Journal of Oilseed Brassica, 9 (2) : 114-121, July 2018

Effect of sowing dates and nitrogen application on growth and productivity of canola oilseed rape (*Brassica napus*)

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(Received: 03 January 2018; Revised: 15 April 2018; Accepted: 15 May 2018)

Abstract

A field study was conducted to observe the effect of nitrogen (N) application time on growth and productivity of canola oilseed rape (*Brassica napus*) under different sowing dates. Treatments comprised three sowing dates (15 October, 30 October and 15 November) allocated to main plots and seven treatments of time of application of two doses of N to sub plots in three replications. Each successive delay in sowing from 15 October to 30 October and further to 15 November significantly delayed the initiation and completion of emergence and required significantly more number of days for initiation and completion of flowering but required lesser number of days to attain physiological maturity. Each delay in sowing also caused significant reduction in plant height (except between 30 October and 15 November at maturity), dry matter, leaf area index, SPAD value at 40 and 120 days after sowing (DAS) and interception of photosynthetically active radiation at 40 and 80 DAS. Crop sown on 15 October produced 4.1% more (significantly) seed yield (2476 kg/ha) and 27.3% more (significantly) stover yield (9458 kg/ha) than 30 October sown crop, which in turn produced 36.1% and 36.4% more seed and stover yields than 15 November sown crop. Effect of dose (100 and 125 kg) and time of application (two or three splits) of nitrogen (N) on initiation or completion of emergence was inconspicuous but application of 125 kg/ha of N delayed the maturity, increased plant height (mean over time of application) at all growth stages over 100 kg/ha of N, whereas its effect on other growth parameters was variable. Application of 125 kg/ha of N resulted in 11.9% higher seed yield and 8.3% higher stover yield (mean over N application time) than that obtained with 100 kg/ha of N. Effect of time of application of N on different growth parameters (DMA, LAI, PARI, SPAD values) at different growth stages was variable. The maximum seed yield (2405 kg/ha) and stover yield (7919 kg/ha) obtained with 125 kg/ha of N applied in three splits (50 + 50 + 25) was at par with application of 125 kg/ha of N (2358 and 7845 kg/ha) and 100 kg/ha of N in two equal splits for seed yield (2324 kg/ha) and 100 kg/ha of N in three splits for stover yield (7606 kg/ha).

Key words: *Growth pattern, nitrogen application, oilseed rape, sowing dates, split application, yield*

Introduction

Widening gap between requirements and availability of edible oils demands concerted efforts to increase the production of oilseeds in the country. Increasing awareness about the qualitative aspects which is guided by fatty acid composition of oil, improved purchasing power and changing food habits have not only increased the demand but also the perception of usage of oil for cooking and food processing. Rapeseed-mustard oil is the major vegetable oil used for cooking in India and the third major source in the world after soybean and oil palm among different oilseed crops due to low amount of saturated fatty acids (<10%) and moderate amounts of mono- and poly-unsaturated fatty acids including essential fatty acids, and presence of antioxidants. Since the development of canola cultivars of rapeseed mustard in which the oil is almost free from harmful erucic acid (<2%) and seed meal after oil extraction from glucosinolates (<30µmoles per gram), use of oil for human consumption and seed meal as a rich source of protein for livestock including poultry have increased mainly in the developed world. In India also, the demand of canola oil and seed meal is increasing which at present is being met through import.

Canola cultivars of oilseed rape (*Brassica napus*) and Indian mustard (*B. juncea*) have also been recently developed by the Punjab Agricultural University, Ludhiana, India. These cultivars have comparable yields with non canola rapeseed-mustard and are resistant to white rust. Oilseed rape in particular has high yield potential and frost tolerance. Sowing time is the most important non-monetary input which determines the potential of a cultivar through its influence on growth and development during different phenological stages of the crop plant. Nitrogen (N) is an integral part of various plant processes and therefore has the most profound effect on growth, development and productivity of crops including rapeseed-mustard. The objective of this research was to study the effect of dose and time of application of N on growth dynamics and productivity of canola oilseed rape under different sowing dates.

