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Response of Early, Timely & Late Genotypes of *Brassica* sps. Grown under Different Temperature Conditions for Oil Content & Fatty Acid Composition

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Authors' contributions

This work was carried out in collaboration among all authors. Authors SKS and SKC designed the study, authors SKS, SK and KP was involved in performing the research work, collection and analysis of data, writing the manuscript and wrote the first draft of the manuscript. Author MK was involved in literature searches and corrections in the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

The effect of four different dates of sowing on oil content and fatty acid composition was studied using eleven rapeseed and Indian mustard varieties at Indian Agricultural Research Institute, New Delhi. Effects of species, maturity duration (early, timely and late sown) and environment (different

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dates of sowing) on the oil content and fatty acid composition was observed. The results indicate specific, genotypic variation as well as different response to the environment, resulting from strong G×E interactions for oil content and delay in sowing compromised the oil content in general. Higher temperature at seed filling and pod maturity stage affected the fatty acid profile. A significant correlation between temperature variables at maturity and fatty acid composition was observed. Linolenic (r= -0.335 to -0.317) and erucic acid (r = -0.578 to -0.568) was significantly and negatively correlated with temperature at maturity stage whereas a positive correlation was found with linoleic acid content (r = 0.324 to 0.338). The results indicated that the sowing of brassica genotypes during 2nd fortnight of October is beneficial as far as the oil content as well as oil quality is concerned.

Keywords: Fatty acid profile; Indian mustard; oil content; rapeseed; temperature.

1. INTRODUCTION

Rapeseed-mustard is the third important oilseed crop in the world after soybean and palm oil. Among nine oilseeds cultivated in India, rapeseed-mustard contributes 29.4 % in the total production with 24.7 % area. The global area, production & productivity of rapeseed-mustard is 36.59 million hectares, 72.37 million tonnes and 1979 kg/ha respectively. India lags behind Canada and China in terms of area and production and fifth in productivity after Germany, France, Canada and China. India is the fifth largest vegetable oil economy with 7.4% oilseeds & 5.8% oil production and 9.3% of edible oil consumption in the world. Oilseeds are the second most important agricultural commodity in India after cereals India and 57% of the domestic edible oil requirement is fulfilled through imports [1]. Indian mustard is predominantly cultivated in Rajasthan, UP, Haryana, Madhya Pradesh, Gujarat and in some non-traditional areas of south India including Karnataka, Tamil Nadu, and Andhra Pradesh. The crop can be raised well under both irrigated and rainfed conditions. Mustard is cultivated mostly under temperate climates. It is also grown in certain tropical and subtropical regions as a cold weather crop. Indian mustard is reported to tolerate annual precipitation of 500 to 4200 mm, annual temperature of 6 to 27°C, and pH of 4.3 to 8.3. Rapeseed-mustard follows C_3 pathway for carbon assimilation. Therefore, it has efficient photosynthetic response at 15–20°C temperature. At this temperature, the plant achieves maximum CO_2 exchange range, which declines thereafter. However, optimum date of sowing also implies many disadvantages with respect to biotic stress factors. Timely sown crop has to face pest infestation that coincides with the growth of the host crop. Early sowing in September helps in the escape from major fungal pests especially *Albugo candida* causing white rust. Sowing date affects the growing conditions which plant receives during various growth phases and that ultimately affects the oil content [2-5] and fatty acid composition [6] in *brassica sps*. Altering the sowing time can affect the crop growth and yield but scanty information is available on the effect of growing conditions on oil content and quality. Plant breeders are developing new varieties suitable for various agro-ecological conditions, in order to diversify areas under Indian mustard, particularly in eastern India. The early varieties are sown under high temperature conditions and harvested under low temperature conditions whereas varieties suitable for late sown conditions are sown at lower temperature & harvested under very high temperature conditions. In order to assess the effect of different dates of sowing on the oil content and oil composition of different genotypes of rapeseed- mustard the present study was carried out, the results of which are presented in this paper.

