Indian Journal of Agronomy **68** (3): 312–318 (September 2023)

Research Paper

Balanced crop nutrition with mid-season foliar fertilization enhances productivity, profitability and partial factor productivity in rainfed castor (*Ricinus communis*)

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Received: January 2022; Revised accepted: January 2023

ABSTRACT

A field experiment was conducted at University of Agricultural Sciences, Bengaluru, Karnataka to study the effect of balanced crop nutrition with mid-season foliar fertilization on productivity, profitability, and partial factor productivity of rainfed castor (*Ricinus communis* L.) during the rainy (*kharif*) seasons of 2019–20. Significantly higher seed yield (1,604 kg/ha) was observed with 30, 30, 15 and 20 kg N, P_2O_5, K_2O and $ZnSO_4$ through soil followed by foliar application of 2% water-soluble 19 : 19 : 19 at 40 days after sowing which gave 11.38 and 54.37% higher yield over 50, 50 and 25, i.e. 125% recommended dose of fertilizer (RDF) and 40, 40 and 20 (100% RDF) kg N, P_2O_5, K_2O/ha respectively. Foliar application of 2% 19 : 19 : 19 enhanced partial factor productivity (PFP). Higher gross returns (₹75,425/ha), net returns (₹46,042/ha) and benefit : cost ratio (2.57) were also higher with 30, 30, 15 and 20 kg N, P_2O_5, K_2O, $ZnSO_4$/ha through soil, followed by foliar application of 2% water-soluble 19 : 19 : 19 at 40 DAS. Therefore, integration of soil and foliar application of plant nutrient looks to be feasible nutrient-management modules of castor in boosting the crop productivity. Further, this nutrient-management module was validated in 50 farmers' fields with large plot study (0.4 ha) showed 92.26% hike in yield (746 kg/ha) over farmers' practice (388 kg/ha).

Key words: Balanced nutrition, Castor, Fertilizer, Foliar, PFP, Productivity

Castor (*Ricinus communis*) is an important non-edible oilseed crop being cultivated in India. Presently, it has 0.826 million ha area under cultivation, with an average productivity of 2.30 tonnes/ha. India is producing about 1.92 million tonnes (ICAR-IIOR, 2021). Globally, India is the pioneer in castor production (FAOSTAT, 2020). In India, it is being cultivated in 2 contrasting growing environments, i.e. high-input managed intensive irrigated condition in North-West India and low-input management rainfed Southern India. Although irrigated castor tracts like Gujrat, Haryana and Rajasthan contribute immensely to the total production, southern rainfed states like Telangana, Andhra Pradesh, Karnataka and Tamil Nadu also have sizable area under cultivation. Owing to its high market price (NMOOP, 2018), lower cost of production (Kumar *et al*., 2019), climate resilience (Yin *et al*., 2019) and drought tolerance (Nikneshan *et al*., 2019) castor attracts the framers to adopt it in their cropping systems. Furthermore, longer duration, multiple picking and wider cropping geometry also enable this crop to integrate in different intercropping systems. Because of all these reasons farmers have adopted castor as one of the important components of their rainfed cropping system (Kumar *et al*., 2021).

Natural precipitation is the source of water for dry farming (Kumar *et al*., 2021). Inherently, rainfall in dry areas are of high intensity and erratic in nature. Farmers in rainfed area usually adjust their sowing window with the onset of monsoon, recommended basal dose of fertilizers are usually applied while sowing. But top-dressing is decided by availability of moisture in the soil. Rainfall being the highly uncertain factor in dry areas, prolonged and intermittent dry spells during cropping season are quite common. In such a situation, top- dressing of nutrients becomes difficult due to moisture deficit in the field. Crop being considerably of longer duration, nutrient supplied during initial phase of its growth may not be adequate to meet out its demand during later phase. While, peak nutrient-demanding stage of the crop is around flowering and reproductive stage (Nahar and Pan, 2015). Especially nitrogen