Materials and Methods

The field experiment was conducted at the research farm of Punjab Agricultural University, Ludhiana (30°54² N latitude, 75°48² E longitude, 247 m above msl) during *Rabi* season of 2016-17 on loamy sand soil of neutral pH (6.9), low organic carbon content (0.28%) and potassium permanganate available nitrogen (171 kg/ha), rich in sodium bicarbonate extractable available phosphorus (24.1 kg/ha) and low in ammonium acetate extractable available potassium (75 kg/ha) at the top 15 cm soil profile. Study comprised three sowing dates (15 October, 30 October and 15 November) allocated to main plots and seven treatments of dose (100 and 125 kg/ha) and time of application of nitrogen (two or three splits) to sub plots which were replicated thrice as per split plot design. Canola oilseed rape variety GSC 7 was sown at row spacing of 45 cm. Plant to plant spacing of 10-12 cm within row was maintained by thinning at about 20 days after sowing (DAS). Nitrogen (N) as per treatments was applied through urea. Phosphorus @ 30 kg P_2O_5/ha in the form of single super phosphate and potassium @ 15 kg K_2O/ha in the form of muriate of potash were applied at sowing. All other recommended cultivation practices were adopted.

Plant height at each growth stage was recorded from 10 plants selected at random and tagged at time of first observation. For dry matter accumulation, plants from 0.5 m row length from second outer most row on either side of each plot were cut at the base, dried first under shade and later in oven at 65°C till constant weight. Sun Scan Canopy Analyzer (Line Quantum Sensor Photometer Model LI-191-SA) was used for leaf area index (LAI) and photosynthetically active radiation (PAR) measurements of plants between 12:00 pm to 2:00 pm. The SPAD reading which indicates chlorophyll content in leaves was recorded in 10 leaves of intact plants with Minolta - SPAD 502 Chlorophyll Meter.

Results and Discussion

Plant height increased consistently up to maturity and followed a sigmoid growth pattern. The maximum increase in plant height was observed between 40 DAS and 80 DAS followed by the period between 80 DAS and 120 DAS. The dry matter accumulation (DMA) increased with advancing age of crop. The maximum increase in DMA was recorded between 80 DAS and 120 DAS. Leaf area index (LAI), SPAD values and PARI increased up to 80 DAS and decreased at 120 DAS.

Dates of sowing

Each successive delay in sowing from 15 October to 30 October and further to 15 November significantly delayed the initiation and completion of emergence (Table 1). Crop sown on 15 November took 1.2 and 1.6 more number of days for initiation and completion of emergence, respectively than 30 October and 1.3 and 2.5 more days, respectively than 15 October sown crop. Favourable temperature and longer day length in mid October sown crop resulted in early emergence in comparison to delayed sowing where fall in maximum and minimum temperatures and reduced day length slowed down the process of emergence. Mean temperature during the week following 30 October sowing was 3.4°C lower than 15 October sown crop (25.3°C). whereas in case of 15 November sowing, mean temperature was 2.7°C and 6.0°C lower than 30 October and 15 October sowing dates, respectively. Mean air temperature of 24°-28°C has been reported to be optimum for germination and seedling emergence of rapeseed-mustard (Kumar and Rana, 2013). Under similar growth conditions, Ethiopian mustard (*B. carinata*) sown on 10 October and 30 October took lesser number of days for completion of emergence than 20 November and 10 December sowing dates (Singh and Dhingra, 2003). Canola oilseed rape (*B. napus)* varieties sown on 31 October germinated 9 days earlier than 11 October sown crop (Yousaf *et al.*, 2002).

Delay in sowing of crop significantly increased the number of days required for initiation and completion of flowering. Crop sown on 15 November took significantly more number of days for initiation of flowering (78.6) completion of flowering (103 days) than 30 October (72.3 and 92.6 days) and 15 October (61.1 and 75.6 days) sown crop (Table 1). Crop sown on 30 October also took significantly more number of days for initiation of flowering than 15 October sown crop. Thus initiation and completion of flowering in 15 October sown crop was 11.2 and 16.9 days, respectively earlier than 30 October sown crop which in turn required 6.3 and 10.4 less number of days than 15 November sown crop for initiation and completion of flowering respectively. Crop sown on 15 October took 3.8 more days than 30 October sown crop which took 5.8 days more than 15 November sown crop to attain physiological maturity. Reduction in reproductive period of late sown crop due to increase in temperature, sunshine hours and day length from mid-February onwards reduced the overall crop duration in comparison to early sown crop. Flowering in Indian mustard was delayed with delay in sowing from 8 November to 18 November at Tikamgarh, Madhya Pradesh (Patel *et al.*, 2013) and from 30 October to 14 November and further to 29 November at Faizabad, U.P. (Singh *et al.,* 2014).