2. MATERIALS AND METHODS

Materials consisted of four early sown (Pusa Mahak, Pusa Agrani, NPJ-112 & EJ-17), two timely sown (Pusa Vijay & Pusa Bold) and two late sown (RGN-145 & NPJ-113) varieties of Indian mustard and three varieties (BBS-1, T-9 & YID-1) of *Brassica rapa.*

Experimental plot was sown on four dates *i.e* 19th September (D1), 12th October (D2), 2nd November (D3) & 22nd November (D4) in rabi season at Indian Agricultural Research Institute, New Delhi in a randomized block design with 3 replications. Ten random plants were tagged from each plot in all the four dates of sowing and seed produced from each of these was harvested individually for further chemical analysis *i.e* estimation of oil content using NMR and fatty acid profiling using Perkin Elmer Clarus

600 Gas Chromatograph [7]. Standard samples of methyl esters of fatty acids (Sigma Aldrich) were used. Other reagents used were H_2SO_4 (AR grade, 98% purity), Hexane (spectroscopic grade), Methanol (AR grade) and anhydrous sodium sulphate (AR grade). Daily weather parameters for the growing period starting from 1st sowing till last harvesting were collected from the meteorological observatory, Division of Agricultural Physics, I.A.R.I., New Delhi, India. All the statistical analysis of the recorded data was carried out using STPR software.

3. RESULTS AND DISCUSSION

3.1 Oil Content

The varieties ranged from 37.58-39.16% for oil content across the sowing dates (Table 1 & Fig. 1). The varieties differed in oil content among sowing dates significantly. Among the four early genotypes, Pusa Agrani had the highest percent of oil content (39.49) in September sowing (D1), which gradually decreased (38.26) as the date of sowing was advanced to last week of November (D4). The same trend was followed by NPJ 112, that showed highest oil content in D1 & D2, which gradually decreased by D4. However, Pusa Mahak, another early genotype, revealed a steadily increasing tendency in its oil content with the advancing sowing date, achieving highest at D4. The fourth early genotype EJ-17 did not show up any relationship in its oil content and date of sowing. The oil content did not follow any specific trend in EJ-17.

Both the timely sown genotypes had the highest oil content in the October (D2), optimum time of sowing for these two genotypes. The oil content waned of when genotypes were planted on different dates other than that they are developed for. The same relationship was found to hold good for late sown genotype NPJ113, which had the higher oil content in D4 sown conditions.

Brassica rapa genotypes also had a trend of oil content similar to timely sown genotypes, revealing maximum in D2 and then gradually declining oil content. The results indicated specific, genotypic variation as well as different response to the environment, resulting from strong G X E interactions. Seeds attain maximum vigour on the mother plant at the end of seed filling stage [8] or slightly later [9] after which they begin to deteriorate on the mother plant or during storage, loosing viability and vigour [10]. The rate of seed deterioration is positively related to ambient temperature, relative humidity and seed moisture content [11]. Heat stress is defined as the rise in temperature beyond a threshold level for a period of time sufficient to cause irreversible damage to plant growth and development. It's a serious threat to crop production worldwide [12] in the present scenario of climate change. During early seedling growth, lipids are mobilized and converted to sucrose that acts as primary source of nutrient. High temperature increases the rate of reproductive development, which shortens the time for photosynthesis to contribute to fruit and seed development [13]. Oil is deposited late during seed development and high temperature exposure during that time results in decrease in oil content [14]. Warm and dry growing condition favour the production of saturated fatty acids, while cooler, moist conditions favour the production of the polyunsaturated fatty acids [15]. Higher temperature provoked damage at the physiological, biochemical and molecular level [16].

Present study revealed that oil content decreased marginally with increase in temperature at the time of seed filling and maturity. Similar results were found by other workers [17].

3.2 Fatty Acid Composition

3.2.1 Saturated fatty acid: Stearic acid

Stearic acid content ranged from 4.84 % to 13.89 % among different varieties across dates of sowing (Table 2A & Fig. 2). However, a fixed pattern of stearic acid content was not observed under different sown conditions but it was observed that stearic acid content was comparable in D1 and D3. Late sown variety RGN-145 had least saturated fatty acid in 1^{st} date of sowing (5.16%) and early varieties, grown in late sown condition, gained higher amount of stearic acid.

