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Productivity, nutrient uptake and economics of mustard hybrid *(Brassica juncea)* under different planting time and row spacing

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ABSTRACT

A field experiment was conducted at Pantnagar during 2007-08 and 2008-09 to evaluate the effect of 3 dates of sowing (October 10, 20 and 30), 3 spacings (30 × 10 cm, 45 × 10 cm and 60 × 10 cm, and 3 mustard [*Brassica juncea* (L.) Czernj & Cosson] hybrids/varieties ('Kranti', 'NRCHB-506' and 'DMH-1'). Yield attributes and seed yield were significantly higher in October 10 sowing compared to delayed sowings. The decrease in seed yield due to sowing on October 20 and October 30 over October 10 was to the tune of 8.7 and 29.2 % during first year and 10.1 and 29.3 % during second year, respectively. The hybrids 'DMH-1' and 'NRCHB-506' recorded 36, 35% and 24, 28% higher seed yield respectively, over 'Kranti'. Spacing 45 × 10 cm had significant effect over 60 × 10 cm on seed yield during both the years. Hybrid 'DMH-1' recorded the highest economic returns when sown on October 10 at spacing of 45 × 10 cm. Nutrient uptake followed same trend as seed yield.

***Key words**:* Hybrid, Indian mustard, Oil yield, Seed yield, Spacing, Sowing date

Temperature is the major factor governing the success and timing of agricultural crop production. Germination, biomass production, average growth rate and growth duration all are controlled by temperature. Mustard is usually planted late in western U.P and Uttarakhand, beginning from last week of October to the whole month of November, either as pure crop or mixed with wheat due to which the seed yield of mustard is low. Under late sown condition, productivity declines primarily due to the shortening of vegetative and reproductive phase. Processes of yield formation are highly variable and depend on genetic, environmental and agronomic factors as well as interactions between them (Sidlauskas and Bernotas, 2003). Moreover, a number of environmental factors interact with optimum sowing like soil temperature and moisture level affecting germination and other growth stages. The yield of *Brassica* species is a function of different yield attributes like number of plants/unit area, number of branches/plant, number of siliquae/plant, number of seeds/siliqua, and 1,000-seed weight. To accommodate more number of yields attributing characters in rapeseed-mustard it needs optimum growth of photosynthetic organs, translocation of photosynthates and finally amount of dry mater production before anthesis which decide the frame for yield attributes. These yield attributing characters possessing a great importance in seed yield and differed variety to variety. Newly developed *B. juncea* hybrid 'DMH-1' utilising '126-1' cytoplasm for male sterility has recorded considerable yield advantage over the best national and regional varieties in multi location trials (Sodhi *et al.*, 2006). The first *moricandia* cytoplasmic male sterility (CMS) based hybrid of Indian mustard developed by National Research Centre on Rapeseed-Mustard, Bharatpur (Rajasthan), which has been released with the name NRC Sankar Sarson (NRCHB 506) during 15th Annual Group Meeting of All India Coordinated Research Project on Rapeseed- Mustard in 2008. This hybrid had shown superiority for oil yield by a margin of about 26 and 20% over existing popular varieties Maya and Varuna, respectively, in 11 trials across 5 states. The sowing date has to be chosen carefully so as to optimize production without considering environmental site effects. Goyal *et al.*, (2006) reported that various important growth characters and seed yield of mustard were significantly influenced by different thermal environments. Spacing of crop plant and their different genotypes mainly depends on their growth habit. Plant density has been observed to have a huge influence on growth, development and seed yield of mustard (Kumar *et al*., 2004). Different cultivars may respond variably to different sowing time and spacing. New hybrids of

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mustard are capable of yielding higher when grown under optimum sowing time and spacing. The productivity of individual plant is limited under late sown conditions owing to poor growth and development hence, higher plant population may compensate for reduction in seed yield. Since spacing and sowing time is a non-monetary input and information particularly in relation to newly developed hybrids of mustard is not available, the present investigation was conducted to study the effect of sowing time and row spacing on yield and quality parameters, nutrient uptake and economics of hybrid mustard production.