Crop sown on 15 October attained significantly more plant height than 30 October sown crop at all growth stages which in turn attained significantly more plant height than 15 November sown crop except at maturity when 6.8% reduction in plant height of 15 November sown crop over 30 October sown crop was non-significant (Table 2). Optimum weather conditions during early sowing might have led to more meristematic cell division and prolonged the vegetative growth phase than delayed sowing conditions where pace of growth was slowed down and crop life span was reduced. Similar effect of sowing dates on plant height of *Brassica juncea* was reported by Singh *et al.* (2014) and Mukherjee (2014).

With successive delay in sowing from 15 October to 15 November, there was significant reduction in dry matter accumulation (DMA) in different plant parts at all growth stages viz; 40, 80 and 120 DAS except in leaf at 120 DAS (Table 2). Crop sown on 15 October produced significantly more dry matter (DM) by plant at 40 DAS, by leaf, stem and total i.e. leaf + stem at 80 DAS, leaf, stem, siliqua and total i.e. leaf + stem + siliqua dry matter at 120 DAS than 30 October and 15 November sown crop. Crop sown on 15 October produced more DM by 17.9% at 40 DAS, 11.0%, 33.6%, 23.5% in leaf, stem and total (leaf + stem), respectively at 80 DAS and 9.9%, 19.3%, 8.4% and 13.1% in leaf, stem, siliqua and total (leaf + stem + siliqua) DM, respectively at 120 DAS than 30 October sown crop which in turn accumulated more DM by 18.6% at 40 DAS, 11.6%, 11.9% in leaf, stem, respectively at 80 DAS, 5.0%, 15.8%, 27.3% and 18.6% in leaf, stem, siliqua and total DM, respectively at 120 DAS than 15 November sown crop. The increase in DM could be attributed to early emergence, plant establishment, increase in plant height and leaf area index due to enhanced vegetative growth in early than late sown crop. Kaur (2001) from Ludhiana also reported reduction in DMA in *Brassica carinata* with delay in sowing from 15 October to 15 December.

Leaf area index (LAI) decreased with delay in sowing at all growth stages but significantly only at 40 DAS where 15 October sown crop registered (1.9) significantly more LAI over crop sown on 15 November (1.5). Effect of sowing dates on SPAD value (an index of leaf chlorophyll content) was significant at 40 and 120 DAS (Table 3). The SPAD value decreased significantly with delay in sowing from 15 October to 30 October at both 40 DAS and 120 DAS; however, it was not influenced by further delay in sowing to 15 November. The crop sown on 15 November attained shorter stature, accumulated less dry matter, lower leaf area at 40 DAS as it was exposed to lower temperature conditions and consequently recorded more concentration of chlorophyll content than 30 October sown crop. The PAR interception by the crop sown on 15 October was significantly higher than 30 October and 15 November sown crop at 40 and 80 DAS (Table 3). Crop sown on 15 October intercepted 25.2%, 16.9% and 1.4% more PAR than 30 October sown crop at 40, 80 and 120 DAS, respectively which in turn intercepted 16.5%, 27.4% and 3.8% more PAR at 40, 80 and 120 DAS, respectively than 15 November sown crop.

Crop sown on 15 October produced 4.1% and 41.6% more (significantly) seed yield (2476 kg/ha) and 27.3% and 73.7% more (significantly) stover yield (9458 kg/ha) than 30 October and 15 November sown crop, respectively (Table 3). Likewise, crop sown on 30 October produced 36.1% and 36.4% more seed and stover yields than 15 November sown crop. This increase in seed yield in early sown crop accrued from better growth, yield attributes such as number of siliquae on main shoot and per plant, number of seeds per siliqua and 1000 seed weight as compared to delayed sowing. Crop sown on 15 October flowered earlier and took lesser number of days for initiation to completion of flowering in comparison to 30 October and 15 November sowing dates. Crop sown on 15 October had the longer reproductive phase i.e. period from initiation of flowering to physiological maturity (80.3 days) in comparison to 30 October (65.3 days) and 15 November (53.2 days) sowing dates. The increased length of the reproductive period indicated more time available for utilization of assimilates for seed setting and development which eventually led to its increased seed yield in comparison to later sowing dates. Several workers from different locations have reported reduction in seed yield of Indian mustard with successive delay in sowing from mid-October up to end November (Singh *et al* 2014; Dinda *et al* 2015; Keerthi *et al* 2017). The higher stover yield in early sown crop may be ascribed mainly to prolonged duration of crop and enhanced DM accumulation owing to favourable weather conditions for plant growth and development as compared to crop sown on later dates where growth duration was curtailed.

