

Growth and yield response of camelina sativa to inorganic fertilizers and farmyard manure in hot semi-arid climate of India

Abstract

Camelina [*Camelina sativa* L. (Crantz)], a potential alternative oilseed crop of family Brassicaceae, has gained renewed interests as a feedstock for biodiesel production. Effect of sulphur (0, 10, 20 and 30 kg ha⁻¹) and farmyard manure (FYM) (20 and 30 tons ha⁻¹) on plant growth, seed yield and oil content of camelina in degraded land of hot semi-arid climate was studied during the winter season (November to February). Both Sulfur and organic fertilizer neither significantly ($P < 0.05$) influenced plant growth nor yield attributes nor even seed oil content of camelina. However, addition of N and P₂O₅ exhibited significant ($P < 0.05$) increase growth and seed yield including seed oil content over control. Maximum seed yield (72.2 g m⁻²) was recorded in treatment combination comprising 30 tons FYM, 20 kg S, 60 kg P₂O₅ and 100 kg N ha⁻¹. Seed oil content, ranged from 29.1 to 32.5%. Quality of seed oil of camelina (grown at the hot semi-arid climate) was also assessed by analyzing the patterns of fatty acids composition. Results indicated that camelina can be successfully cultivated in the degraded land of hot semi-arid zone during the winter season that too in a short growing period. Considerable seed yield and oil content as well as corresponding fatty acid profile of camelina oil reported in this study indicated promising potentials for its suitability for the hot semi-arid regions. However, it would be pertinent to further identify growth and production requirements for the crop in order to strengthen baseline data on its agronomic attributes for ensuring its efficient cultivation on degraded lands of hot semi-arid region.

Keywords: camelina, biofuel crops, biodiesel, organic manure, sulfur fertilization

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Soumai Kant Joshi, Sharif Ahamada, Lekha Charan Meher, Ankur Agarwal, Mohammed Nasim

Defence Institute of Bio-Energy Research, India

Correspondence: Ankur Agarwal, Defence Institute of Bio-Energy Research, Goraparao, Haldwani- 263 139, Uttarakhand, India, Tel +91 5946232800; Fax +91 5946232719, Email ankurdr@rediffmail.com

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Introduction

Commonly known as ‘false flax’ and ‘Gold of Pleasure’, *Camelina sativa* (L.) Crantz (Brassicaceae) is believed to be the native of northern Europe, the Mediterranean region and Central Asia. It has gained renewed interest as a biofuel feedstock.¹⁻³ Oil content in camelina seeds is reported in the range from 32 to 46%.⁴ Camelina is favoured as an alternative feedstock for biodiesel production due to its low cost in comparison to commodity oils.⁵ Moreover, the fuel properties including cold flow properties, oxidative stability, kinematic viscosity and cetane number of biodiesel made from camelina are similar to those of the soybean-based biodiesel⁶ and canola.³ Recently, camelina oil-based jet fuel has been developed and test flights of different passenger aircrafts as well as fighter jets have been successfully conducted.⁵ These facts clearly indicate the suitability of camelina oil for making biofuels. Moreover, because of its unique nutritive properties, camelina meal has been identified as a high-value animal feed.⁷ Thus it holds high economic potential. Such a high economic value of camelina meal has tremendous potential in ensuring camelina biodiesel economically more viable. Growing environments influence quality and quantity of seed and oil yield of oilseed crops.⁸ therefore it is important to develop region-specific production technologies for a newly introduced crop in a particular agro-climatic region. Identification of nutrients requirement is one of the important factors that need to be standardized for such crop. In order to avoid food versus fuel conflict, it is advocated that biofuel crops should be grown on degraded lands, which are generally not suitable for growing other agricultural food crops as they either cannot grow or exhibit poor growth and low production in such soils. In view of this, and because

