Indian Journal of Agricultural Sciences **87** (3): 369–72, March 2017/Article
https://doi.org/10.56093/ijas.v87i3.68721

Response of split application of sulphur on growth, yield and oil content of false flax (*Camelina sativa*)

ANUJA KUMARI[1], P K JOSHI[2], MOHAMMED MOHSIN[3] and M C ARYA[4]

Defence Institute of Bio-Energy Research (DIBER) Field Station, Uttarakhand 262 501

Received: 30 April 2016; Accepted: 28 October 2016

ABSTRACT

False flax [*Camelina sativa* (L.) Crantz.] popularly known as gold-of pleasure, a proposed biofuel species is an oil seed crop of *Brassicaceae,* family introduced in India in 2009. A study was carried out at Defence Institute of Bio-Energy Research, Field Station- Pithoragarh, Uttarakhand, India during 2011-13 to know the effect of split application of sulphur (20 kg/ha S) on growth, yield and oil content of *C. sativa* cv Calena (EC-643910). Statistical analysis revealed that split application of sulphur significantly affected parameters undertaken during the study viz. plant height, branch/plant, number of pods/plant, seeds/pod, flowering, pod formation as well as maturity duration, seed yield and oil yield. *Camelina* productivity enhanced with two split application of S (T 2) and gave 170.84% higher seed yield compared to control. Thus, sulphur applied in two splits resulted in the higher seed yield (1 061.13 kg/ha), oil content (36.43%) and oil yield of 434.345 lit/ha and is recommended for improving the productivity of *Camelina* as a emerging biofuel crop.

Key words: Biofuel crop, *Camelina*, False flax, Sulphur

Global energy demand and an emphasis on sustainable system has recently renewed interest in agriculturally produced biofuels. Oilseed crops are the efficient way to produce biofuel, with a net energy gain of up to 93% after all production process is completed. With reference to current scenario of demand for fuel and to realize self-reliance in energy, India is stepping up the National Biofuel Policy proposing a blending of 20% biofuels with petrol-diesel by 2017 and *Camelina sativa* is an oil seed crop recently introduced in India from Austria as a potential biodiesel crop (Agarwal *et al*. 2010). *C. sativa* (L.) Crtz. of origin Mediterranean to Central Asia belongs to *Brassicaceae* family. There has been recent interest in *Camelina* because of its potential as a low-cost feedstock for biofuels and hence the need to optimize its production.

According to Baligar *et al.* (2001), many agricultural soils of the world are deficient in one or more of essential plant nutrients to support plant growth and thus inorganic sources of fertilizers have been used by producers to achieve desirable crop yields.

Sulphur (S) is an essential plant nutrient and oilseed crops have high demand of S, requiring approximately 16 kg S to produce 1 tonne of seeds containing 91% of dry matter (Mc Grath and Zhao 1996). According to Rausch and Wachter (2005), sufficient S nutrition is vital for plant health and resistance to pathogens. S deficiency can inhibit plant use of N efficiently and vice versa (Malhi and Gill 2002). Singh *et al*. (2012) stated that regular supply of available S is required throughout the growing season. *Camelina* is reported to have low nutritional requirements for nitrogen (N), phosphorous (P), potassium (K) and sulphur (S) and is also able to produce moderate yields on poorer soils than most oilseed crops (Wojtkowiak *et al.* 2009). Jiang *et al*. (2013), Sintim *et al.* (2015) and Solis *et al*. (2013) studied interaction of N and S on *Camelina* seed and oil yields. But information is lacking on split application of S and its impact on yield. The discrepancy in *Camelina* response to S demonstrates the need to determine site specific S requirements in split doses during critical growth and development for *Camelina* production. Hence, the present study was undertaken to evaluate the effect of split application of S on growth and yield and oil content of *C sativa* cv Calena (EC-643910) for the environmental conditions of Central Western Himalayas of India.

