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Sulphur levels on growth, yield parameters, yield, nutrient uptake, quality and economics of castor (*Ricinus communis.* L): A review

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Abstract
Castor, belong to non-edible oilseed crop plays an important role in industrial sector. Sulphur application to castor has positive effect in increasing the overall yield and quality of oil owing to composition of three amino acids *viz.*, cysteine, cysteine and methionine content. Sulpur application @ 40 kg ha^{-1} recorded higher growth, yield parameters, yield and better oil quality. The present paper is critical review on sulphur application effect on castor from the research findings of eminent researchers.

Keywords: Castor, sulphur, yield, quality

Introduction
Castor (*Ricinus communis* L.) is a non-edible, industrial oilseed crop, which plays an important role in Indian economy. The crop is well known for its non-edible oil (45-50% oil in seeds), which is completely biodegradable with its tremendous uses. India plays a lead role in the production and productivity of castor in the world with a production of 2.34 million tones seeds while China, producing 0.18 million tones of castor is the second largest producer (Anonymous, 2012) [1]. Cultivation of castor in India has mainly been confined to Gujarat, Andhra Pradesh, Telangana, Rajasthan and Tamil Nadu. Sulphur plays an important role in the formation of amino acids, synthesis of proteins, chlorophyll, oil content and nutritive quality (Jamal *et al.*, 2009) [18]. Sulphur has become one of the major limiting nutrients for oilseed crop production in recent years due to its widespread deficiency (Singh and Singh, 1999) [19]. Sulphur deficiency is responsible for stunted growth of the crop and subsequent reduction in the yield and quality of the crop (Singh, 1991) [20]. Use of non-sulphur fertilizers in intensive agricultural activities results soil sulphur deficiency in the country. On an average, oil seed crops including castor absorbs as much sulphur as they absorb phosphorus. Productivity of oil seed crops can be increased by application of sulphur (Tandon, 1995) [21]. Castor (*Ricinus communis* L.) is an important non edible oil seed crop widely grown in arid and semi-arid regions and plays an important role in the agricultural economy of the country by increasing substantial foreign exchange due to export of the castor oil, apart from fulfilling the internal demand of various industries. Castor oil has a wide range of uses in industries as lubricants, medicines for human and animals, non drying oil and fuel for operating aero engines. Castor oil is also used for producing sebacic acid for the synthesis of nylon and fibreto manufacture perfumed hair oil, cotton dye, printing ink and leather industries. Stem pulp of castor is used for manufacturing paper and its leaves are used for rearing silkworm. Castor cake is also used as manure.

Effect of sulphur application on growth and growth parameters of castor
Fyzee and Raju (1991) [2] obtained higher dry matter yield (1.91 t ha^{-1}) with sulphur application at 40 kg ha^{-1} as compared to 20 kg ha^{-1} recording lowest (1.77 t ha^{-1}) in castor. Sharma and Gupta (2003) [14] found that application of 60 kg ha^{-1} of sulphur gave significant increase in dry matter production to the tune of 18%, 31% and 38% compared to control in castor. Murthy and Muralidharudu (2003) [9] documented an significant increase in dry matter production of castor with increasing levels of sulphur fertilization in alfisol. Kumar *et al.*, (2018) [5] found that 60 kg ha^{-1} of sulphur fertilization gave maximum plant height and dry matter production at growth stages and harvest stages against control in castor.

Mukhtar *et al.*, (2022) [7] recorded higher growth parameters such as plant height, leaf area index with application of sulphur @ 60 kg ha^{-1} when compared to lower levels tried.

Effect of sulphur application on yield parameters of castor

Najeeb (1987) [11] found that yield attributes were significantly increased with 40 kg ha^{-1} of sulphur application compared to lower levels and control in castor. Anonymous, (2012) [1] reported that 20 kg ha^{-1} of sulphur application significantly increased the yield parameters *viz.*, length of spike, capsule number spike^{-1} and hundred seed weight in castor. Yield attributes were higher with application of 75 kg ha^{-1} of sulphur in castor against lower levels Sharma *et al.*, (2015) [13]. Application of 20 kg ha^{-1} of sulphur recorded maximum branches plant^{-1} (6.6 and 6.8), number of spikes plant^{-1} (7.1 and 8.0), spike length (56.7 and 50.5 cm) and capsules plant^{-1} (65.1 and 65.5) as compared to no application (4.8 and 5.3, 5.3 and 6.0, 44.3 and 43.3cm, 50.9 and 51.1) respectively in castor in two years Srivastava and Kumar (2015) [16]. Productive spikes plant^{-1} (9.33) and capsule number spike^{-1} (36.14) were higher with sulphur fertilization at 15 kg ha^{-1} over control in castor Kowser *et al.*, (2018) [4]. Muneshkumar *et al.*, (2019) [8] reported that yield attributes *viz.*, number of spikes plant (6.17), length of primary spike (37.43 cm), number of capsules spike^{-1} (45.27) and hundred seed weight (29.90 g) were significantly higher with 20 kg ha^{-1} of sulphur application compared to control (4.30, 32.10,40.23 and 24.60) respectively in DCH-177 castor. Similar results were obtained with YRCH-1, HCH-6 variety of castor from his study. Application of 60 kg ha of sulphur recorded maximum increase in number of branches plant^{-1}, number of spikes plant^{-1} and number of beans plant^{-1} castor Mukhtar *et al.*, (2022) [7]