of its wide adaptability to different climates and soils.^{9,10} Camelina seems to be a potential biofuel crop. This is particularly important in the Indian context, where degraded lands in the semi-arids are widely available and are more or less underutilized due to unavailability of a suitable low input crop. Camelina seems to be a potential candidate crop for this region being short duration, drought tolerant and low input requiring. Realizing the potential, the crop has already been introduced in India and found successful in central Himalayan region.¹¹ Efforts are been made for assessing its adaptability and developing agro-technologies for in semi-arid zones of India. However, fertilization and agronomic requirements of the crop for such agro-ecological regions need to be standardized for obtaining optimal yields. In general, oilseed crops have a much higher requirement for sulphur for attaining optimum growth and yield vis-à-vis quality and quantity of oil.⁵ Plant use efficiency of nitrogen from fertilizers is inhibited by deficiency of Sulfur.¹³ That may cause increased losses of nitrogen.¹⁴ Therefore, fertilizers containing Sulfur seem to be effective in camelina nutrition and subsequently in obtaining copious seed and oil yield. In addition to mineral fertilizers, organic fertilizers play a vital role in increasing soil fertility and productivity thereby increasing the yield in sustainable manner. Organic matter supplied in the form of farmyard manure (FYM), green manure or compost to the soil is considered as the most important factor for enhancing crop productivity.¹⁵ As it positively affects physical, chemical and biological properties of soil.¹⁶ The objectives of the study were to evaluate the effect of Sulfur and organic fertilizer on plant growth, seed yield and oil content in camelina in the degraded land of hot semi-arid zone of Deccan Plateau, India.

Materials and methods

Study site and land preparation

The present research work was carried out at DIBER Project Site, Chichondi Patil, Ahmednagar, Maharashtra, India (18°58' N; 74°54' E; 708m a.s.l.). It is one of the project sites of DIBER, where plantation of *Jatropha curcas* L. (*jatropha*) has been established on degraded pasture in hot semi-arid ecosystems of the Deccan Plateau. Mild and dry winters, hot and humid summers and low annual rainfall (300 to 550mm) are the characteristics of the climate of the region. Mean maximum and minimum temperature of the study sites during the study period (November 2011 to February 2012) were 32.4 (ranged from 30.4 to 37.3°C) and 16.8 (14.2 to 18.5°C), respectively. The average monthly relative humidity during this period ranged from 40.2 to 57.7% (maximum) and 23.1 to 35.9% (minimum). The soil of the study site was shallow black having low fertility levels (245.0kg N ha⁻¹; 3.6kg P ha⁻¹; 0.38% organic carbon). Field experiments were undertaken during November 2011 to February 2012 (winter season) on a land, which was previously used to raise *jatropha* nursery once each in the year 2010 (February to July) and 2011 (February to August). Prior to growing *jatropha* nursery, the land (pasture) was occupied by perennial grasses. Also, frequent occurrence of boulders was there on the pasture. Therefore, for raising *jatropha* nursery for the first time, the land was prepared by carrying out one deep ploughing followed by two shallow ploughing s with a mouldboard plough in December 2009 followed by removal of boulders and grass residues. Thereafter, nursery of *jatropha* was established twice on the prepared land, i.e. first batch during February to July, 2010 and second one during February to August 2011 and the saplings of each batch were harvested for transplantation in the field in the respective rainy seasons of each year. Hence, after uprooting the second batch of *jatropha* nursery in August 2011, the nursery space was left for two months without any intercultural practices and interventions. In October 2011, one deep ploughing was carried out on the same field and experimental beds (plots) were prepared to carry out the present research work.

Plant material

Small quantity of nucleus seeds of camelina cv. Calena (EC 643910) was obtained from Austria through the National Bureau of Plant Genetic Resources (NBPGR), New Delhi by DIBER. These seeds were successfully multiplied at DIBER Field Station, Pithoragarh, Uttarakhand, India (1700m a.m.s.l.).¹¹ Seeds, thus multiplied, were brought to DIBER Project Site, Chichondi Patil, Ahmednagar (Maharashtra), the present study site, and stored at room temperature in muslin cloth bag until utilized for experimental work in the present study.