MATERIALS AND METHODS

A field experiment was conducted during the winter

[1]Scientist 'C' (e mail: anuja.hort@rediffmail.com), Snow and Avalanche Study Establishment (SASE), Research and Development Centre (RDC), Plot No. 01, Him Parisar, Sec 37-A, Defence R&D Organisation, Ministry of Defence, Chandigarh 160 036. [2]Technical Officer (e mail:pkjshi@rediffmail.com) Defence Institute of Bio-Energy Research Field Station, Post Bag No.06, Pithoragarh, Uttarakand 262 501. [3]Scientist 'C' (e mail: mmchem@yahoo.com), [4]Scientist 'G' (e mail: diber_pith@rediffmail.com), Defence Institute of Bio-Energy Research (DIBER), Defence R &D Organisation, Ministry of Defence, Goraparao, Haldwani Uttarakhand, 263 139.

(*rabi*) season of 2011-12 and 2012-13 at Defence Institute of Bio-Energy Research (DIBER) Field Station, Pithoragarh, Uttarakhand, situated in Central Western Himalayas of India (29° 29'-30°49'N latitude; 85°05'- 81°31'E longitude; 1700 m a msl). *C. sativa* cv. Calena (EC 643910) was used for the study. The soil was gravelly sandy- clay loam in texture, organic carbon contents was 0.36%, available N, 250 kg/ha, available P, 11 kg/ha exchangeable K, 115 kg/ha, available S, 29.9 kg/ha and soil pH ranged from 6.1-7.5. The experiment was designed and laid out in randomized block design (RBD) and replicated five times. The treatment consisted of split doses of S (20 kg/ha) and N (40 kg/ha) applied in following combinations detailed below:

Treatment code	Treatment combination	Detail of application
T_1	0 kg S + 20 kg N (A*) + 20 kg N /ha (B**)	S was absent at basal dose; N was applied at two split doses (basal as well as 30 days of crop germination)
T_2	10 kg S + 20kg N / ha (A*)+ 10 kg S /ha+ 20 kg N/ha (B*)	In case of T-2, S was split into two doses and applied first at the time of sowing (basal) and the second, at 30 days after crop germination; N was applied at two split doses (basal as well as 30 days of crop germination)
T_3	10 kg S + 20kg N / ha (A*) + 5 kg S /ha+ 20 kg N/ha (B**) + 5 kg S (C***)	In case of T-3, S was split in three doses and applied at the time of sowing (basal), second at 30 days after crop germination, third at 45 days after crop germination; N was applied at two split doses (basal as well as 30 days of crop germination)

Note: A*- as basal dose; B**- 30 days after crop germination; C***- 45 days after crop germination.

The source of S and N were gypsum and urea, respectively. Soil was prepared to fine tilth. The crop was manually sown in October using seed rate of 4.5 kg/ha and harvested in February. The crop was manually sown in October using seed rate of 4.5 kg/ha and harvested in February. The plot size was 7.45 and 9.25 m^2 in 2011-12 and 2012-13, respectively. Two irrigations were given to the crop as life saving measure, first at early seedling stage and then at pre-flowering stage. One hoeing was given to keep the crop free from weed. No plant protection measure was taken during the studies. Days to flower and pod were determined as the number of days from date of seeding to approximately 50% flowering and pod formation, respectively. All the data were collected on plot basis and fifteen representative plants were randomly selected from each plot. Then, the plant height, branches/plant, number of pods/plant, number of seeds/pod, and 1 000 seed weight were recorded. Days to maturity was determined as the number of days from date of seeding to physiological maturity, i.e. when about 95% of the pods had changed colour and the seeds were firm, representing a moisture of about 25% (Guggel and Falk 2006) Seed yield was recorded per plot and then converted into kg/ha. Oil content was estimated by solvent extraction method using soxhlet apparatus. The 10 g shade dried seed were ground in mortal and pastel. Petroleum ether was used as solvent for extraction of total fats. Extraction was carried out for 10 hr at 65°C. Total fats recovered after evaporation of excessive solvent were expressed as oil content (%). The oil yield per unit area (l/ha) was determined as the product of seed yield multiplied by oil percentage divided by the density of the *Camelina* oil (0.89 g/cc). The data of two years winter season, i.e. 2011-12 and 2012-13 were pooled for various parameters and were subjected to analyze using analysis of variance (ANOVA) technique for RBD using the package OPSTAT, 2008 to draw inference of the results. Valid conclusions were drawn only on significant differences between treatment means at P=0.05 level of probability.