The highest harvest index of 30 October sown crop (24.3%) was at par with 15 November sown crop and significantly more than 15 October sown crop (20.7%). Early sown crop produced more total biological yield (seed + stover) at maturity whereas the biomass yield in later sowing dates was lesser due to shortening of growth

Table 1: Effect of dates of sowing and nitrogen management on seedling emergence, flowering and days to maturity of canola oilseed rape

Treatments	Number of days required for				
	Initiation of emergence	Completion of emergence	Initiation of flowering	Completion of flowering	Physiological maturity
Date of sowing					
15 October	4.1	7.7	61.1	75.7	141.4
30 October	4.5	8.9	72.3	92.6	137.6
15 November	5.7	10.2	78.6	103.0	131.8
SEm+	0.1	0.1	0.2	0.2	0.3
CD (p=0.05)	0.3	0.2	0.5	0.4	0.7
Dose (per ha) and time of application of nitrogen					
50* + 50**	4.8	8.8	70.1	89.9	135.2
25* + 75**	4.8	9.7	70.8	90.9	137.0
50* + 25** + 25***	4.6	8.8	68.4	88.1	136.0
25* + 50* + 25***	5.0	9.6	69.6	88.4	133.9
34* + 33** + 33***	5.0	8.9	69.9	90.8	136.8
62.5* + 62.5**	4.6	8.0	75.1	94.3	140.6
50* + 50** + 25***	4.9	8.8	71.2	90.6	139.1
SEm+	-	-	0.1	0.1	0.08
CD (p=0.05)	NS	NS	0.7	0.7	0.5

* = Sowing, ** = Initiation of stem elongation, *** = Initiation of flowering

period and reduced length of reproductive phase. Improvement in harvest index in 30 October over 15 October sown crop accrued from proportionately lesser reduction in total biomass (21.7%) compared to stover yield (27.3%) in 30 October over 15 October sowing date.

Nitrogen management

Effect of dose (100 and 125 kg) and time of application (two or three splits) of nitrogen (N) on initiation or completion of emergence was inconspicuous (Table 1). The trend however, indicated that increasing dose of nitrogen at sowing speeded the process of completion of emergence. Application of 125 kg/ha of N in two equal splits at sowing and initiation of stem elongation took maximum and significantly more number of days for initiation of flowering (75.1) and completion of flowering (94.3) than all other treatments of N application dose and time (Table 1). The numbers of days taken for initiation and completion of flowering with application of 125 kg/ha of N in three splits (71.2 and 90.6 days), 100 kg/ha of N applied in two splits as 25 + 75 (70.8 and 90.9 days) and 100 kg/ha of N applied in two equal splits (70.1 and 89.9 days) were significantly more than the number of days taken with application of 100 kg/ha of N in three splits in which 67 to 75 per cent of total N was applied up to initiation of stem elongation stage i.e. before flowering initiation. Application of 125 kg/ha of N delayed the physiological maturity (139.8 days) by four days over 100 kg/ha of N. Application of 125 kg/ha of N in two equal splits resulted in significantly more number of days to attain physiological maturity (140.6) than all other treatments. Increase in N dose and its higher amount at early growth stage prolonged vegetative growth phase probably due to increased cell division and consequently delayed maturity of plants.