Experimental design and seed sowing

Plots (1m x 1m) having a vacant inter-plot space of 30cm was prepared for carrying out the experimental work. In order to provide moisture for seed germination, each plot was irrigated (2.5litre plot⁻¹) one day prior to seeding. Line sowing method was used for seeding and there were three lines in each plot having 30cm of inter-line space. Initially, 35-40 seeds were hand-drilled in each of the three lines at a depth 2-3cm in each plot on 16 November, 2011. After 28days of seeding, when plants attained rosette stage, thinning was carried out so that 28 plants remained in each row. Thus, a total of 84 plants were maintained in each plot. The experiment was carried out in a randomized complete block design with three replications.

Manure and fertilizer treatments

Treatments consisted of combinations of three levels of well-decomposed FYM (0, 20 and 30 tons ha⁻¹) and four levels of S (0, 10, 20 and 30kg ha⁻¹). To some of these combinations of FYM and S, 60kg ha⁻¹ P₂O₅ and 100kg ha⁻¹ N were also added. In all, a total of 15 treatment combinations (T1-T15) including control were tested in the experiment (Table 1). FYM, chiefly composed of cattle dung and urine along with litter and left over material from fodder and containing 0.5% N, 0.2% P₂O₅ and 0.5% K₂O, was applied 30days prior to seeding. P₂O₅ was applied as diammonium phosphate (DAP) (46% P₂O₅ and 21% N) at the time of seeding through broadcast in selected treatments (T4 to T12), whereas S was applied as ammonium sulphate (24% S and 21% N) after 28 days of seeding. Nitrogen was provided as urea (46% N) after 34 days of seeding. In order to balance the dose of N (100kg ha⁻¹), amount of urea was adjusted to the treatments that received N fertilization through DAP and ammonium sulphate. Treatments T13, T14 and T15 received 10, 20 and 30kg S ha⁻¹ respectively, though partial dose of N (8.8, 17.6 and 26.4kg ha⁻¹ in T13, T14 and T15 respectively) was also gone to them through ammonium sulphate (Table 1).

Table 1 Details of treatment combinations of FYM and inorganic nutrients

Treatment	FYM	Sulphur	P ₂ O ₅	Nitrogen
	(tons ha ⁻¹)	(kg ha ⁻¹)	(kg ha ⁻¹)	(kg ha ⁻¹)
T1 (Control)	0	0	0	0
T2	20	0	0	0
T3	30	0	0	0
T4	0	10	60	100
T5	20	10	60	100
T6	30	10	60	100
T7	0	20	60	100
T8	20	20	60	100
T9	30	20	60	100
T10	0	30	60	100
T11	20	30	60	100
T12	30	30	60	100
T13	0	10	0	8.8
T14	0	20	0	17.6
T15	0	30	0	26.4

Intercultural operations and management

After seedling emergence, irrigation (2litres per plot) was carried out daily by water cans until 23rd day of emergence. Thereafter, irrigation with same amount of water was carried out on alternate days until 42nd day and after this period, at every 4th day until pod setting. Weeding was done manually as and when required. Harvesting was carried out after 82days of seeding (i.e., on 05 February 2012) when 70% silicles turned light-brown in colour. Harvested biomass was shade dried for four days and threshed by hand.

Data collection

Data on plant height (cm), number of branches plant⁻¹, number of silicles plant⁻¹ and seed yield were recorded for 12 plants plot⁻¹ (four randomly selected plants in each of the three rows in each plot) at the

time of harvest. Number of seeds silicle⁻¹ was measured by counting number of seeds in five randomly selected silicles on the above-mentioned plants (12 plants plot⁻¹), for which data on growth and yield parameters was recorded. Thus, a total of 60silicles were sampled in each plot for collecting data on number of seeds silicle⁻¹. Data were subjected to analysis of variance (ANOVA) for determination of significance among the treatments.