3.2.2 Mono-unsaturated fatty acids: Oleic and erucic acid

These two fatty acids are the by-products of a linear reaction. Oleic acid, product of the first reaction, is the substrate for the synthesis of the erucic acid. As a result, when oleic is more, erucic acid is less and vice-a-versa. Oleic acid content varied significantly among the varieties and date of sowing (Table 2B & Fig. 2). Since none of the variety was of canola quality, hence oleic acid was lower in general for all the

Table 1. Effect of date of sowing on oil content (%) of seeds of rapeseed –mustard varieties

Varieties	Date of sowing				
	D1	**D2**	**D3**	**D4**	**MEAN**
NPJ- 112	38.14 (37.93)	38.28 (38.03)	35.24 (36.23)	33.38 (35.03)	36.23 (36.80)
PUSA AGRANI	39.49 (38.73)	38.99 (38.43)	38.82 (38.33)	38.26 (38.03)	38.89 (38.38)
PUSA MAHAK	38.93 (38.43)	39.41 (38.73)	39.69 (38.93)	40.27 (39.83)	39.57 (38.83)
EJ- 17	38.62 (38.83)	39.99 (39.03)	37.67 (37.73)	39.10 (38.53)	38.83 (38.38)
PUSA BOLD	38.77 (38.33)	39.57 (38.83)	38.63 (38.23)	35.63 (36.53)	38.15 (37.98)
PUSA VIJAY	34.67 (35.93)	39.05 (38.53)	33.23 (35.03)	34.00 (35.53)	35.23 (36.25)
RGN- 145	34.61 (35.83)	37.50 (37.63)	35.94 (36.63)	35.82 (36.68)	35.96 (36.68)
NPJ- 113	36.78 (37.13)	37.91 (37.83)	38.54 (38.21)	39.17 (38.63)	38.10 (37.95)
BBS- 1	38.2 (38.03)	38.94 (38.43)	38.99 (38.43)	39.17 (38.63)	38.82 (38.38)
YID- 1	38.39 (38.13)	40.35 (39.23)	38.4 (38.13)	38.39 (38.13)	38.88 (38.40)
T- 9	40.14 (39.13)	40.84 (39.53)	40.38 (39.33)	40.32 (39.23)	40.42 (39.30)
MEAN	37.88 (37.80)	39.16 (38.56)	37.77 (37.75)	37.58 (37.65)	38.10 (37.94)
CD (p=0.05)					
DOS	0.125				
Variety	0.206				
DOS X Variety	0.413				

DOS: date of sowing; D1:19 Sept.; D2:12 Oct.; D3:2 Nov.; D4:22 Nov. Figures in parenthesis are transformed values