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being the nutrient responsible for source development, its deficiency and suboptimal concentration in plant system hinders the leaf production, leaf-area development and photosynthesis in castor (Reddy and Matcha, 2010). Many researchers opined that nutrient stress in plant system directly affects hydraulic conductivity of crop as a result crop is prone to the moisture stress (Reddy and Matcha, 2010). Therefore, under moisture-limited condition, balanced nutrition imparts desirable rate of leaf production, expansion, photosynthesis and hydraulic conductivity (Reddy and Matcha, 2010; Kumar *et al*., 2015; Hiremath *et al*., 2016). Again, Reddy and Matcha (2010) reported that, overall growth rates of castor plant declined with lower leaf nitrogen; it could be due to suboptimal leaf-area expansion. Nutrient concentration in plant body directly takes part in photosynthetic apparatus development, and any deviation in crop-nutrient management directly come in the way of its productivity. Hence, devising sound nutrient-management strategy is very much essential especially under rainfed situation. In this study we conceptualized 9 nutrient-management strategies (treatment) which include soil and foliar mode of crop fertilization and were compared with 100 and 125% recommended N, P_2O_5, and K_2O along with unfertilized control.

MATERIALS AND METHODS

A field experiment was conducted during the rainy (*kharif*) seasons of 2019 and 2020 at research farm of All India Co-ordinated Research Project on Castor, University of Agricultural Sciences, Gandhi Krishi Vignana Kendra (GKVK), Bengaluru (13.0801° N, 77.5785° E) to study the effect of balanced crop nutrition on growth and productivity of rainfed castor. The soil of the experimental site was sandy loam, moderately acidic, medium (0.56) in organic carbon and available nitrogen (386.56 kg/ha), medium in available phosphorus (29.67 kg/ha) and high in available potassium (428.40 kg/ha). Similarly, available nutrient state of secondary and micronutrients were in the range of sufficiency. The experiment consisted of 12 treatments, viz. T_1, recommended dose of fertilizer (RDF), i.e. 40, 40 and 20 kg N, P_2O_5 and K_2O/ha; T_2, 125% RDF; T_3, 75% RDF + 2% 19 : 19 : 19 at 40 DAS; T_4, 50% RDF + 2% 19 : 19 : 19 at 40 DAS; T_5, 75% RDF + 2% 19 : 19 : 19 at 30 + 50 DAS; T_6, 50% RDF + 2% 19 : 19 : 19 at 30 + 50 DAS; T_7, 75% RDF + 2%19 : 19 : 19 at 40 DAS + 15 kg $ZnSO_4$/ha; T_8, 50% RDF + 2% 19 : 19 : 19 at 40 DAS + 15 kg $ZnSO_4$/ha; T_9, 75% RDF + 2% 19 : 19 : 19 at 40 DAS + 20 kg $ZnSO_4$/ha; T_{10}, 50% RDF + 2% 19 : 19 : 19 at 40 DAS + 20 kg $ZnSO_4$/ha; T_{11}, 2% 19 : 19 : 19 at 20, 35 and 50 DAS and T_{12}, Absolute control and were replicated thrice in a randomized complete-block design. Castor hybrid 'DCH 177' was used in the study. The seed material was uniformly treated with strains of nitrogen-fixing (*Azospirillum*) and phosphorus-solubilizing bacteria (*Bacillus megaterium*) each @ 750 g/ha. The seed rows at 90 cm apart and inter-row spacing of 60 cm was maintained to obtain 18, 518 plants/ha. Basal dose of nitrogen (50% of RDN), phosphorus (100% RD P_2O_5) and potassium (100% RD K_2O) were applied at the time of sowing and the remaining nitrogen was applied in 2 splits each at 50 and 75 days after sowing. Experimental site was treated with pre-emergence application of Pendimethalin 1 kg a.i./ha and weeds emerged at later phase of crop growth was managed with intercultural operations. Observations on growth, seed yield and yield attributes were recorded as per the standard procedure. Data were statistically analysed as suggested by Gomez and Gomez (1984).