RESULTS AND DISCUSSION

Results of pooled analysis are given in Table 1. The results revealed that when S was applied in split dose, it significantly influenced the physiological parameters, yield and oil content of *C. sativa* cv Calena (EC-643910) at 5% level of significance.

The split application of S showed significant differences in flowering duration at 5% probability level (Table 1). The flowering was found to be much earlier (78.00 days) in T_3 (20 kg/ha S, applied in 3 splits) compared to T_2 (84.00days) and T_1 (95.00 days). Application of S increases the availability of nutrients in overall biosynthesis

Table 1 Effect of split application of Sulphur on physiology, seed yield and oil of C. sativa cv Calena (mean of two years).

Treatment	Flowering (days)	Pod formation (days)	Plant height (cm)	Branches/ plant (No)	Pods/ Plant (No)
T1	95.00	118.00	66.10	9.70	193.90
T2	84.00	110.25	72.70	11.80	284.30
T3	78.00	106.50	77.20	20.00	308.92
CD @5%	5.12	3.19	1.31	1.78	6.78
Se(m)	1.27	1.28	1.31	0.69	2.17
CV	2.56	2.01	3.17	4.77	10.62
	Seeds/ Pod (No)	1000 seed weight (g)	Maturity duration (days)	Seed yield (kg/ha)	Oil content (%)
T1	13.70	1.190	130.15	621.11	34.62
T2	12.10	1.101	135.49	1061.13	36.43
T3	10.90	1.150	139.73	853.35	35.10
CD @5%	0.007	NS	2.10	9.34	0.005
Se(m)	0.86	0.002	1.01	3.31	0.001
CV	5.22	0.245	7.30	0.67	0.003

*Two years data results compiled.

process (Lal *et al.* 2014). Ahmed *et al.* (1999) reports that inadequate supply of S and N at flowering time not only decreases the photosynthetic area and its duration but also the photosynthetic rate. Hawkesford, (2000) also suggests that efficiency of S utilization improved through its split application in plants. Patel *et al.* (2013) reveals that supply of S in adequate and appropriate amount helps in flower primordial initiation for its reproductive part, which govern the number of pods/ plant, length of pod, number of seeds/ pod in green gram.

It was evident from the Table 1 that the pod formation was significantly affected by various treatments and it followed similar trend as in the case of flowering. Average pod formation took lesser time (106.50 days) in T_3. Split application of sulphur significantly affected and decreased the pod formation duration from 106.50 to 118.00 days. This is because of early flowering which ultimately led to earlier pod formation.

The maximum plant height (77.20 cm) and branch per plant (20.00) was noticed in T_3 and minimum plant height (66.10 cm) and branch per plant (9.70) in T_1 treatment, respectively. S, with its involvement in the metabolic processes, enhances the meristematic activity and thus causes higher apical growth with expansion of photosynthetic surface (Piri *et al.* 2012). S not only results in greater translocation of photosythates initially but also accounted for greater number of productive tillers during reproductive phase (Saed *et al.* 2012). The probable reason of increase in plant height as well as number of branches in *Camelina* may be attributed to the splitting of S dose that led to stimulation in chloroplast protein synthesis in plants, higher synthesis of chloroplast results in greater photosynthetic efficiency and ultimately increased dry matter production per plant of *Camelina.*

The pod per plant and seeds per pod were significantly affected due to split application of sulphur. The maximum number of pods/plant (308.92) and minimum seeds per pod were noticed in T_3 treatment while T_1 exhibited the minimum number of pods (193.90) and maximum number of seeds/ pod (13.70) revealing the fact that less number of pods are getting better nourishment adding to the more number of seeds/pod (Kumari *et al.* 2014). Ngezimana and Agenbag (2013) reported that S had larger effect on reproductive growth than on vegetative (leaf) growth in Canola.