Seed oil content and fatty acid composition

Oil content in camelina seeds was determined by solvent extraction method. About 50g of seed of each treatment (except those exhibited very low seed yield) were crushed to fine powder. For oil content determination, the powdered samples of seeds were extracted in Soxhlet apparatus using petroleum ether (60-80°C) as solvent. The extract was concentrated under vacuum at 65-70°C, the residual oil was cooled and weighed. Fatty acid composition of seed oil was determined by gas chromatographic method. Preparation of fatty acid methyl esters from camelina seed oil was carried out using AOCS official method Ce 2-66.¹⁷ Where boron trifluoride in methanol is used as trans methylating agent. The fatty acid methyl esters derived from camelina oil were analyzed by capillary gas chromatography using AOCS official method Ce 1-62.¹⁸

Results and discussion

Plant height and number of branches and silicles per plant

Plant height was recorded between 48.7cm (control) and 63.1cm (T10) (Table 2). Although variations in plant height were observed among the treatments, not all the treatments were significantly ($P<0.05$) different from each other. Addition of N (100kg ha⁻¹) and P2O5 (60kg ha⁻¹) to the treatments (T4 to T12) has significantly influenced plant height over control. Improvement in growth of camelina has been observed with nitrogen fertilization (60-120kg ha⁻¹) and a constant dose of P and K.¹⁹ Number of branches plant⁻¹ was recorded from 4.5 (control) to 9.4cm (T12) (Table 2). Slightly lower number of branches (4.6 to 7.3 branches plant⁻¹) than the present study was reported by Agegnehu and Honermeier.²⁰ In camelina, who observed significant increase in number of branches plant⁻¹ in presence of N, P2O5, K and CaO. Number of silicles plant⁻¹ ranged between 60.8 (control) and 222.2 (T12). Addition of N (100kg ha⁻¹) and P2O5 (60kg ha⁻¹) to the treatments, resulted in significant ($P<0.05$) increase in number of silicles plant⁻¹. Although addition of N and P to the soil

has positively influenced plant height and number of branches and silicles, application of S could neither alone nor in combination with N, P2O5 and FYM significantly influence these attributes. Positive and synergistic effects of N and S on number of branches in camelina are well documented.¹⁴ But Sulfur addition had no effect at lower dose of Nitrogen.^{21,22} Perhaps due to this phenomenon, the dose of N (100kg ha⁻¹) applied in the present study was not sufficient enough to get synergize with S and promote plant growth.

Seed yield and yield attributing traits

Number of seeds silicle⁻¹ was recorded between 11.9 (T6) and 14.1 (T5), though the differences among the treatments were not significant ($P<0.05$) (Table 2). Number of seeds silicle⁻¹ in the present study broadly fell within the range reported by different researchers in camelina.^{19,23} Crop matured in 82days after seeding relatively earlier in comparison to the crop maturity period (i.e., 105 to 234days) in camelina as reported by Berti et al.²³ in their study conducted in cold and temperate Mediterranean climate in Chile. Shorter crop maturity period in the study was perhaps due to the hotter climate of our study site. Seed yield increased significantly ($P<0.05$) by addition of N (100kg ha⁻¹) and P2O5 (60kg ha⁻¹) to the treatments (T4 to T12). However, lower N dosage (8.8, 17.6 and 26.4kg ha⁻¹) could not affect seed yield (T13 to T15). Nitrogen positively affects number and weight of pods and seed and flowers per plant and thus promote seed yield.¹⁴ In camelina, increase in seed yield with increased N.²⁰ And N, P and K.¹⁹ Fertilization has already been reported. Wide variation in seed yield has been reported ranging from 420kg ha⁻¹ to 2314kg ha⁻¹ in camelina cultivated at different environments (locations) in Chile.²³ Although camelina is reported to exhibit adaptability to different climates and soil.¹⁰ Unfavorable climatic conditions adversely affect its seed yield.¹⁹ Particularly discussing the patterns of seed yield of camelina cv. Calena in the Indian context, seed yield ranging from 226.7 to 458.9kg ha⁻¹.²⁴ And up to 1481kg ha⁻¹.²⁵ in open field have been reported in Central Western Himalaya. In view of this, seed yield in the present study was considerable indicating promising potentials of cultivating camelina in hot climate of semi-arid zone. Although Sulfur is reported to increase seed yield in different plants of Brassicaceae family.^{22,26,27} No such effect of Sulfur was observed in the present study. Higher dose of Sulfur (135kg ha⁻¹) in comparison to the lower dose (75kg ha⁻¹) in presence of a constant dosage of N have exhibited higher seed yield in camelina.¹⁴ This suggested that dosages of Sulfur applied in the present study were in low range that could not affect the seed yield although up to 30kg S ha⁻¹ itself has been found effective in increasing seed yield in mustard.²⁷

