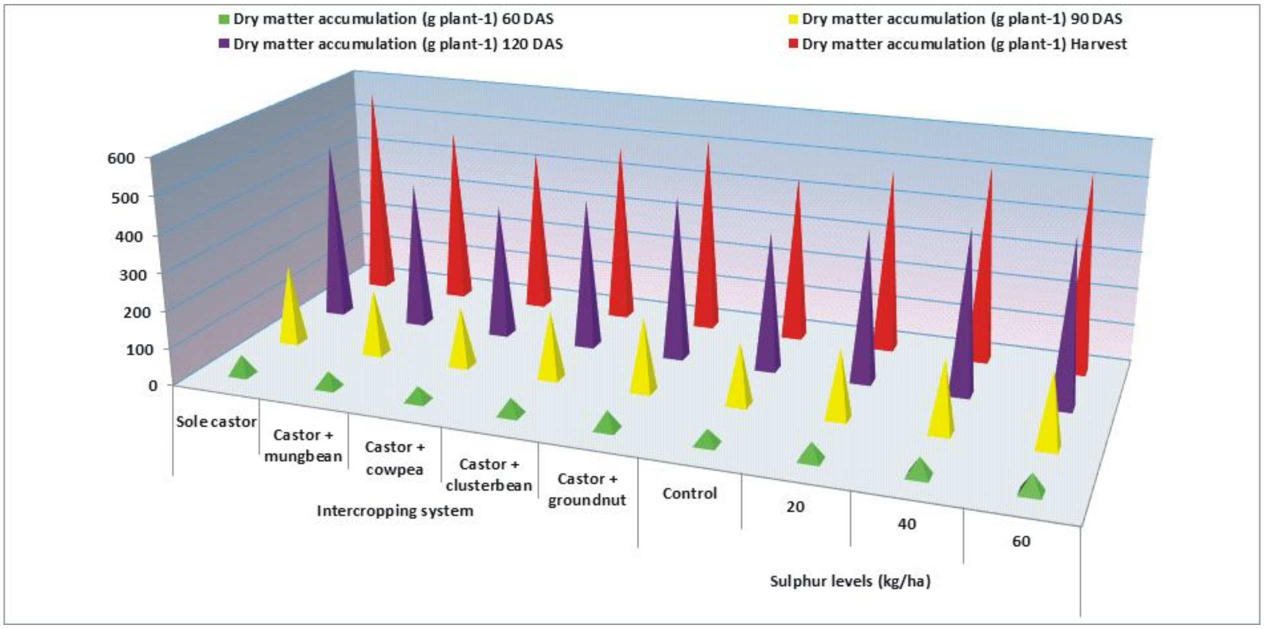

Fig. 2 : Effect of castor + legume intercropping systems and sulphur fertilization on dry matter accumulation of castor.

Yield attributes of castor

A critical examination of the data Table 4 and Fig. 3 revealed that Sole castor recorded the maximum number of spikes per plant (23.22, 23.05 and 23.14) and was found significantly superior to all intercropping treatments. Among the legume-based intercropping systems, castor + groundnut recorded significantly higher number of spikes per plant over other intercropping treatments, while castor + clusterbean was significantly superior to castor + cowpea but remained statistically at par with castor + mungbean. Pooled analysis indicated that sole castor increased the number of spikes per plant by 33.47, 20.29, 16.91 and 7.82 per cent over castor + cowpea, castor + mungbean, castor + clusterbean and castor + groundnut intercropping systems, respectively. The higher spike number under sole castor was due to absence of interspecific competition, whereas reduced values under intercropping were due to competition for light, water and nutrients. However, better performance of legume-based systems like groundnut and clusterbean may be attributed to complementary resource use and nitrogen fixation. These results are in agreement with earlier findings reported by Keshavamurthy and Yadav (2019), Vaghela *et al.* (2019), Kumar Naik *et al.* (2020), Gangadhar *et al.* (2022) and Aruna and Chandrika (2023).

Sole castor recorded the maximum number of capsules spike^{-1} (82.79, 83.08 and 82.94) and was found significantly superior to all intercropping treatments. Among the legume-based intercropping systems, castor + groundnut recorded significantly higher number of capsules spike^{-1} over other intercropping treatments. However, castor + clusterbean and castor + mungbean were found statistically at par with each other but remained significantly superior to castor + cowpea during both the years as well as in pooled analysis. Pooled analysis indicated that castor + groundnut increased the number of capsules spike^{-1} by 6.89, 10.29 and 18.29 per cent over castor + clusterbean, castor + mungbean and castor + cowpea, respectively. The higher capsule number under sole castor was due to better availability of resources and absence of competition, whereas reduced values under intercropping were due to interspecific competition. The better performance of castor + groundnut may be attributed to beneficial effects of legumes like nitrogen fixation and efficient resource use. These results are in agreement with earlier findings reported by Keshavamurthy and Yadav (2019), Vaghela *et al.* (2019), Gangadhar *et al.* (2022) and Aruna and Chandrika (2023).