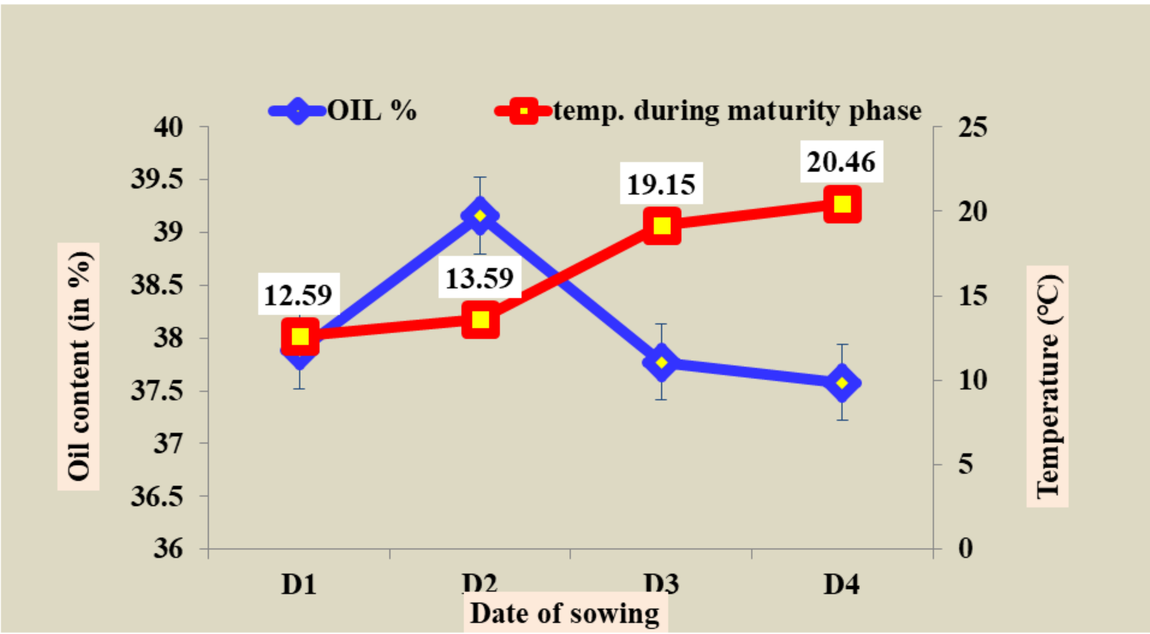

Fig. 1. Effect of date of sowing and average temperature during maturity phase on oil content (%) of seeds of rapeseed –mustard varieties

varieties and for all dates of sowing as compared to erucic acid (Table 2C & Fig. 2) content. Oleic acid level was the lowest in second date of sowing in most of the varieties. In EJ-17 and BBS-1, it decreased with delay in the date of sowing. Oleic content varied significantly among the varieties with the maximum value in T-9 (24.83%) and RGN-145 (21.46%). Cultivar NPJ-113 showed highest oleic acid content in D4 (29.97%) and had a corresponding decrease in the erucic acid content. Mean erucic acid content increased in D2 (39.26%) from D1 (38.33%) and then decreased in D3 (32.95%) and D4 (28.12%) (Table 2E). Among the varieties, erucic acid content varied significantly with maximum value in YID-1 (41.49%). In D4, the minimum erucic acid content was recorded in NPJ-113 (16.9%). EJ-17 also showed lower erucic acid in late sowing condition (18.42% and 19.32% in D3 and D4, respectively).

Table 2. Effect of date of sowing on fatty acid composition of seeds of rapeseed –mustard varieties

A. Stearic acid

Varieties	Date of sowing				
	D1	D2	D3	D4	MEAN
NPJ- 112	8.06 (16.5)	11.37 (19.7)	8.41 (16.9)	10.8 (19.2)	9.66 (18.0)
PUSA AGRANI	6.34 (14.6)	7.41 (15.8)	8.37 (16.8)	10.01 (18.4)	8.03 (16.4)
PUSA MAHAK	6.97 (15.3)	6.00 (14.2)	6.59 (14.9)	10.43 (18.8)	7.49 (15.8)
EJ- 17	6.68 (15.0)	7.48 (15.9)	4.84 (12.7)	5.76 (13.9)	6.19 (14.3)
PUSA BOLD	7.63 (16.0)	8.09 (16.5)	6.27 (14.5)	7.13 (15.5)	7.28 (15.6)
PUSA VIJAY	6.70 (15.0)	8.53 (17.0)	7.33 (15.7)	10.47 (18.9)	8.25 (16.6)
RGN- 145	5.16 (13.1)	8.07 (16.5)	7.48 (15.9)	7.06 (15.4)	6.94 (15.2)
NPJ- 113	6.96 (15.3)	5.69 (13.8)	6.41 (14.7)	9.34 (17.8)	7.10 (15.4)
BBS- 1	10.28 (18.7)	9.36 (17.8)	7.90 (16.3)	13.89 (21.9)	10.35 (18.6)
YID- 1	7.63 (16.0)	7.75 (16.2)	8.48 (16.9)	8.24 (16.7)	8.02 (16.4)
T- 9	6.64 (14.9)	7.10 (15.5)	7.68 (16.1)	6.95 (15.3)	7.09 (15.4)
MEAN	7.18 (15.4)	7.89 (16.2)	7.25 (15.5)	9.09 (16.1)	7.85 (16.1)
CD (p=0.05)					
DOS	0.10				
Variety	0.16				
DOS X Variety	0.33				