In order to demonstrate impact of balanced nutrition on growth and yield of rainfed castor, 20.23 ha of field demonstration was conducted in Bengaluru Rural, Chikkballapur, Tumkur, Chamarajanagar and Chitradurga districts of Karnataka State. The details of experimental sites are summarized in the Table 1. In selected districts, clusters of castor-growing villages were selected and in

Table 1. Details of demonstration sites

Cluster	Number of demonstrations	Geographical co-ordinates	Soil type	Available N (kg/ha)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)
C-1	8	13°26'59.8"N 77°29'12.4"E	Red sandy loam	326.56	27.45	384.14
C-2	5	13°26'15.9"N 77°28'32.0"E	Red sandy loam	334.84	21.24	311.14
C-3	13	13°24'45.2"N 77°44'22.6"E	Sandy loam	314.41	26.58	307.83
C-4	8	13°30'12.7"N 76°45'29.4"E	Sandy loam	298.40	29.67	354.20
C-5	7	11°53'42.2"N 77°17'10.2"E	Clay loam	394.87	34.14	428.40
C-6	9	13°57'07.0"N 76°40'28.5"E	Deep black soil	386.50	28.98	398.11

each cluster, farmers were selected through purposive sampling technique. The selected farmers were trained by conducting 1 day training and demonstration programme detailing importance of balanced nutrition in castor specific and other crop husbandry activity in general in each selected village. In all the farmers' fields' 2 equidimensional plots were demarked and were separated with bunds. At each site 2 treatments, i.e. Improved technology (T_1) and Farmer's practice (T_2) were imposed. Plots with improved technology was applied with N, P_2O_5, K_2O and $ZnSO_4$ @ 30, 30, 15 and 20 kg/ha through soil application, followed by 2% spray of water-soluble 19 : 19 : 19 N : P : K at 40 DAS, whereas Farmers' practice included basal application of 100 kg (2 bags) of any complex fertilizer available at the time of sowing, followed by urea @ 50 kg/ha, if moisture exists at the first inter-cultivation. All necessary production inputs and seed material ('DCH 177') were distributed to farmers well before the sowing time. Cropping activity was monitored at regular interval by providing need-based crop advisory. Growth, yield and yield attributes were recorded as per the standard procedure. Partial factor productivity (PFP) for different treatments was calculated as per methodology suggested Dobermann (2007).

$$\text{PFP (kg/kg)} = \frac{\text{Grain yield (kg/ha)}}{\text{Nutrient applied (kg/ha)}}$$

The cost of cultivation, gross, net returns and system net returns of both the crops were calculated on the basis of prevailing market price of different input and output. Data were statistically analysed as suggested by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Growth attributes

In this study, important growth-attributing traits such as plant height, node numbers, stem diameter, number of leaves/plant were examined at various growth stages on castor and were significantly higher in the plots with 75% of recommended N, P_2O_5, K_2O along with 20 kg $ZnSO_4$/ha, followed by foliar application of 2% 19 : 19 : 19 N : P : K at 40 DAS (Table 2). Dry-matter production is the manifestation of growth in crop plants (Kumar *et al*., 2015). On account of higher growth attributes, significantly higher total dry-matter production at primary spike initiation (43 DAS) and final harvesting (165 DAS) was also observed with former treatment. This profound influence of former treatment on castor could be owing to consistent and adequate supply of nitrogen, phosphorus, potassium, zinc and sulphur all through the cropping period. Castor, being a long-duration crop, bound to produce higher dry matter per unit area. Optimum and continuous supply of essential

Table 2. Effect of balanced nutrition on growth parameters of castor during 2019 and 2020