Sulphur fertilization

Growth Parameters of Castor

A scrutiny of data in Table 2 revealed that sulphur fertilization exerted a significant positive influence on the vegetative growth of castor. Every incremental level of sulphur up to 40 kg S ha^{-1} significantly enhanced plant height over the control and 20 kg S ha^{-1} treatments. Applying 40 kg S ha^{-1} resulted in increase of 13.71% in plant height at harvest over the control; however, further increasing the dose to 60 kg S ha^{-1} did not result in additional significant gains in pooled analysis. The higher sulphur content in plants is known to have important role

Table 3 : Effect of castor + legume intercropping systems and sulphur fertilization on dry matter accumulation of castor.

Treatments	Dry matter accumulation (g plant^{-1})														
	30 DAS			60 DAS			90 DAS			120 DAS			Harvest		
	2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled
Intercropping															
I_1	12.07	11.35	11.71	54.80	53.10	53.95	216.1	210.0	213.1	478.65	476.88	477.77	573.92	571.83	572.87
I_2	11.83	11.09	11.46	44.60	42.86	43.73	179.7	173.5	176.6	401.08	389.52	395.30	482.23	475.43	478.83
I_3	11.82	11.38	11.60	39.83	38.90	39.37	162.7	159.4	161.1	367.65	353.36	360.50	447.63	434.20	440.91
I_4	11.71	11.13	11.42	45.70	44.45	45.07	183.6	179.2	181.4	409.24	398.55	403.89	491.79	479.13	485.46
I_5	11.27	11.61	11.44	50.22	49.14	49.68	199.8	195.9	197.8	445.89	432.63	439.26	535.57	519.88	527.72
S.Em.±	0.29	0.22	0.18	1.30	1.18	0.88	4.6	4.2	3.1	10.21	10.45	7.30	10.99	11.61	7.99
CD (p=0.05)	NS	NS	NS	4.24	3.86	2.64	15.1	13.8	9.4	33.29	34.08	21.90	35.85	37.86	23.97
CV (%)	8.45	6.62	7.63	9.58	8.97	9.29	8.5	8.0	8.3	8.41	8.82	8.61	7.52	8.11	7.81
Sulphur levels (kg/ha)															
S_0	11.94	11.64	11.79	41.31	39.75	40.53	168.0	162.5	165.2	369.97	368.68	369.33	446.44	446.98	446.71
S_1	11.97	11.46	11.71	46.57	45.06	45.81	186.8	181.4	184.1	412.63	398.18	405.40	496.91	481.89	489.40
S_2	11.81	11.11	11.46	49.46	48.32	48.89	197.1	193.0	195.0	446.09	432.51	439.30	536.50	522.50	529.50
S_3	11.24	11.04	11.14	50.78	49.62	50.20	201.8	197.6	199.7	453.32	441.38	447.35	545.06	533.00	539.03
S.Em.±	0.30	0.28	0.20	0.91	0.79	0.60	3.2	2.8	2.1	6.72	6.42	4.65	8.05	7.10	5.37
CD(p=0.05)	NS	NS	NS	2.63	2.29	1.71	9.4	8.2	6.1	19.41	18.55	13.15	23.26	20.49	15.18
CV (%)	9.76	9.59	9.68	7.49	6.72	7.13	6.7	6.0	6.3	6.19	6.06	6.13	6.16	5.54	5.86

Note: I_1: Sole castor; I_2: Castor + mungbean; I_3: Castor + cowpea; I_4: Castor + clusterbean; I_5: Castor + groundnut; S_0: Control; S_1: 20 kg ha^{-1} S_2: 40 kg ha^{-1}; S_3: 60 kg ha^{-1}.

in the better development and thickening of xylem and collenchyma tissues. These favourable results might have resulted in the stronger stem thereby increasing no. of spikes per plant. Mukhtar *et al.* (2022) recorded higher growth parameters of castor such as plant height, leaf area index with increasing doses of sulphur. The similar results were also reported by Kumar Naik *et al.* (2020), Pawar *et al.* (2023), Bhat *et al.* (2025).