DOS: date of sowing; D1:19 Sept.; D2:12 Oct.; D3:2 Nov.; D4:22 Nov. Figures in parenthesis are transformed values

B. Oleic acid

Varieties	Date of sowing				
	D1	D2	D3	D4	MEAN
NPJ- 112	17.71 (25.0)	5.27 (13.0)	21.77 (28.0)	18.12 (25.0)	15.71 (22.7)
PUSA AGRANI	19.39 (26.0)	9.21 (17.6)	15.33 (23.0)	28.86 (32.3)	18.17 (24.7)
PUSA MAHAK	18.21 (25.3)	12.28 (20.6)	18.15 (25.0)	22.32 (28.0)	17.34 (24.7)
EJ- 17	18.94 (26.0)	15.63 (23.0)	10.18 (18.6)	10.54 (19.0)	13.82 (21.6)
PUSA BOLD	22.68 (28.3)	19.53 (26.0)	18.59 (25.6)	22.23 (28.0)	20.75 (27.0)
PUSA VIJAY	17.13 (24.3)	13.47 (21.6)	19.02 (26.0)	12.8 (21.0)	15.60 (23.2)
RGN- 145	15.25 (23.0)	17.29 (24.6)	27.98 (32.0)	25.32 (30.0)	21.46 (27.4)
NPJ- 113	14.94 (23.0)	13.41 (21.3)	18.47 (25.3)	29.97 (33.0)	19.19 (25.6)
BBS- 1	15.90 (25.3)	16.92 (24.3)	11.52 (20.0)	5.67 (14.0)	12.50 (20.4)
YID- 1	16.08 (23.6)	19.89 (26.3)	17.42 (24.6)	23.61 (29.0)	19.25 (25.9)
T- 9	23.71 (29.0)	23.46 (29.0)	26.91 (31.0)	25.25 (30.0)	24.83 (29.7)
MEAN	18.17 (25.1)	15.12 (22.5)	18.65 (25.3)	20.42 (26.3)	18.09 (24.8)
CD (p=0.05)					
DOS	0.14				
Variety	0.24				
DOS X Variety	0.49				

DOS: date of sowing; D1:19 Sept.; D2:12 Oct.; D3:2 Nov.; D4:22 Nov. Figures in parenthesis are transformed values

C. Erucic acid

Varieties	Date of sowing				
	D1	D2	D3	D4	MEAN
NPJ- 112	31.39 (34.0)	34.97 (36.2)	22.68 (28.4)	25.67 (30.4)	28.67 (32.3)
PUSA AGRANI	38.72 (38.4)	43.63 (41.3)	41.01 (39.8)	18.16 (25.2)	35.38 (36.2)
PUSA MAHAK	39.16 (38.7)	43.93 (41.5)	38.88 (38.5)	29.00 (32.5)	37.74 (37.8)
EJ- 17	39.55 (38.9)	39.79 (39.1)	18.42 (25.4)	19.32 (26.0)	29.27 (32.3)
PUSA BOLD	32.11 (34.5)	35.79 (36.7)	24.66 (29.7)	34.85 (36.1)	31.85 (34.3)
PUSA VIJAY	42.56 (40.7)	41.36 (40.0)	39.43 (38.8)	33.9 (35.0)	39.31 (38.8)
RGN- 145	41.47 (40.0)	38.50 (38.3)	28.52 (32.2)	26.46 (30.9)	33.73 (35.4)