Effect of sulphur application on yield of castor

Naik *et al.*, (1993) [10] recorded the higher seed yield with 100 mg sulphur kg^{-1} in altisol in castor. Srivastava (2007) [15] obtained a significant increase in seed yield (2577 kg ha^{-1}) with application of 20 kg ha^{-1} of sulphur compared to control (2087 kg ha^{-1}) in castor. Anonymous, (2012) [1] obtained higher seed yield with application of 20 kg ha^{-1} of sulphur application. Seed yield and stalk yield were significantly higher in castor with 75 kg ha^{-1} of sulphur application than lower levels Sharma *et al.*, (2015) [13]. Seed yield was higher with sulphur application at 20 kg ha^{-1} (2685 kg ha^{-1}and 2716 kg ha^{-1}) over control (2093 kg ha^{-1} and 2138 kg ha^{-1}) in castor Srivastava and Kumar (2015) [16]. Castor bean yield (1356 kg ha^{-1}) was maximum with sulphur application at 15 kg ha^{-1} against no application Kowser *et al.*, (2018) [4]. Kumar *et al.*, (2018) [5] noticed that seed yield, stalk yield and harvest index were higher (17.37 q ha^{-1}, 37.77 q ha^{-1}and 31.50%) with 60 kg ha^{-1} of sulphur application against control (14.29 q ha^{-1}, 31.44 q ha^{-1} and 31.25%) respectively in castor. Zeinali *et al.*, (2018) [17] revealed that 40 kg ha^{-1} of sulphur application gave higher seed yield (2896.67 kg ha^{-1}) than control (2474.58 kg ha^{-1}) in castor. Ghilotia *et al.*, (2019) [3] stated that seed yield, stalk yield and biological yield were significantly higher with 60 kg ha^{-1} over control and remained at par statistically with 40 kg ha^{-1} in castor. Muneshkumar *et al.*, (2019) [8] documented a significant increase in seed yield of DCH-177 (1388.9 kg ha^{-1}), YRCH-1 (1200.2 kg ha^{-1}, HCH-6 (1250.9 kg ha^{-1}) with 20 kg ha^{-1} of sulphur fertilization compared to control (1082. 2 kg ha^{-1}, 1012.2 kg ha^{-1} and 1062.8) in castor genotypes. Higher yield was obtained with S application @ 60 kg ha^{-1}compared to lower levels applied in castor Mukhtar *et al.*, (2022) [7].

Effect of sulphur application on nutrient uptake of castor

Fyzee and Raju (1991) [2] found that sulphur uptake was higher with application of sulphur at 40 kg ha^{-1} as compared to control in castor. Raju, (1994) [12] found that sulphur uptake (6.4%) was higher with sulphur application at 40 kg ha^{-1} compared to no application (0.83%) in castor. Increased uptake of N, P, K, and S content in grain and straw in castor were recorded with 75 kg ha^{-1} of sulphur application Sharma *et al.*, (2015) [13]. Kumar *et al.*, (2018) [4] reported that application of sulphur at 90 kg ha^{-1} increased the total nitrogen uptake (70.30 kg ha^{-1}) and total sulphur uptake (9.51 kg ha^{-1}) against control (47.27 and 6.59 kg ha^{-1}) respectively in castor.

Effect of sulphur application on quality parameters of castor

Anonymous, (2012) [1] found oil yield was maximum with application of 20 kg ha sulphur in castor. Sharma *et al.*, (2015) [13] stated that quality parameters were significantly increased with sulphur application at 75 kg ha^{-1} in castor. Sulphur application at 60 kg ha^{-1} increased nitrogen content in seed by 17.29% over control in castor Kumar *et al.*, (2018)[a]. Oil yield was higher (1309.35 kg ha$^{-1)}$ with 40 kg ha^{-1} of sulphur fertilization over control (1044.72 kg ha^{-1}) Zeinali *et al.*, (2018) [17]. Muneshkumar *et al.*, (2019) [8] revealed that 20 kg ha^{-1} of sulphur application significantly increased the in oil content and oil yield of DCH-177 (45.17% and 627.3 kg ha^{-1}), YRCH-1 (44.62% and 558.1 kg ha^{-1}), HCH-6 (43.58% and 523.0 kg ha^{-1}) with 20 kg ha^{-1} of sulphur fertilization compared to control (39.12% and 423.3 kg ha^{-1}, 37.20% and 376.5 kg ha^{-1}, 38.40% and 408.1 kg ha^{-1}) in castor genotypes. Ghilotia *et al.*, (2019) [3] stated that oil content, oil yield, protein content and carbohydrate percentage were maximum with 60 kg ha^{-1} over control and remained statistically on par with 40 kg ha^{-1} in castor. S application @ 60 kg ha^{-1} enhanced the quality parameters compared to lower doses applied in castor Mukhtar *et al.*, (2022) [7]

Effect of sulphur application on economics of castor

Anonymous, (2012) [1] reported that sulphur application at 20 kg ha^{-1} gave maximum net returns and benefit cost ratio in castor. Sharma *et al.*, (2015) [13] registered maximum gross return (Rs.133955 ha^{-1}), net returns (Rs.116285 ha^{-1}), and benefit cost ratio (6.58) with sulphur application at 75 kg ha^{-1} in castor – legume intercropping under bael agri-horti system. Srivastava and Kumar (2015) [16] reported that sulphur application at 20 kg ha^{-1} through single superphosphate gave maximum gross returns (Rs. 88,605 ha^{-1}), net returns (Rs. 66,233 ha^{-1}) and benefit cost ratio (3.96) over control recording minimum gross returns (Rs. 69,069 ha^{-1}), net returns (Rs. 47,003 ha^{-1}) and benefit cost ratio (3.13) in castor. Kowser *et al.*, (2018) [4] recorded maximum net returns (Rs. 21831 ha^{-1}) with sulphur fertilization at kg ha^{-1} than control in castor.

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