Sulphur fertilization exerted a significant positive influence on the vegetative growth of castor. Every incremental level of sulphur up to 40 kg S ha^{-1} significantly enhanced dry matter accumulation over the control and 20 kg S ha^{-1} treatments (Table 3). Applying 40 kg S ha^{-1} resulted in a pooled increase of 18.53% in dry matter accumulation at harvest over the control; however, further increasing the dose to 60 kg S ha^{-1} did not result in additional significant gains, as both levels were statistically at par. The increase plant height under sulphur fertilization might be due to improved sulphur availability, which in turn enhanced the photosynthetic activity and plant metabolism resulting in to better growth. It is also obvious due to the fact that sulphur application has been reported to improve availability of sulphur itself and other nutrients, which are considered as important for growth and development of plants. The overall improvement in vegetative growth of crop with the sulphur application in present investigation is corroborate with the findings of Kumar *et al.* (2018), Meena *et al.* (2019) and Ghilotia *et al.* (2019).

Yield attributes of castor

Regarding sulphur fertilization, every increase in sulphur level up to 40 kg S ha^{-1} significantly enhanced these yield attributes (Table 4). Application of 40 kg S ha^{-1} recorded a significantly higher number of spikes per plant (21.56), which was found statistically at par with the 60 kg S ha^{-1} treatment. In the pooled analysis, 40 kg S ha^{-1} increased the number of spikes per plant by 24.39% over the control and 8.81% over the 20 kg S ha^{-1} level. The positive response to sulphur fertilization regarding the number of spikes is due to the pivotal role of sulphur in tissue differentiation from somatic to reproductive stages. Optimum sulphur supply enhances the translocation of photosynthates from the leaves to the reproductive sinks (capsules and seeds). Furthermore, sulphur is essential for chlorophyll synthesis and enzyme activation, which improves the overall nutritional environment of the plant, leading to better floral primordia initiation and seed setting. The results are supported by Kumar *et al.* (2018) and Meena *et al.* (2019), who noted that sulphur improves energy transformation and

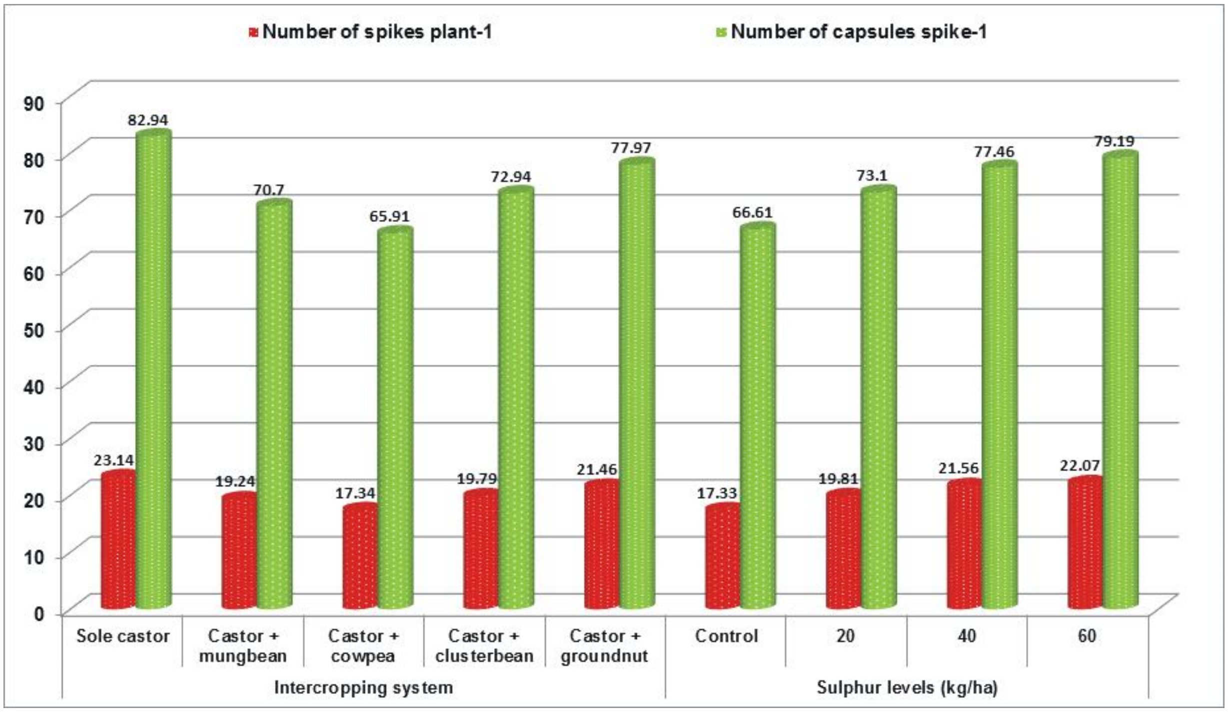

Fig. 3 : Effect of castor + legume intercropping systems and sulphur fertilization on yield attributes of castor.