Plant height increased with increasing dose of N from 100 to 125 kg/ha (mean over time of application) at all growth stages (Table 2). At 40 DAS, plant height obtained with application of 125 kg/ha of N in two equal splits at sowing and initiation of stem elongation (31.3 cm) was at par with 100 kg/ha of N applied in two equal splits at sowing and initiation of stem elongation or in three equal splits (34 + 33 + 33) at sowing, initiation of stem elongation and flowering initiation and 125 kg/ha of N applied in three splits as 50 kg as sowing, 50 kg at initiation of stem elongation and 25 kg at flowering initiation. Increased N application particularly at sowing might have increased the availability of photosynthates and meristematic cell activity. Effect of N application on plant height at 80 DAS was non-significant (Table 2). At 120 DAS, plant height discerned with 125 kg/ha of N applied in three splits as 50 + 50 + 25 (159.3 cm) was at par with 100 kg/ha of N applied as 25 kg at sowing + 75 kg at initiation of stem elongation (156.1 cm) and significantly more than all other treatments which in turn were statistically at par with each other. At

Table 2: Effect of dates of sowing and nitrogen management on plant height (cm), leaf area index and dry matter accumulation of canola oilseed rape at different growth stages

Treatments	Plant height (cm)				Dry matter accumulation (kg/ha)								Leaf area index		
	40	80	120	At	40	80 DAS			120 DAS				40	80	120
	DAS	DAS	DAS	maturity	DAS	Leaf	Stem	Total	Leaf	Stem	Siliqua	Total	DAS	DAS	DAS
Date of sowing															
15 October	38.8	131.4	164.6	187.0	1257	2138	3191	5329	2375	6878	6583	15835	1.9	3.0	2.5
30 October	26.3	116.8	154.6	166.8	1066	1926	2389	4315	2162	5765	6073	14000	1.8	2.7	2.3
15 November	22.9	93.8	143.3	156.2	899	1726	2134	3860	2060	4977	4770	11807	1.5	2.4	2.1
SEm+	0.5	6.2	1.7	6.4	68	87	94	163	-	102	139	317	0.15	-	-
CD (p=0.05)	1.1	12.3	3.4	12.8	137	174	188	326	NS	204	277	633	0.3	NS	NS
Dose (per ha) and time of application of nitrogen															
50* + 50**	31.2	115.7	153.7	173.7	1100	1868	2595	4462	2412	6038	5846	14297	1.8	2.9	2.3
25* + 75**	28.0	114.3	156.1	171.7	1071	1875	2659	4534	2043	5895	6058	13996	1.8	2.7	2.3
50* + 25** + 25***	28.2	114.2	152.2	166.8	992	1909	2442	4351	1850	6117	6183	14150	1.7	2.5	2.3
25* + 50* + 25***	28.3	109.2	150.5	163.7	977	1914	2408	4321	2107	5155	5711	12973	1.8	2.1	2.3
34* + 33** + 33***	29.1	115.4	153.1	173.9	1090	1890	2468	4357	2121	5215	5476	12812	1.6	2.4	2.2
62.5* + 62.5**	31.3	112.2	154.2	170.3	1189	2023	2743	4766	2445	6363	5634	14442	1.6	3.0	2.4
50* + 50** + 25***	29.3	117.0	159.3	170.2	1100	2033	2685	4717	2416	6329	5752	14498	1.8	3.4	2.3
SEm+	0.4	-	0.8	1.0	-	40	25	34	32	44	58	80	-	0.06	-
CD (p=0.05)	2.2	NS	5.0	6.0	NS	237	148	206	194	265	348	481	NS	0.4	NS

* = Sowing, ** = Initiation of stem elongation, *** = Initiation of flowering

Table 3: Effect of dates of sowing and nitrogen management on the SPAD values and PAR interception at different growth stages, seed yield, stover yield and harvest index of canola oilseed rape