C. Erucic acid					
Varieties	**Date of sowing**				
	D1	**D2**	**D3**	**D4**	**MEAN**
NPJ- 113	42.00 (40.3)	41.21 (39.9)	34.94 (36.2)	16.90 (24.2)	33.76 (35.2)
BBS- 1	34.93 (36.2)	35.86 (36.7)	38.05 (38.0)	34.99 (36.2)	35.95 (36.8)
YID- 1	44.61 (41.9)	41.42 (40.0)	41.28 (39.9)	38.67 (38.4)	41.49 (40.1)
T- 9	35.21 (36.3)	35.46 (36.5)	34.68 (36.8)	31.47 (34.1)	34.20 (35.7)
MEAN	38.33 (38.2)	39.26 (38.7)	32.95 (34.8)	28.12 (31.8)	34.67 (35.9)
CD (p=0.05)					
DOS	0.11				
Variety	0.19				
DOS X Variety	0.38				

DOS: date of sowing; D1:19 Sept.; D2:12 Oct.; D3:2 Nov.; D4:22 Nov. Figures in parenthesis are transformed values

D. Linoleic acid					
Varieties	**Date of sowing**				
	D1	**D2**	**D3**	**D4**	**MEAN**
NPJ- 112	24.92 (29.4)	26.42 (30.9)	30.83 (33.7)	29.69 (33.0)	27.96 (31.9)
PUSA AGRANI	21.19 (27.4)	17.28 (24.5)	20.23 (26.7)	28.86 (32.4)	21.89 (27.7)
PUSA MAHAK	20.18 (26.6)	19.81 (26.4)	20.08 (26.6)	24.81 (29.8)	21.22 (27.4)
EJ- 17	20.7 (27.0)	18.94 (25.7)	14.57 (22.4)	14.78 (22.6)	17.24 (24.4)
PUSA BOLD	23.29 (28.8)	20.63 (27.0)	38.26 (38.2)	21.46 (27.5)	25.91 (30.4)
PUSA VIJAY	19.89 (26.4)	18.09 (25.1)	21.22 (27.4)	27.36 (31.5)	21.64 (27.6)
RGN- 145	19.67 (26.3)	19.01 (25.8)	27.63 (31.7)	24.42 (29.6)	22.68 (28.3)
NPJ- 113	19.99 (26.5)	20.21 (26.7)	21.12 (27.3)	28.39 (32.1)	22.42 (28.2)
BBS- 1	23.88 (29.2)	20.97 (27.2)	20.38 (26.8)	30.73 (33.6)	23.99 (29.2)
YID- 1	21.91 (27.9)	22.14 (28.0)	18.34 (25.3)	21.56 (27.6)	20.98 (27.2)
T- 9	20.83 (27.1)	21.07 (27.3)	19.62 (26.2)	22.25 (28.1)	20.94 (27.2)
MEAN	21.49 (27.6)	20.41 (26.8)	22.93 (28.4)	24.93 (29.8)	22.44 (28.1)
CD (p=0.05)					
DOS	0.75				
Variety	0.12				
DOS X Variety	0.24				

DOS: date of sowing; D1:19 Sept.; D2:12 Oct.; D3:2 Nov.; D4:22 Nov. Figures in parenthesis are transformed values

E. Linolenic acid					
Varieties	**Date of sowing**				
	D1	**D2**	**D3**	**D4**	**MEAN**
NPJ- 112	13.72 (21.7)	15.72 (23.3)	12.40 (20.6)	12.16 (20.4)	13.50 (21.5)
PUSA AGRANI	12.18 (20.4)	16.18 (23.7)	11.97 (20.2)	12.32 (20.5)	13.16 (21.2)
PUSA MAHAK	12.38 (20.6)	15.18 (22.9)	13.84 (21.8)	10.53 (18.9)	12.98 (21.0)
EJ- 17	10.69 (19.0)	12.95 (21.0)	8.37 (16.8)	6.73 (15.0)	9.68 (18.0)
PUSA BOLD	11.58 (19.8)	13.92 (21.9)	7.69 (16.0)	8.87 (17.3)	10.51 (18.8)
PUSA VIJAY	11.74 (20.0)	15.28 (23.0)	10.72 (19.1)	11.95 (20.2)	12.42 (20.5)
RGN- 145	12.03 (20.2)	12.92 (21.0)	8.39 (16.8)	12.13 (20.3)	11.36 (19.6)
NPJ- 113	13.16 (21.2)	14.73 (25.5)	16.20 (23.7)	13.23 (21.3)	14.33 (22.2)
BBS- 1	11.81(20.0)	13.07 (21.1)	11.74 (20.0)	12.89 (21.0)	12.37 (20.5)
YID- 1	8.58 (17.0)	7.24 (15.6)	6.32 (14.5)	5.29 (13.2)	6.85 (15.1)
T- 9	8.60 (17.0)	8.27 (16.7)	5.99 (14.1)	10.27 (18.6)	8.28 (16.6)
MEAN	11.49 (19.7)	13.22 (21.1)	10.33 (18.5)	10.57 (18.8)	11.40 (19.5)
CD (p=0.05)					
DOS	0.65				
Variety	0.10				
DOS X Variety	0.21				