The test weight of the *Camelina* seeds did not differ significantly due to split application of sulphur and found maximum weight of 1.190 g/1 000 seeds in T_1 and minimum (1.101 g/1000 seeds) in T_2 ie. 20 kg S/ha S in two splits.

Days to physiological maturity of the crop was found earlier in T_1(130.15) and the maturity duration rose with split application of sulphur from 135.49 and 139.73 days in T_2 and T_3, respectively, and can be related to better vegetative growth, plant canopy area and efficient photosynthetic activities which might have enhanced the reproductive phase resulting in delay of crop maturity (Noquet *et al.* 2004). Soil applied S delays maturity in canola (Rehuman *et al.* 2013). Significantly higher seed yield of 1 061.13 kg/ha was recorded in T_2 (20 kg/ha S in two splits) and the average seed yield was 170.84% and 137.39%, respectively, in T_2 and T_3 over T_1. In the present study, among all the treatments, split application of S at 20 kg/ha at two splits, viz. first as basal and second at 30 days after crop germination (T_2) resulted in better and efficient translocation and utilization of photosynthates with adequate availability of S at appropriate stage and has ultimately resulted in higher yield of *C. sativa*. Split application of S enhances its utilization by crops. Application of S in 2 splits or more than 2 splits increased the S availability even at later stages of growth in *Brassica juncea* under field conditions (Abraham 2001). Similarly, Ahmad *et al.*(2005) suggested that application of S fertilizer in split doses during growth stages is better than application of the entire amount of S at any stage for obtaining optimum yield of rapeseed. Lakshman *et al.* (2015) observed highest seed yield up to 35.77% with split application of S as 50% basal and 50% at flowering (1.90 tonnes/ha) over the control (1.40 tonnes/ha) in *Glycine max* (Soybean).

Maximum oil content (36.43%) was observed for T_2 (Table 1). Seed oil content (%) was significantly affected due to variation in split application of sulphur and increase in oil content may be ascribed to involvement of sulphur in biosynthesis of oil and protein molecules (Fismes *et al*. 2000, Gupta *et al*. 2004 and Rehuman *et al.* 2013). The increase in the oil content was 13.0–52.0% with S fertilization over the control treatment in rapeseed. S fertilization also increased acetyl-CoA concentration, acetyl-CoA carboxylase activity, and soluble protein, sugar, and starch content in the developing seeds (Ahmad *et al.* 2000).

The oil yield was shown in Fig 1 and was found to be maximum for T_2 treatment (two split application of S; as basal dose and 30 days after crop emergence of S) (434.35 l/ha) compared to T_3 (336.55 l/ha) or no sulphur (241.605 l/ha) owing to optimization of splitting of sulphur doses. Application of S increased the lipid content in the seeds from the initial stage. The maximum increase was observed, when S was applied in three portions, there was a positive strong co-relation between S and lipid content in the seeds of *Brassica campestris* L. (Ahmad and Abdin 2005). The results obtained are in consonance with the findings of split application of S by Ahmad *et al*. (1999) in *Brassica*

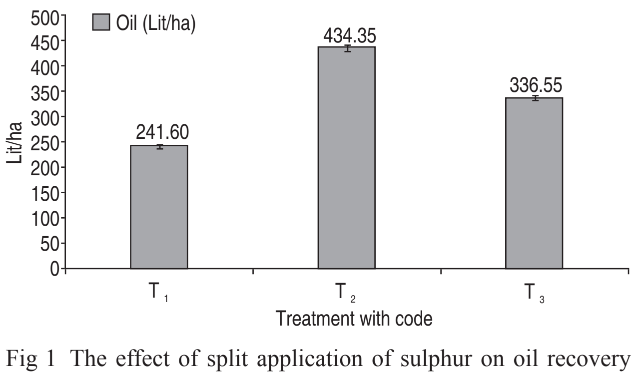

Fig 1 The effect of split application of sulphur on oil recovery of *Camelina*

genotypes, Hussain *et al.* (2011) in sunflower, Lakshman *et al.* (2015) and Madhavi *et al.* (2015) in soybean.