Treatments	SPAD			PAR interception (%)			Seed yield	Stover yield	Harvest
	40 DAS	80 DAS	120 DAS	40 DAS	80 DAS	120 DAS	(kg/ha)	(kg/ha)	index (%)
Date of sowing									
15 October	40.8	48.7	46.3	74.1	94.6	80.4	2476	9458	20.7
30 October	37.5	48.9	41.8	59.2	80.9	79.3	2379	7427	24.3
15 November	38.2	48.0	41.3	50.8	63.5	76.4	1748	5445	24.2
SEm+	1.2	NS	0.6	2.7	5.5	-	39	117	0.3
CD (p=0.05)	2.3	NS	1.2	5.3	10.9	NS	78	234	0.5
Dose (per ha) and time of application of nitrogen									
50* + 50**	39.6	48.0	44.9	66.2	81.5	72.5	2324	6937	25.4
25* + 75**	38.7	47.2	42.8	59.4	77.7	81.4	2053	7153	22.6
50* + 25** + 25***	38.3	47.0	42.0	52.9	75.8	82.8	2012	7398	21.5
25* + 50* + 25***	38.2	49.4	42.1	59.0	81.9	76.5	2038	7606	21.4
34* + 33** + 33***	38.7	49.2	41.9	60.4	77.7	80.9	2219	7310	23.6
62.5* + 62.5**	39.2	49.3	44.4	63.5	80.2	78.7	2358	7845	23.5
50* + 50** + 25***	39.1	49.3	43.7	68.0	82.7	77.9	2405	7919	23.6
SEm+	-	0.3	0.3	1.2	-	-	19	81	0.2
CD (p=0.05)	NS	2.0	1.5	7.4	NS	NS	115	484	1.4

* = Sowing, ** = Initiation of stem elongation, *** = Initiation of flowering

maturity, maximum plant height attained with 100 kg/ha of N applied in 3 splits as 34 + 33 + 33 (173.9 cm) was at par with with application of 100 kg/ha of N in two splits as 50 + 50 or 25 + 75 kg, 125 kg/ha of N applied in two equal splits at sowing and initiation of stem elongation or in three splits as 50 + 50 + 25 and significantly more than the treatment comprising application of part of N (25 kg/ha) at flowering initiation. This trend indicated that the part of N applied at flowering initiation was not efficiently utilized by the plant for its infrastructure build up as the vegetative growth ceased with on set of flowering. Punia *et al* (2001) reported increase in plant height of Ethiopian mustard with each successive increase in N up to 90 kg/ha.

Differences in DMA at 40 DAS due to application of N at different times and its doses were non-significant (Table 2). At 80 DAS, application of 125 kg/ha of N resulted in more DMA in leaf, stem and total than 100 kg/ha irrespective of time of application. The maximum DMA at 80 DAS in leaf (2033 kg/ha) and stem (2743 kg/ha) was obtained with 125 kg/ha of N applied in three splits (50 + 50 + 25) and in two equal splits, respectively. At 80 DAS, total DMA with application of 125 kg/ha of N in two equal splits (4766 kg/ha) was at par with its application in three splits (4717 kg/ha) as 50 + 50 + 25, and significantly higher than all other treatments of N application. Application of 100 kg/ha of N in two splits (25 + 75) resulted in significantly more DMA in stem and total (leaf + stem) than its application in three splits as 25 + 50 + 25. At 120 DAS, maximum DM in leaf (2445 kg/ha) obtained with 125 kg/ha of N in two equal splits was at par with its application in three splits as 50 + 50 + 25 (2416 kg/ha) or 100 kg/ha of N in two equal splits (2412 kg/ha). The DMA by stem at 120 DAS with application of 125 kg/ha of N in two equal splits (6363 kg/ha) was at par with its application in three splits as 50 + 50 + 25 (6329 kg/ha) and application of 100 kg/ha of N in three splits as 50 + 25 + 25 (6117 kg/ha). In siliquae, the maximum DM (6183 kg/ha) at 120 DAS obtained with 100 kg/ha of N applied in three splits as 50 + 25 + 25 was at par with 100 kg/ha of N applied in two equal splits (5846 kg/ha) or as 25 + 75 (6058 kg/ha) and was significantly higher than all other treatments. The maximum total (leaf + stem + siliqua) DMA at 120 DAS was obtained with application of 125 kg/ha of N in three splits as 50 + 50 + 25 (14498 kg/ha) and was at par with 125 kg/ha of N applied in two equal splits (14442 kg/ha) and with 100 kg/ha of N in two splits (14297 kg/ha) or in three splits as 50 + 25 + 25 (14150 kg) and significantly higher than other treatments of N application.