DOS: date of sowing; D1:19 Sept.; D2:12 Oct.; D3:2 Nov.; D4:22 Nov. Figures in parenthesis are transformed values

Table 3. Weather data (maximum, minimum and average temperature) for the growing period under 4 dates of sowing

Temperature(^{0}C)	Vegetative phase	Reproductive phase	Seed filling and maturity phase
D1			
Tmax	33.37	28.48	20.07
T min	19.56	12.31	5.12
Tav	26.46	24.03	12.59
D2			
Tmax	31.06	23.65	20.50
T min	14.55	7.02	6.59
Tav	22.81	19.82	13.59
D3			
Tmax	27.26	19.86	27.65
T min	11.25	5.23	10.66
Tav	19.25	12.54	19.15
D4			
Tmax	21.79	21.68	29.02
T min	6.57	6.94	11.89
Tav	14.18	14.31	20.46

Table 4. Relationship between temperature at different crop growing periods with oil content, quality and enzyme activity in rapeseed –mustard varieties grown under 4 sowing dates

Character	Reproductive growth period			Seed filling and maturity period		
	Tmax	Tmin	Tav	Tmax	Tmin	Tav
Oil Content	0.036^{NS}	-0.038^{NS}	0.111^{NS}	-0.203^{NS}	-0.164^{NS}	-0.186^{NS}
Stearic acid	-0.152^{NS}	-0.142^{NS}	-0.164^{NS}	0.224^{NS}	0.256^{NS}	0.239^{NS}
Oleic acid	-0.043^{NS}	0.032^{NS}	-0.119^{NS}	0.218^{NS}	0.181^{NS}	0.202^{NS}
Linoleic acid	-0.188^{NS}	-0.120^{NS}	-0.252^{NS}	0.338^{*}	0.324^{*}	0.333^{*}
Linolenic acid	0.179^{NS}	0.089^{NS}	0.260^{NS}	-0.335^{*}	-0.293^{NS}	-0.317^{*}
Erucic acid	0.386^{**}	0.288^{NS}	0.471^{**}	-0.578^{**}	-0.568^{**}	-0.575^{**}

Tmax: Av. of maximum temperature; T min: Av. of minimum temperature; Tav: Average of average temperature; POX: peroxidase; NA: not applicable