Treatment	Plant height (cm)	Number of leaves /plant		No. nodes to primary spike maturity (cm)	Stem diameter at primary	Total dry-matter production (g/plant)	
		50 DAS	100 DAS			50 DAS	100 DAS
RDF (40 : 40 : 20 N : P_2O_5 : K_2O/ha)	52.7	1.12	1.29	10.75	5.87	67.2	143.2
125% RDF	67.1	1.18	1.36	12.48	6.24	73.4	153.4
75% RDF + 2% 19 : 19 : 19 @ 45 DAS	57.0	1.14	1.27	11.62	5.98	60.4	139.5
50% RDF + 2% 19 : 19 : 19 @ 45 DAS	52.7	1.07	1.14	10.75	5.65	56.2	112.1
75% RDF + 2% 19 : 19 : 19 @ 30 + 50 DAS	60.2	0.97	1.11	12.27	6.14	67.2	113.4
50% RDF + 2% 19 : 19 : 19 @ 30 + 50 DAS	57.5	1.01	1.19	11.72	5.96	60.4	122.8
75% RDF + 2% 19 : 19 : 19 @ 40 DAS + 15 kg $ZnSO_4$/ha	64.6	1.10	1.32	12.11	6.15	68.1	169.4
50% RDF + 2% 19 : 19 : 19 @ 40 DAS + 15 kg $ZnSO_4$/ha	54.3	1.11	1.25	11.07	6.04	65.7	153.1
75% RDF + 2% 19 : 19 : 19 @ 40 DAS + 20 kg $ZnSO_4$/ha	73.6	1.23	1.48	12.16	6.24	73.5	178.4
50% RDF + 2% 19 : 19 : 19 @ 40 DAS + 20 kg $ZnSO_4$/ha	58.1	1.13	1.27	11.84	6.10	66.4	154.7
2% 19 : 19 : 19 @ 20, 35 and 50 DAS	44.8	0.82	1.01	9.12	5.20	36.2	59.6
Absolute control	24.5	0.42	0.34	5.99	3.28	22.2	24.8
SEm±	0.8	0.07	0.10	0.18	0.26	1.0	5.3
CD (P=0.05)	2.3	0.24	0.32	0.53	0.82	3.1	19.4
CV (%)	8.5	10.7	14.78	9.85	6.84	8.7	14.7

RDF, recommended dose of fertilizer; DAS, days after sowing plant nutrient favours the crop growth (Subhash, 2002). In our study, constant supply of nitrogen helps in protein and amino acid synthesis which takes part in overall plant development by way of developing optimal photosynthetic apparatus. Likewise, phosphorus is another macro-nutrient required for energy transfer, nucleic acid synthesis, enzymatic regulation, respiration, photosynthesis and rhizosphere establishment (Harger *et al.,* 2007). Soil and foliar application of nutrient sources in said treatment has assured the continuous availability of phosphorus. Similarly, potassium is also an essential nutrient for castor, as it activates more than 60 enzymes (Peuke *et al*., 2002). Further, availability of zinc in combination with nitrogen might have favourably supported the crop in formation of chlorophyll and synthesis of growth-promoting hormone like auxins. Unhindered plant metabolism encourages optimum cell-division and their enlargement, as a result over all plant development was good. Further, direct feeding of N, P_2O_5, K_2O to the site of action directly at 40 DAS through aqueous solution would boost the current photosynthetic rate at primary spike-development stage. In this study plot received relatively higher amount of fertilizers (100 and 125% of RDF) failed to favour good crop growth, this could be due to lack of constant nutrient supply at various growth phases due to want of soil moisture. Castor being the predominate crop of rainfed situation, mostly confined to marginal lands. Inherent poor-fertility status and ill-distributed rainfall discourage spilt application of fertilizers and as a result, crop suffers due to suboptimal nutrient supply. Hence, balanced supply of all macro-nutrient in combination with zinc and sulphur might have collectively contributed for favourable growth in combination with soil and foliar means of nutrient supplements.