Table 2 Growth performance, seed yield and oil content of camelina in response to different treatment combinations of FYM and inorganic nutrients

Treatments	Plant height (cm) ^a	Number of branches Plant ^{-1a}	Number of silicles Plant ^{-1a}	Number of SEEDS Silicle ^{-1a}	Seed Yield (g m ²) ^a	Seed oil content (%)
T1 (control)	48.7±1.7db	4.5±0.6e	60.8±7.4f	13.3±0.2a	12.8±1.5c	31.5
T2	52.9±1.6bcd	4.8±0.6e	78.6±12.6def	13.3±0.9a	19.5±2.2c	na
T3	55.5±1.8abcd	5.5±0.5cde	108.6±15.8cdef	12.4±0.1a	23.5±3.3c	na
T4	59.8±2.9abc	7.4±0.8abc	172.9±24.4abc	13.3±0.8a	48.1±9.8b	31.2
T5	59.9±1.2ab	7.8±0.8abc	151.9±24.2abcd	14.1±0.6a	63.6±5.5ab	29.1
T6	59.6±1.6abc	8.9±1.3ab	168.4±44.5abc	11.9±0.3a	66.8±12.2ab	31.7
T7	62.9±1.2a	7.7±0.6abc	148.6±6.1abcde	13.4±1.0a	71.8±8.8a	31.4
T8	60.3±0.6ab	8.6±0.6ab	160.7±9.2abc	12.4±1.3a	70.7±4.8a	31.5

Table Continued..

Treatments	Plant height (cm) ^a	Number of branches Plant ^{-1a}	Number of siliques Plant ^{-1a}	Number of SEEDS Silicle ^{-1a}	Seed Yield (g m ²) ^a	Seed oil content (%)
T9	59.3±2.6abc	7.4±0.7abc	143.5±10.2bcde	12.9±1.0a	72.2±4.1a	30.9
T10	63.1±3.8a	7.5±0.7abc	175.5±37.6abc	13.0±0.6a	65.6±6.3ab	32.5
T11	57.9±2.2abc	7.2±0.3abcd	193.3±25.9ab	13.3±0.9a	67.4±5.9ab	32.3
T12	58.1±2.7abc	9.4±0.7a	222.2±40.4 a	12.8±0.6a	66.3±7.7ab	31.4
T13	53.2±2.6bcd	4.7±0.6e	73.6±8.7 ef	12.2±1.0a	16.7±1.8c	na
T14	52.3±1.1cd	5.1±0.2de	108.6±9.7 cdef	13.0±0.7a	18.7±1.9c	na
T15	53.6±3.5bcd	6.7±0.8bcde	105.4±21.2 cdef	12.5±0.3a	18.7±3.3c	29.8

^a: Values are means (±SEM) of three replicates.^b: Values within each column followed by the same letter did not differ significantly (P<0.05).^{na}: Seed oil content not analysed.