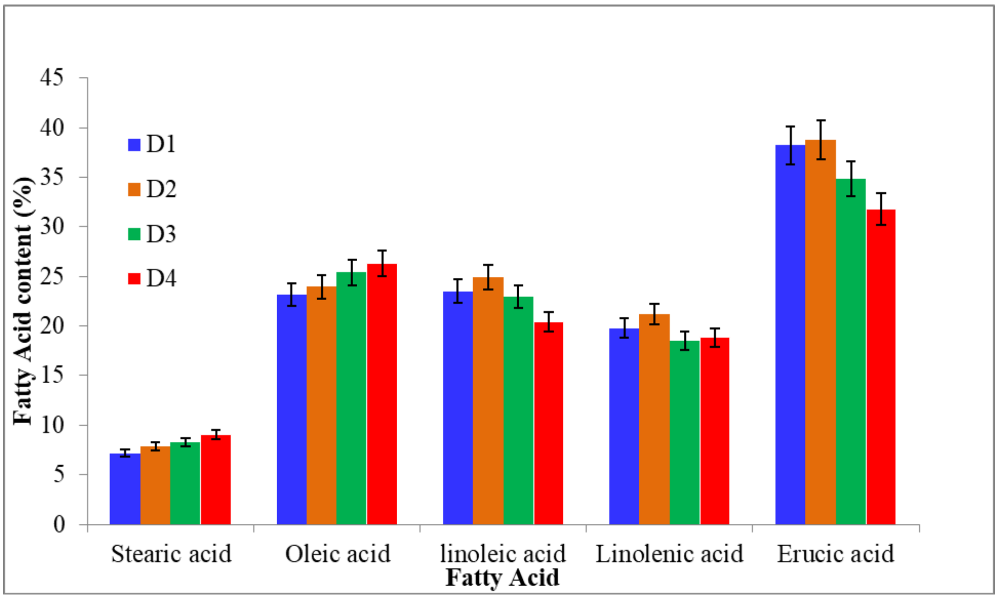

Fig. 2. Fatty acid composition as affected by dates of sowing (temperature at seed filling and maturity phase)

3.2.3 Poly-unsaturated fatty acids: Linoleic and linolenic acid

Both linoleic and linolenic acids are produced from oleic acid by the addition of double bonds in the same 18-carbon chain. Therefore, the relative proportions of the three fatty acids represent the preponderance of a particular step in the fatty acid synthesis pathway. As compared to the timely sown conditions viz. D2, linoleic acid content increased with delay in date (D3 & D4) of sowing (Table 2D & Fig. 2). It also varied significantly among the varieties; NPJ-112 had the higher value (27.96). EJ-17 had the lowest linoleic content in D4 (14.78). All *B. rapa* varieties had higher linoleic content in D4. NPJ-112 (29.69), NPJ-113 (28.39), Pusa Agrani (28.86) and Pusa Vijay (27.36) had maximum linoleic content in D4. As against this linolenic acid was recorded highest in D2 (13.22%), whereas it was significantly lower in other dates of sowing (Table 2E & Fig. 2). It was observed that late sowing condition was good for decrease in linolenic acid content. It also varied among varieties significantly. *B.rapa* varieties T-9 (5.99%) and YID-1 (5.29%) had the lowest linolenic content in D3 and D4 respectively, in comparison to those in early sowing dates. NPJ-112 showed a decreasing trend of the linolenic acid content. In other cultivars, it showed a slight increase in D2 in comparison to D1 and then decreased in late sowing.

A significant correlation between temperature variables at maturity and various fatty acid composition was observed (Table 4). In life cycle of plants, right from its emergence and seedling establishment in the field until maturity there is variation in environmental condition at various growth stages (Table 3). The impact of these environmental factors at different stages has potential to modify various seed quality parameters [18]. Oil content and quality also greatly affected by temperature. Linolenic acid content was significantly and negatively correlated with temperature (r= -0.335 to -0.317). A highly significant but negative correlation was observed in erucic acid (-0.578 to -0.568). A positive correlation was found with linoleic acid content. The decrease in oil content may be attributed to less formation of storage reserve and their subsequent free radical mediated degradation. Both genotype and environment parameters determine the amount and quality of canola oil [19]. Sowing date may influence the fatty acid composition through improving ontogenesis [20]. It was observed that late sowing partially decreased the content of oleic acid content and increased the linoleic acid. At the period of seed filling and maturity, unsaturated fatty acid such as linoleic and linolenic acids are influenced by environmental factors. Erucic acid showed a negative correlation with the mean temperature during seed development as reported by other workers [21] whereas linoleic acid increased with rise in temperature during grain filling period. Similar results were reported by Yaniv and co-workers [22-26].

4. CONCLUSION

The results of rapeseed-mustard varieties being grown under different temperatures and seeds harvested at lower and higher temperature conditions indicated a high influence of temperature during growing period particularly at seed filling and maturity period on oil content and quality. Second to third week of October can be the suitable planting window of these varieties in Delhi conditions beyond which high temperature stress may cause decrease in different seed and oil quality parameters.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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