Yield attributes

Yield attributes are the manifestation of dry-matter production and its remobilization into sink (Kumar *et al*., 2015; Kumar *et al*., 2021). In castor, primary spike contributes to much of the total seed yield (Solanki and Joshi, 2000; Lavanya and Solanki, 2010). Higher dry-matter production during flowering to primary spike development obviously contribute for effective development of reproductive units in castor. In our study, dry-matter production at primary spike maturity was the highest with plots which received 75% of recommended N, P_2O_5, K_2O along with 20 kg $ZnSO_4$/ha followed by foliar application of 2% 19 : 19 : 19 at 40 DAS and was reflected in production development of lengthier primary spike and higher number of capsules on primary spike. This significant improvement in yield-attributing characters were traced back to the excellence in growth-attributing traits observed with plots received with former treatment (Table 2). Plant with higher source size and its effective mobilization into sink yields higher units of yield-attributing parameters. In this study, adequate and balanced crop nutrition might have nourished the crop all through the vegetative and reproductive phase. Hence, higher growth attributes observed were also reflected in yield-attributing parameters. Sangwan *et al*., (2015) in Aridisols of Haryana obtained persistently higher yield in plots fertilized with nitrogen @ 60 kg/ha and phosphorus @ 20 kg/ha over their corresponding lower doses and alone application of each nutrient. This signifies balanced nutrition in castor under rainfed situation plays a great role in unlocking productivity of crop.

Table 3. Yield attributes of castor as influenced by balanced nutrition during 2019 and 2020

Treatment	Primary spike length (cm)	Effective spikes/ plant	Capsules/ primary	100-seed weight (g)	Yield (kg/ha)	Oil content (%)	Oil yield (kg/ha)
RDF (40 : 40 : 20 N : P_2O_5 : K_2O/ha)	43.0	4.0	47.5	25.4	1039.6	45.32	471.1
125% RDF	55.1	6.2	66.0	25.9	1440.2	46.20	665.3
75% RDF + 2% 19 : 19 : 19 @ 45 DAS	49.1	5.2	58.6	25.1	1252.1	45.31	567.3
50% RDF + 2% 19 : 19 : 19 @ 45 DAS	43.2	4.8	54.1	23.6	1148.5	43.25	496.7
75% RDF + 2% 19 : 19 : 19 @ 30 + 50 DAS	51.9	5.5	61.9	24.6	1312.3	44.40	582.6
50% RDF + 2% 19 : 19 : 19 @ 30 + 50 DAS	49.5	5.3	59.1	24.0	1271.0	43.24	549.5
75% RDF + 2% 19 : 19 : 19 @ 40 DAS + 15 kg $ZnSO_4$/ha	55.7	6.0	66.5	25.6	1470.6	46.11	678.0
50% RDF + 2% 19 : 19 : 19 @ 40 DAS + 15 kg $ZnSO_4$/ha	46.7	5.0	55.7	24.9	1191.4	45.65	543.8
75% RDF + 2% 19 : 19 : 19 @ 40 DAS + 20 kg $ZnSO_4$/ha	61.9	6.8	74.1	26.1	1604.8	46.64	748.4
50% RDF + 2% 19 : 19 : 19 @ 40 DAS + 20 kg $ZnSO_4$/ha	50.0	5.3	59.7	24.4	1275.9	45.51	580.6
2% 19 : 19 : 19 @ 20, 35 and 50 DAS	33.4	4.1	31.6	21.3	529.9	40.47	214.4
Absolute control	9.5	1.3	10.1	16.2	150.3	41.45	62.3
SEm±	0.8	0.1	0.7	0.6	13.2	0.63	62
CD (P=0.05)	2.3	0.3	2.1	1.8	38.8	20.14	192
CV (%)	10.3	12.0	7.9	4.0	7.0	5.64	14