Table 4: Effect of castor + legume intercropping systems and sulphur fertilization on yield attributes of castor.

Treatments	Number of spikes plant^{-1}			Number of capsules spike^{-1}			Number of seeds capsule^{-1}			Seed index (g)		
	2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled
Intercropping												
I_1	23.22	23.05	23.14	82.79	83.08	82.94	2.99	2.94	2.96	30.94	30.76	30.85
I_2	19.11	19.36	19.24	71.03	70.36	70.70	2.90	2.85	2.88	30.37	29.83	30.10
I_3	17.44	17.23	17.34	66.15	65.68	65.91	2.89	2.83	2.86	29.65	29.35	29.50
I_4	19.77	19.81	19.79	72.82	73.07	72.94	2.94	2.89	2.92	30.57	30.07	30.32
I_5	21.55	21.37	21.46	77.79	78.15	77.97	2.97	2.94	2.95	30.85	30.54	30.69
S.Em.±	0.49	0.47	0.34	1.40	1.43	1.00	0.07	0.06	0.05	0.78	0.68	0.52
CD (p= 0.05)	1.61	1.52	1.02	4.55	4.66	3.00	NS	NS	NS	NS	NS	NS
CV (%)	8.44	8.00	8.22	6.52	6.69	6.61	7.93	7.76	7.85	8.82	7.80	8.33
Sulphur levels (kg/ha)												
S_0	17.28	17.38	17.33	67.30	65.92	66.61	2.87	2.82	2.85	29.82	29.44	29.63
S_1	19.88	19.74	19.81	73.17	73.04	73.10	2.91	2.88	2.89	30.40	30.01	30.20
S_2	21.58	21.54	21.56	77.19	77.73	77.46	2.98	2.92	2.95	30.73	30.43	30.58
S_3	22.14	22.01	22.07	78.80	79.58	79.19	2.98	2.94	2.96	30.95	30.56	30.75
S.Em.±	0.39	0.43	0.29	1.23	1.28	0.89	0.06	0.04	0.04	0.60	0.56	0.41
CD (p= 0.05)	1.13	1.24	0.82	3.55	3.70	2.51	NS	NS	NS	NS	NS	NS
CV (%)	7.49	8.21	7.86	6.43	6.70	6.56	7.49	6.00	6.80	7.61	7.15	7.39

Note: I_1: Sole castor; I_2: Castor + mungbean; I_3: Castor + cowpea; I_4: Castor + clusterbean; I_5: Castor + groundnut; S_0: Control; S_1: 20 kg ha^{-1} S_2: 40 kg ha^{-1}; S_3: 60 kg ha^{-1}.

carbohydrate metabolism, directly impacting on number of spikes per plant.

Sulphur levels significantly influenced the number of capsules per spike of castor during both the years and in pooled analysis. Application of 60 kg S ha^{-1} recorded the highest number of capsules per spike, which was significantly superior to lower levels but remained statistically at par with 40 kg S ha^{-1}. Pooled data indicated that 40 and 60 kg S ha^{-1} increased capsule number by 16.28 and 18.88 per cent over control and by 5.96 and 8.33 per cent over 20 kg S ha^{-1}, respectively. Furthermore, with the increment in supply of sulphur, the process of tissue differentiation from somatic to reproductive, meristematic activity, and development of floral primordial might have increased, resulting in more flowers and capsules. When the supply of sulphur is optimum, greater translocation of photosynthates occurs from leaves to the site i.e., capsules and seeds. Sulphur is a very essential element which increases root growth, promotes nodule formation and stimulates seed formation. These findings corroborate with the findings of Kumar *et al.* (2018), Meena *et al.* (2019), and Ghilotia *et al.* (2019).

Data revealed that neither intercropping systems nor sulphur fertilization exerted a significant influence on the number of seeds per capsule and the seed index of castor. These parameters remained statistically uniform across all treatments, suggesting they are governed more by genetic factors than by the nutritional or competitive environment provided in this study (Table 4).

Conclusion

Based on the two years field experiment conducted to evaluate the performance of castor-based intercropping systems as influenced by sulphur fertilization under semi-arid region of Rajasthan, it can be concluded that sole castor exhibited the highest plant height, dry matter accumulation, number of spikes per plant and capsules per spike, which was significantly higher over rest of the treatments. Among the different intercropping system, castor + groundnut recorded the significantly higher growth and yield attributes. Under the sulphur fertilization, application of sulphur at 40 kg S/ha recorded the significantly higher plant height, dry matter accumulation, number of spikes per plant and capsules per spike over no application of sulphur and 20 kg S/ha, while it was found statistically at par with 60 kg S/ha.

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Conflict of interest

The author's declare that they have no conflict of interest.

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