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Influence of sowing time, environment and spacing on seed yield and oil recovery in camelina (*Camelina sativa*)

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ABSTRACT

An experiment was conducted to standardize the agro-technology of newly introduced crop camelina [*Camelina sativa* (L.) Crtz.] in India at DIBER field station, Pithoragarh. Four sowing times (October, November, December and January), two environment (open and polyhouse) and two line spacings (30 and 40 cm) along with broadcasting were used to study the effect on yield, yield attributing traits and oil content. The results revealed the significant effect of sowing time, environment and spacing on the seed yield of camelina. Results of this experiment revealed that October-November is the best month for sowing the crop with a seed yield of 13.68 –14.81 q/ha irrespective of the growing environment. Line spacing exhibited significantly higher seed yield (12.05-12.64 q/ha) over broadcasting (10.23 q/ha) with 30cm line spacing showing superiority over 40 cm.

Key words: Agro-technology, Biofuel, Plant geometry, Quality, Yield

Camelina, false flax or gold-of-pleasure [*Camelina sativa* (L.) Crtz.] is an under-exploited oilseed crop of family Brassicaceae with agronomic low-input features (Putnam *et al.* 1993) and an unusual fatty acid composition with high levels of alpha-linolenic acid (Budin *et al.* 1995) vis-à-vis unusually high cholesterol and brassicasterol content (188 and 133 ppm respectively) than other vegetable oils (Shukla *et al*. 2002). It has been an important oil crop during Bronze and Iron ages and was gradually replaced with modern *Brassica* cultivars in the middle ages and thereafter (Vollmann *et al.* 1996). Recently, interest in camelina has been renewed mainly due to the demand for alternative low-input crops with a potential for non-food industrial utilization specially biofuel without interfering the food security. Seed oil content of camelina has been reported between 320–480 g/kg and seed yield up to 2800 kg/ha (Vollmann *et al*. 1996, 2007). Although presence of omega-3 fatty acids makes its oil unique and nutritionally rich but presence of high cholesterol and eicosenoic acid (15%) pose a hurdle for its approval as food oil (Leonard 1998 and Lu 2008) and thus making it suitable raw material for biofuel. Although presence of polyunsaturated fatty acids cause susceptibility to oxidation but it appears to be sufficiently stable during storage in experiments. The other important attribute is that cold pressed meal of camelina after oil extraction contains 10-14% oil by weight and protein (40%) with lower glucosinolate levels making it more desirable animal feed (Pilgeram *et al.* 2007). A variety of non-food usage of oil as drying oil and in environmentally safe painting and coating application, cosmetics to low emission biodiesel biofuels has been documented.

In the present world scenario, biodiesel has been accepted as clean and safe alternative fuel. Feasibility of camelina oil as biodiesel has been successfully demonstrated by Japan Airline (JAL) and Dutch Airline (KLM) during 2009 and by US Navy during 2010 on Earth day by flying Super Sonic 'Green Hornet' F/A-18 (Anon 2009). India is also stepping steadily in this direction with successful introduction of *Camelina sativa* during 2009 (Agarwal *et al.* 2010) at Pithoragarh, Uttarakhand (1700 m above MSL). Though camelina have very high rate of germination in temperature range of 10-32ºC but several factors like nutrition, seed rate, sowing date and growing environment (Agegnehu and Honermeier 1997, Gilbertson *et al.* 2007, Vollmann *et al.* 1996 and 2007) affect its growth, seed and oil yield. Low seed rate and small seed size pose problem during mechanized sowing. Broadcasting has traditionally being used for sowing grains in many parts of India. Therefore, present study has been carried out to compare the effect of broadcasting vs. line sowing and to study the effect of environment and sowing date on yield attributing traits of camelina.

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MATERIALS AND METHODS

The experiment was conducted at Defence Institute of Bio-Energy Research, Field Station, Pithoragarh (1700 m MSL) with camelina cv Calena (EC 643910). The average annual rainfall of the area is 1200 mm and average monthly temperature variation is presented in Fig. 1. Crop was raised through direct sowing during second week of every month (October 2009 to January 2010) at a line spacing of 40 cm in the first experiment. In the second experiment, crop was sown during second week of December in three different geometry, i e broadcasting, 30 cm line spacing and 40 cm line spacing. Experiments were laid out in randomized block design (RBD) with three replications and data were recorded on ten plants randomly selected from each plot for various yield attributing traits. Observations were recorded on plant height, seed pods/plant, days to maturity, 1 000 seed weight, seed yield/plant, oil content and estimated seed yield extrapolating the data available for seed yield/plot. 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. Data were analysed using standard statistical procedures.

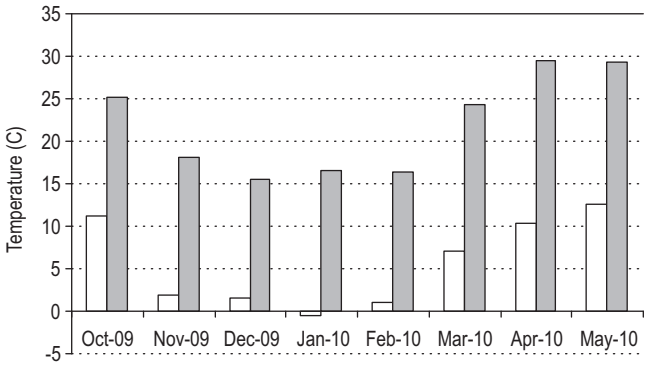

Fig 1 Monthly temperature variation during the experimentation period of camelina