RDF, Recommended dose of fertilizer; DAS, days after sowing

Table 4. Fertilization schedule and partial factor productivity in castor during 2019 and 2020

Treatment	Soil application (kg nutrient/ha)			Foliar application (kg nutrient/ha)			Total fertilizer applied (kg/ha)	Partial factor productivity (kg/kg)
	Basal	30 DAS	50 DAS	30 DAS	45 DAS	50 DAS		
RDF (40 : 40 : 20 N : P_2O_5 : K_2O/ha)	20:40:20	10:0:0	10:0:0	×	×	×	100	10.4
125% RDF	25:50:25	12.5:0:0	12.5:0:0	×	×	×	125	11.5
75% RDF + 2% 19 : 19 : 19 @ 45 DAS	15:30:15	7.50:0:0	7.50:0:0	×	5.0	×	80	15.7
50% RDF + 2% 19 : 19 : 19 @ 45 DAS	10:20:10	5:0:0	5:0:0	×	5.0	×	55	20.9
75% RDF + 2% 19 : 19 : 19 @ 30 + 50 DAS	15:30:15	7.5:0:0	7.50:0:0	5.0	×	5.0	85	15.4
50% RDF + 2% 19 : 19 : 19 @ 30 + 50 DAS	10:20:10	5:0:0	5:0:0	5.0	×	5.0	60	21.2
75% RDF + 2% 19 : 19 : 19 @ 40 DAS + 15 kg $ZnSO_4$/ha	15:30:15:15	7.50:0:0	7.50:0:0	×	5.0	×	95	15.5
50% RDF + 2% 19 : 19 : 19 @ 40 DAS + 15 kg $ZnSO_4$/ha	10:20:10:15	5:0:0	5:0:0	×	5.0	×	70	17.0
75% RDF + 2% 19 : 19 : 19 @ 40 DAS + 20 kg $ZnSO_4$/ha	15:30:15:20	7.50:0:0	7.50:0:0	×	5.0	×	100	16.0
50% RDF + 2% 19 : 19 : 19 @ 40 DAS + 20 kg $ZnSO_4$/ha	10:20:10:20	5:0:0	5:0:0	×	5.0	×	75	17.0
2% 19 : 19 : 19 @ 20, 35 and 50 DAS	×	×	×	5.0	5.0	5.0	15.0	35.3
Absolute control	×	×	×	×	×	×	×	-

RDF, Recommended dose of fertilizer; DAS, days after sowing; X, Crop growth stage at no amount of fertilizer was applied

Yield and economics

Yield is the dependent of yield-attributing traits. Castor being the crop with multiple harvests, yield attributes of each harvest contribute for ultimate cumulative productivity of the crop. In this study, on account of higher yield-attributing characters registered with plots which received 75% of recommended N, P_2O_5, K_2O along with 20 kg $ZnSO_4$/ha, followed by foliar application of 2% 19 : 19 : 19 at 40 DAS (Table 3). It is obvious that crop with higher yield attributes records higher yield. These findings support the results of Sangwan *et al*., (2015); Kumar *et al*., (2021) and Yamanura and Kumar (2020). Further, 50 demonstrations were conducted in farmer's fields in order to ascertain effect of best treatment obtained at research station. To know the effect of balanced fertilization on castor yield and fertilizer economy in farmers' field along with former nutrient-management module (N, P_2O_5, K_2O along with 20 kg $ZnSO_4$+ foliar application of 2% 19 : 19 : 19 at 40 DAS). The data obtained from the farmers' fields also indicated application of 75% N, P_2O_5, K_2O along with 20 kg $ZnSO_4$/ha, followed by foliar application of 2% 19 : 19 : 19 at 40 DAS found to be superior by recording 92.26% higher seed yield over farmer's practice.