According to results, it may be concluded that split application of S significantly affected the physiological traits, yield and oil content of *Camelina*. The S application @ 20 kg/ha in 2 splits is recommended for *Camelina* for improving productivity as a emerging biofuel crop.

ACKNOWLEDGEMENT

We are grateful to Dr J Vollmann, BOKU – University of Natural Resources and Applied Life Sciences Vienna, Austria for providing the nucleus seed of *C. sativa* cv Calena for research study; Director, NBPGR, New Delhi for his co-operation and support in customs and quarantine clearance for import of *Camelina* seed from Austria and equally thankful to Dr Z Ahmed (Ex-Director, DIBER, Haldwani) and presently Director, Directorate of Management Services, DRDO Bhawan, New Delhi), Dr Ankur Agarwal, Sc 'D' and Sh T. Pant, Sc 'F'(Ex), Dr P S Negi, Sc 'E' and technical staff members of DIBER Field Station Pithoragarh for their cooperation in carrying out the work.

REFERENCES

Abraham G. 2001. Increasing productivity of Indian mustard (*Brassica juncea*) through split application of sulphur. *Indian Journal of Agricultural Sciences* **71**(10): 674–5.

Agarwal A, Pant T and Ahmed Z. 2010. *Camelina sativa*: A new crop with biofuel potential introduced in India. *Current Science* **99**(9): 1 194–5.

Ahmad A and Abdin M Z. 2005. Effect of sulphur application on lipid, RNA and fatty acid content in developing seeds of rapeseed (*Brassica campestris* L.). *Plant Science* **150**(1): 71–6.

Ahmad A, Abrol Y P and Abdin M Z.1999. Effect of split application of sulphur on growth and yield attributes of *Brassica* genotypes different in time of flowering. *Canadian Journal of Plant Science* **79**(2): 175–80.

Ahmad A, Khan I and Abdin M Z. 2000. Effect of sulfur fertilisation on oil accumulation, acetyl-CoA concentration, and acetyl-CoA carboxylase activity in the developing seeds of rapeseed (*Brassica campestris* L.). *Australian Journal of Agricultural Research* **51**(8): 1 023–9.

Ahmad A, Khan I, Anjum N A M, Iram D, Abdin, M Z and Muhammad I .2005. Effect of timing of sulphur fertilizer application on growth and yield of rapeseed. *Journal of Plant Nutrition* **28**(6): 1 049–59.

Baligar V C, Fageria N K and He Z L.2001. Nutrient use efficiency in plants. *Communication in Soil Science and Plant Analysis* **32:** 921–50.

Fismes J, Vong P C, Guckret A and Frossard E. 2000. Influence of sulphur on apparent N-use efficiency, yield and quality of oilseed rape (*Brassica napus* L) grown on calcareous soil. *European Journal of Agronomy* **12:** 127–41.

Gugel R K and Falk K C. 2006. Agronomic and seed quality evaluation of *Camelina sativa* in Western Canada. *Canadian Journal of Plant science* **86:** 1 047–58.

Gupta V K, Kumar S and Singh A K. 2004. Yield and quality wheat (*Triticum aestivum*) as influenced by sulphur nutrition and weed management. *Indian Journal of Agricultural Sciences* **74**(5): 254–6.