RESULTS AND DISCUSSION

The results revealed the significant effect of sowing time and environment on various traits of camelina under study (Table 1). Effect of sowing time on number of seed pods/plant, days to maturity, 1 000 seed weight, seed yield and oil content was significant, whereas effect of environment was significant on seed yield/plant, 1 000 seed weight and oil content. Interaction effect of sowing time and environment were significant on days to maturity and 1 000 seed weight (Table 1). The analysis of data in Table 2 revealed that plants grew comparatively better under polyhouse over open field condition but differences were non-significant. Number of seed pods/plant was the highest and significantly superior in October sown crop and decreased gradually thereafter in further sowing dates irrespective of sowing environment. Crop maturity also affected significantly and maturity in late sown crop was hastened significantly which may be attributed to the rise in temperature during the maturity of crop in the month of March and beyond. The results also revealed that crop matured comparatively quickly inside the polyhouse in all sowing dates which may be attributed to comparatively higher temperature inside polyhouse. The 1 000 seed weight also affected significantly by sowing dates and environments and was the maximum in October sowing under polyhouse condition (1.211g). The results also revealed that 1 000 seed weight reduced significantly under January sown crop, whereas the average was at par among rest three sowing dates irrespective of environment. Vollmann *et al.* (2007) found that 1 000 seed weight is an important criteria for genetic improvement of camelina lines for high oil content because large seed genotypes were inferior to small seeded genotypes in terms of yield and oil content. Although effect of growing environment on seed weight was non-significant. Johnson *et al.* (2008) found that 1 000 seed weight in camelina is not affected by planting densities. Seed yield also affected significantly by environment and sowing time and was the maximum (3.17 g/plant) under polyhouse condition in October sown crop and decreased gradually in further sowing dates. Although seed yield/plant decreased as sowing advanced from October to January irrespective of environment, the effect was non-significant. Results presented

Table 1 ANOVA of mean square of sums for various traits of camelina as influenced by sowing time and environment

Source of variation	df	Mean sum of squares						
		Plant height (cm)	No. of seed pods/plant	Days to maturity	Seed yield/ plant (g)	1 000 seed wt (g)	Seed yield (q/ha)	Oil content (%)
Replication	2.0	29.38	1014.0	0.375	0.136	0.0001	0.250	0.908
Sowing time	3.0	24.42	3784.9**	655.4**	0.167	0.0089**	10.84**	0.723*
Environment	1.0	446.33	6534.0	150.0	0.311**	0.0003**	24.08	0.377**
Interaction	3.0	17.84	141.11	19.0**	0.022	0.0010**	0.134	0.068
Error	14.0	17.50	197.7	2.327	0.077	0.00005	0.429	0.125
Total	23.0							

Table 2 Effect of sowing time and environment on camelina seed yield and yield attributing traits

Treatment		Plant height	No. of seed	Maturity	1 000 seed	Seed yield/	Seed yield	Oil content
Sowing time	Env.	(cm)	pods/plant	(days)	wt (g)	plant (g)	(q/ha)	(%)
Oct 2009	Polyhouse	104.7	481.0	128.6	1.211	3.17	15.59	38.9
	Open	94.7	438.7	138.6	1.166	3.02	14.04	38.9
Nov 2009	Polyhouse	104.2	450.0	120.0	1.188	3.12	14.77	38.5
	Open	94.2	422.7	123.6	1.195	2.85	12.60	38.8
Dec 2009	Polyhouse	98.7	444.3	110.3	1.193	3.14	13.68	38.5
	Open	95.2	404.3	115.0	1.190	2.77	11.56	38.7
Jan 2010	Polyhouse	100.8	410.7	110.0	1.106	2.75	12.79	37.8
	Open	89.8	388.3	111.6	1.120	2.64	10.62	38.3
CD sowing time		NS	17.41	1.88	0.009	NS	0.81	0.438
CD Environment		NS	NS	NS	0.006	0.242	NS	0.310
CD interaction		NS	NS	2.67	0.012	NS	NS	NS

Table 3 Effect of line sowing vs broadcasting (December 2009 sowing in open condition) on camelina seed yield

Treatment	Maturity (days)	1 000 seed wt (g)	Seed yield/plant (g)	Seed yield (q/ha)	Oil content (%)
Broadcasting	117.6	1.184	2.86	10.23	38.37
Line sowing (30 cm)	119.3	1.188	3.40	12.64	38.77
Line sowing (40 cm)	119.3	1.185	3.55	12.05	39.07
CD (P=0.05)	NS	NS	NS	0.703	NS

in Table 1 also revealed that average seed yield in October sown crop was the highest (14.81 q/ha) and decreased further as sowing was delayed. Higher yield in the October sown crop can be attributed to the better test seed weight and seed yield/plant as discussed earlier. Gilbertson *et al.* (2007) also reported that sowing date and growing environment significantly affect seed yield and oil yield in camelina. Although seed oil content affected significantly by the sowing time but significant decrease was noticed only in January sown crop compared to earlier sowing dates. Vollmann *et al.* (1996) found that seed yield and oil content were highly influenced by year and location effects among 10 genotypes of camelina.

In other experiment, effect of line sowing vs broadcasting was studied. The results revealed the significant difference of line sowing and broadcasting on seed yield (Table 3). Although, line sowing at 30 cm and 40 cm showed statistically at par yield but both exhibited significant superiority over broadcasting. Effect on other yield attributing traits and oil content were non-significant but line sowing exhibited the superiority over broadcasting. Johnson *et al.* (2008) reported that plant densities affect the maturity of camelina and higher plant densities hastened maturity as much as by 7 days. The optimum density ranged from 125-200 plants/m^2 giving maximum seed yield. Results of this experiment revealed that October-November is the best month for sowing the crop with a seed yield of 13.68 –14.81 q/ha irrespective of the growing environment. Line spacing exhibited significantly higher seed yield (12.05-12.64 q/ha) over broadcasting (10.23 q/ha) with 30 cm line spacing showing superiority over 40 cm.

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