Economic analysis was done to workout cost benefit involved in castor production, both at station and farmer's field. The gross returns, net returns and benefit : cost ratio followed the similar trend as that of grain yield in both stations experiment as well as demonstration conducted at farmers' fields. However, higher gross returns (₹75,425/ha), net returns (₹46,042/ha) and benefit : cost ratio (2.57) were obtained with 75% RDF + 2% 19 : 19 : 19 @ 40 DAS + 20 kg ZnSO4/ha over other treatments at research station (Table 4). Further, even at farmers' fields 75% RDF + 2% 19 : 19 : 19 @ 40 DAS + 20 kg ZnSO4/ha registered higher gross returns (₹35,062/ha), net returns (₹19,462/ha) and benefit : cost ratio (2.25) over farmers practice (₹18,236/ha, ₹6,836/ha and 1.60, respectively, gross returns, net returns and benefit cost ratio). This indicates, there is profound influence of balanced crop nutrition in rainfed castor. Hence, in order to exploit its complete potentiality, incorporation of micronutrient such as $ZnSO_4$ along with location-specific recommended major nutrients and foliar feeding of water-soluble multi-nutrient as foliar fertilization during rain-shadow situation would boost the productivity and profitability of rainfed castor.

Partial factor productivity

Partial factor productivity (PFP) indicates seed yield obtained per unit nutrient applied (Dobermann, 2007). In this study, we observed significant variation in PEP due to different treatments. In general, all the treatments with foliar application of water-soluble 19 : 19 : 19 (NPK) showed

Table 5. Balanced nutrition on gross return, net return and benefit : cost ratio in castor

Treatment	Gross returns (₹/ha)	Net returns (₹/ha)	Benefit: cost ratio
RDF (40 : 40 : 20 N : P_2O_5 : K_2O/ha)	48,860	19,717	1.68
125% RDF	67,690	37,497	2.24
75% RDF + 2% 19 : 19 : 19 @ 45 DAS	58,851	30,028	2.04
50% RDF + 2% 19 : 19 : 19 @ 45 DAS	53,979	26,756	1.98
75% RDF + 2% 19 : 19 : 19 @ 30 + 50 DAS	61,678	31,575	2.05
50% RDF + 2% 19 : 19 : 19 @ 30 + 50 DAS	59,739	31,236	2.10
75% RDF + 2% 19 : 19 : 19 @ 40 DAS + 15 kg $ZnSO_4$/ha	69,118	39,875	2.36
50% RDF + 2% 19 : 19 : 19 @ 40 DAS + 15 kg $ZnSO_4$/ha	55,994	28,351	2.03
75% RDF + 2% 19 : 19 : 19 @ 40 DAS + 20 kg $ZnSO_4$/ha	75,425	46,042	2.57
50% RDF + 2% 19 : 19 : 19 @ 40 DAS + 20 kg $ZnSO_4$/ha	59,967	32,184	2.16
2% 19 : 19 : 19 @ 20, 35 and 50 DAS	24,905	-2,578	0.91
Absolute control	7,066	-9,077	0.44

RDF, Recommended dose of fertilizer; DAS, days after sowing

higher values of PFP (Table 4) when compared with RDF and 125% of RDF though soil application alone. It signifies the yield improvement in castor owing to foliar application of 19 : 19 : 19 at 2%. This could be owing to better nourishment of crop at reproductive stage by direct feeding of nutrient to site of photosynthetic apparatus, it might have relieved plants from possible nutrient stress during imbalanced crop nutrition and as a result of significant improvement in sink size and development.

Foliar application of 19 : 19 : 19 at 2% was found effective in rainfed castor along with soil application of 75% of recommended dose of N, P_2O_5, K_2O, $ZnSO_4$ (30 : 30 : 15 : 20 kg/ha, respectively) over soil application of 40 : 40 : 20 kg N, P_2O_5, K_2O/ha. By adoption of this nutrient-management module, grower can increase productivity, nutrient-use efficiency while curtailing cost of production in rainfed situation.

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