The effect of dose and time of application of N on LAI was significant only at 80 DAS where application of 125 kg/ha of N in three splits resulted in statistically similar LAI with its application in two equal splits but was significantly higher than all other treatments of dose and time of application of N (Table 2). This increase in LAI might be due to increase in leaf area and numbers with enhanced supply of N. Nitrogen application is known to delay leaf senescence by prolonging assimilate supply. Differences in SPAD values with varied doses and split application of N were inconspicuous at 40 DAS (Table 3). At 80 DAS, the highest SPAD value (49.4) was obtained with 100 kg/ha of N applied in three splits (25 + 50 + 25). Application of 100 kg/ha of N in two splits as 25 + 75 or in three splits as 50 + 25 + 25 resulted in significantly lower SPAD values than all other treatments except over application of 100 kg/ha of N in two equal splits. At 120 DAS, application of 100 and 125 kg/ha of N in two equal splits and 125 kg/ha of N in three splits resulted in statistically similar but significantly higher SPAD value than all other treatments. Application of 125 kg/ha of N in three splits was at par with 100 kg/ha of N applied as 25 + 75 kg/ha. Application of 125 kg/ha of N in 3 splits as 50 + 50 + 25, 100 kg/ha and 125 kg/ha of N applied in two equal splits resulted in similar PARI at 40 DAS whereas, at 80 and 120 DAS, differences in PAR interception among all treatments were non-significant (Table 3).

Application of 125 kg/ha of N resulted in 11.9% higher seed yield and 8.3% higher stover yield (mean over N application time) than that obtained with 100 kg/ha of N (2129, 7281 kg/ha, respectively). The maximum seed yield (2405 kg/ha) and stover yield (7919 kg/ha) obtained with 125 kg/ha of N applied in three splits (50 + 50 + 25) was at par with application of 125 kg/ha of N (2358 and 7845 kg/ha) and 100 kg/ha of N in two equal splits for seed yield (2324 kg/ha) and 100 kg/ha of N in three splits for stover yield (7606 kg/ha). This might be due to improvement in yield attributes due to increased dose of N and its application at higher rate at early stage which might have resulted in better development of plant and accumulated more amount of assimilates for supply to sink at later stages. Nitrogen application of 125 kg/ha in three splits resulted in 6.5% higher seed yield than its application in two equal splits. Results indicated that N applied at sowing and initiation of stem elongation stage resulted in higher yield. Application of 125 kg/ha of N in three splits advanced the onset of flowering (71.2 DAS) by about 4 days and increased the reproductive phase (67.9 days) by 2.4 days in comparison to its application in two equal splits. There might have been better seed development with increased number of splits of N application. The numbers of days taken for initiation of flowering to completion of flowering and for reproductive phase with application of 100 or 125 kg/ha of N in two equal splits were similar and therefore the seed yield under these treatments was also at par with each other. Jadhav *et al.* (1995) obtained higher seed yield of Indian mustard with application of 90 kg/ha of N as 25% at sowing + 75% at 30 DAS than its full dose at sowing or in two equal splits at sowing and 30 DAS. Reager *et al.* (2006) obtained highest seed yield of Indian mustard with application of 100 kg/ha of N in three equal splits at sowing, 30 DAS and 60 DAS than application of its full dose at sowing or in two equal splits at sowing and 30 DAS. Earlier Mohapatra (1993) reported similar beneficial effect of split application of N on seed yield of Indian mustard. The highest value of harvest index (25.4%) obtained with 100 kg/ha of N applied in two equal splits was significantly higher than all other treatments of N application (Table 3). Application of 125 kg/ha of N in two or three splits and 100 kg/ha of N in three equal splits resulted in similar harvest index.

Interaction

Interaction between sowing dates and N management (dose and time of application) for total DMA was significant at 80 and 120 DAS. At both stages, total DMA decreased with successive delay in sowing irrespective on N treatment (Table 4). The maximum and significantly more total DM by 15 October sown crop was produced with application of 100 kg/ha of N in two equal splits at 80 DAS and with three splits (50 + 25 + 25) at 120 DAS than all other treatments of N management. The DMA by 30 October and 15 November sown crop with application of 125 kg/ha of N in three splits (50 + 50 + 25) or in two equal splits was at par with each other and significantly higher than all other N treatments at respective sowing dates. At 120 DAS, the highest total DM produced by 30 October sown crop with 125 kg/ha of N application in three splits was also at par with 100 kg/ha of N applied as 50 + 50 or as 25 + 75 or in three splits as 50 + 25 + 25. Similarly the maximum total DM produced by 15 November sown crop with application of 125 kg/ha of N was also at par with 100 kg/ha of N applied in two equal splits. In early sown crop, increase in dose of N from 100 to 125 kg/ha did not increase DM significantly whereas in delayed sowing, increased dose of N significantly increased DM.