Seed oil content and fatty acid composition

Seed oil content of camelina ranged between 29.1% (T5) and 32.5% (T10) (Table 2). Seed oil content of the samples of treatments T2, T3, T13 and T 14 was not analyzed as seed yields were low in them. As such, seed oil content of camelina in the present study fell within the range reported by different researchers across the world.^{4,9,14} Nearly 32% oil content in camelina cv. Calena has been reported.⁷ Which also corresponded with that of the present study? However, higher range of oil content (35.9 to 38.7%) in the same cultivar (Calena) of camelina, grown at the temperate zone of Central Western Himalaya has been reported.²⁴ Since, adaptability of crop to the environment is reported to cause considerable variations in the seed oil content among different locations.^{7,9} variation in the oil content of cv calena may be attributed to this fact. Results revealed that seed oil content in most of the treatment combinations of FYM, S, N and P2O5 remained either lower or nearly equal to that in control indicating no effect of fertilizers on seed oil content of camelina. Although it is reported that Sulfur positively affects oil content in oilseed crops.²⁶ no such trend was observed in the present study as also reported by other

workers.^{14,27} Organic fertilizers have been considered as a source of nutrients as well as they can positively influence P-availability in soil.^{15,16} And consequently promote crop production. However, in the present study, FYM could neither influence vegetative growth nor seed yield nor seed oil content of camelina. Oil composition was analyzed only in seed samples of control (T1) in order to assess the patterns of fatty acid profile of seed oil of camelina grown in hot semi-arid climate. Results revealed that linolenic (C18:3), linoleic (C18:2), eicosenoic (C20:1) and oleic (C18:1) acids are the principal fatty acid components of camelina seed oil (Table 3). In general, patterns of fatty acid composition of camelina (cv. Calena) oil observed in the present study were almost identical to those reported previously for the same cultivar.⁹ However, concentration of linoleic acid (20.5%) reported in the present study was higher. On the other hand, linoleic acid content in camelina oil in the present study was nearly equal to that described in other studies.⁸ Such variations in fatty acid content in camelina oil may be explained by the fact that besides cultivar specific characteristics, environmental conditions also affect fatty acid composition.^{2,7}

Table 3 Fatty acid composition of seed oil of camelina grown at hot semi-arid climate

Fatty Acid Content (%)											
Myristic	Palmitic	Stearic	Oleic	Linoleic	Linolenic	Arachidic	Eicosenoic	Eicosadienoic	Behenic	Erucic	Others
(C14:0)	(C16:0)	(C18:0)	(C18:1)	(C18:2)	(C18:3)	(C20:0)	c (C20:1)	(C20:2)	(C22:0)	(C22:1)	1.6
0.2	5.5	2.3	14.8	20.5	32	traces	15.9	1.8	0.2	5.2	1.6

Conclusion

The study concluded that successful cultivation of camelina can be carried out in degraded lands of hot semi-arid region and considerable seed yield and oil content can be obtained that too by applying relatively lesser nutrient inputs. Application of N (100kg ha⁻¹) and P2O5 (60kg ha⁻¹) was found critical for achieving optimal plant growth and seed yield of camelina, whereas S (up to 30kg ha⁻¹) and FYM (up to 30tons ha⁻¹) fertilization could neither influence plant growth nor seed yield nor oil content. Camelina seed oil content remained unaffected by tested dosages of both organic manure and mineral nutrients (N, P2O5, and S). Fatty acid composition of camelina seed oil was comparable to those described in the previous reports. Since, this is the first study assessing the agronomic attributes of camelina in the degraded land of hot semi-arid zone of India; therefore, there is a wide scope for enhancing the seed yield and oil content of camelina

by optimizing its water and nutrient requirements and standardizing planting time and density for the region.

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Conflict of interest

The author declares no conflict of interest.

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