Hawkesford M**.** 2000. Plant response to Sulphur deficiency and the genetic manipulation of sulphate transporters to improve Sulphur utilization efficiency. *Journal of Experimental Botany* **51**(342): 131–8.

Hussain S S, Misger F A, Amit K and Baba M H. 2011. Response of nitrogen and sulphur on biological and economic yield of Sunflower (*Helianthus annuus* L.). *Research Journal of Agricultural Sciences* **2**(2): 308–10.

Jiang Y, Caldwell C D, Falk K C, Lada R R and MacDonald D. 2013**.** *Camelina* yield and quality response to combined nitrogen and sulphur. *Agronomy Journal* **105:** 1 847–52.

Kumari A, Mohsin M, Joshi P K, Arya M C and Ahmed Z. 2014. Optimization of irrigation schedule for *Camelina sativa*, a biofuel crop. *Indian Forestor* **140**(11): 1 127– 130.

Lakshman K, Vyas A K , Shivakumar B G and Rana D S. 2015. Effect of levels and time of sulphur application on growth, yield and quality of soybean (*Glycine max*). *Indian Journal of Agronomy* **60**(1): 121–5.

Lal G, Mehta R S, Maheria S P and Sharma Y. 2014. Influence of sulphur and zinc on growth and yield of coriander (*Coriandrum sativum* L.). *International Journal of Seed Spices* **4**(2): 32–5.

Madhavi A, Babu P Surendra, Susheela R and Ramanjaneyulu A. 2015. Effect of split application of sulphur on yield and use efficiency by soybean in light soil. *Journal of Progressive Agriculture* **6**(1): 17–20.

Malhi S S and Gill K S. 2006. Cultivar and Fertilizer S rate interaction effects on canola yield, seed quality and S uptake. *Canadian Journal of Plant Science* **86**(1): 91–8.

Mc Grath S P and Zhao F J. 1996. Sulphur uptake, yield responses and the interactions between nitrogen and sulphur in winter oilseed rape (*Brassica napus*). *Journal of Agriculture Sciences* **126:** 53–62.

Ngezimana W and Agenbag G A. 2013. Effect of nitrogen (N) and sulphur (S) on Canola (*Brassica napus* L.) vegetative and reproductive growth under controlled conditions. *African Journal of Agricultural Research* **8**(39): 4 887–94.

Noquet C, Avice J C, Rossato L, Beauclair P, Henry M P and Oury A. 2004. Effects of altered source–sink relationships on N allocation and vegetative storage protein accumulation in *Brassica napus* L. *Plant Science* **166**(4): 1 007–18.

Patel H R, Patel H F, Maheriya V D and Dodia I N. 2013. Response of kharif green gram (*Vigna ranata* Wilczek) to sulphur and phosphorus fertilization with and without biofertilizer application. *The Bioscan* **8**(1): 149–52.

Piri I, Rahimi A, Tavassoli A, Rastegaripour F and Babaein M. 2012. Effect of sulhur fertilizer on sulphur uptake and forage yield of *Brassica juncea* in condition of different regimes of irrigation. *African Journal of Agricultural Research* **7**(6): 958–63.

Rausch T and Watcher A. 2005. Sulphur metabolism: A versatile platform for launching defence operations. *Trends Plant Science* **10**: 503–9.

Rehuman H U, Iqbal Q, Farooq M, Wahid A, Afzal I and Shazad, M A Basr . 2013. Sulphur application improves the growth, seed yield and oil quality of canola. *Acta Physiologiae Plantarum* **35**(10): 2 999–3 006**.**

Saed B, Gul H, Khan A Z and Parveen L. 2012. Growth factors and straw yield of wheat cultivars in relation with nitrogen and sulphur fertilization. *ARPN Journal of Agriculture and Biological Sciences* **7**(1): 13–22.

Singh J, Sahay N, Singh H and Bhaduaria H S**.** 2012. Nitrogen and Sulphur requirement of mustard under different crop sequences. *Annals of Plant Soil Research* **14**(2): 113–5.