Crop sown on 15 October produced higher but statistically similar seed yield with 30 October sown crop at different N treatments except with application of 100 kg/ha of N as 25 kg at sowing + 75 kg at initiation of stem elongation when differences were significant and, with application of 100 kg/ha of N in three splits as 25 kg at sowing + 50 kg at initiation of stem elongation and 25 kg at flowering initiation where the reverse but non-significant trend was discerned (Table 5). Crop sown on 15 October and 30 October produced significantly higher seed yield than that sown on 15 November, at all treatments of N. In all sowing dates, the highest seed yield obtained with application of 125 kg/ha of N in three splits (50 + 50 + 25) was at par with 125 kg/ha and 100 kg/ha of N applied in two equal splits at sowing and at initiation of stem elongation and significantly higher than all other treatments of N. The highest seed yield obtained with 125 kg/ha of N in three splits was also at par with application of 100 kg/ha of N in three equal splits in case of 30 October and 15 November sowing dates, and also with 100 kg/ha of N applied in three equal splits as 50 + 25 + 25 or 25 + 50 + 25.

Thus, each successive delay in sowing from 15 October to 30 October and to 15 November significantly delayed the emergence and required significantly more number of days for flowering but attained early physiological maturity. Each delay in sowing caused significant

Table 4: Interactive effect of dates of sowing and nitrogen management on total dry matter accumulation (kg/ha) by canola oilseed rape at 80 and 120 DAS

Dose (per ha) and time of application of nitrogen	Date of sowing					
	15 October	30 October	15 November	15 October	30 October	15 November
	80 DAS			120 DAS		
50* + 50**	5506	4248	3634	16280	13986	12624
25* + 75**	5402	4262	3937	15851	14252	11884
50* + 25** + 25***	5387	3833	3833	17167	14450	10834
25* + 50* + 25***	5062	4396	3507	15605	12896	10419
34* + 33** + 33***	5539	3966	3567	13927	13290	11218
62.5* + 62.5**	5239	4677	4380	15773	14724	12829
50* + 50** + 25***	5165	4825	4163	16248	14403	12842
SEm+	30	70				
CD (p=0.05)	356	834				

* = Sowing; ** = Initiation of stem elongation; *** = Initiation of flowering

Table 5: Effect of nitrogen management on seed yield (kg/ha) of canola oilseed rape sown on varied dates

Dose (per ha) and time of application of nitrogen	Date of sowing		
	15 October	30 October	15 November
50* + 50**	2575	2460	1936
25* + 75**	2449	2139	1570
50* + 25** + 25***	2318	2318	1401
25* + 50* + 25***	2247	2406	1459
34* + 33** + 33***	2464	2353	1838
62.5* + 62.5**	2597	2462	2015
50* + 50** + 25***	2681	2515	2018
SEm+	17		
CD (p=0.05)	201		

* = Sowing; ** = Initiation of stem elongation; *** = Initiation of flowering

reduction in all the growth traits (plant height, dry matter, LAI, SPAD value PAR interception) at different growth stages and consequently 15 October sown crop produced significantly more seed (4.1%) and stover (27.3%) yields than 30 October sown crop which in turn produced 36.1% and 36.4% more seed and stover yields than 15 November sown crop. Effect of N application dose and application time on emergence and flowering was inconspicuous and on different growth traits was variable. However, 125 kg/ha of N delayed maturity, increased plant height at all growth stages and increased seed yield by 11.9% and stover yield by 8.3% (mean over N application time) over 100 kg/ha of N. The maximum seed yield (2405 kg/ha) and stover yield (7919 kg/ha) obtained with 125 kg/ha of N applied in three splits (50 + 50 + 25) was at par with application of 125 kg/ha of N (2358 and 7845 kg/ha) and 100 kg/ha of N in two equal splits for seed yield (2324 kg/ha) and with 100 kg/ha of N in three splits for stover yield (7606 kg/ha).

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