MATERIALS AND METHODS

The experiment was conducted during *rabi* seasons of 2007-08 and 2008-09 at Crop Research Centre, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand. Geographically, Pantnagar is situated at 29°01'20" N latitude and 79°29'20" E longitude and at an altitude of 243.8 m above mean sea level in the foothills of Kumaon Himalaya, locally known as *Tarai*. The experimental soil was loamy, deep, nearly neutral to slightly alkaline with moderate base saturation having pH 7.5 and organic carbon 0.90%. Its available nitrogen, phosphorus and potash content was 236, 21 and 306 kg/ha respectively. Two mustard hybrids 'DMH-1' and 'NRCHB-506' were developed using cytoplasmic male sterility system and identified by All India Coordinated Research Project on Rapeseed-mustard during 2008.Twenty seven combinations of three sowing dates (10, 20 and 30 October), 3 varieties including two hybrids ('Kranti', 'NRCHB-506' and 'DMH-1') and 3 spacings (60 × 10 cm, 45 × 10 cm and 30 × 10 cm) were tested in a 3 times replicated split-split plot design, allocating dates to main plots, hybrids/varieties to sub-plots and spacing to sub-sub plots. Sowing was done as per schedule in respective dates (10, 20 and 30 October) and row spacing (30 × 10 cm, 45 × 10 cm and 60 × 10 cm). Plant to plant spacing of 10 cm was maintained by thinning at 15 days after sowing. Both maximum and minimum temperature showed fluctuation throughout the crop growth during both the years. In general, the maximum temperature declined from the time of sowing (October), till the end of January and thereafter, increasing trends were observed. The lowest values of maximum temperature were 18.1°C (4th week of January) during 2007-08 and 16.8°C (1st week of January) during 2008-09. Minimum temperature was found to decrease continuously till second week of December and then it fluctuated up and down but the lowest (2.6°C) was recorded in the 4th week of January and later on increased till the harvest of the crop during first year. Whereas, during the second year, the fluctuation in minimum temperature was recorded from the fourth week of November till harvest of crop with minimum (6.6°C) being in the 2nd week of January. The total rainfall received during the crop season was 16.0 mm (2 rainy days) and 41.0 mm (6 rainy days) in the first and second year, respectively. During 2007-08, out of total 16.0 mm rainfall, 13.2 mm rain occurred in October. In the second year, 23.4 mm rainfall occurred during October and remaining in February. The recommended dose of fertilizer was 60 kg N + 17.2 kg P + 16.6 kg K/ha. Full dose of phosphorus and potassium and half dose of nitrogen were applied at the time of sowing and remaining half dose of nitrogen was top dressed after 1st irrigation. The seed samples were taken out from each plot to determine oil content using Soxhlet's extraction method and N (%) was estimated by micro-Kjeldahl's method. The seed and stover of mustard were analyzed separately for N, P and K concentration following standard procedures and the total uptake of different nutrients by seed and stover was calculated. The economics of hybrid mustard production was worked out on the basis of prevailing market price of different inputs and final produce. The main difference in cost of cultivation was due to high variation in seed cost of hybrids and check variety 'Kranti'.

RESULTS AND DISCUSSION

Growth and yield attributes

Performance of crop was marginally better during 2008-09 than 2007-08 (Table 2). This advantage in growth and yield attribute could be ascribed to the favourable climatic conditions especially duration of sunshine hours during the crop season of 2008-09 which resulted in the larger leaf area, higher photosynthesis, and thus more dry matter production. Contrarily, during 2007-08 crop experienced mild to moderate climatic stress particularly early rise in temperature during reproductive phase and foggy conditions during vegetative phases and biotic stress like infestation of downy mildew and mustard aphids caused slight reduction in seed yield.

Growth and various yield attributes of mustard were significantly influenced by different sowing time, variety and spacing (Table 1). October 10 sown crop resulted in significantly higher plant height, number of primary and secondary branches at harvest over October 30 sowing during both years. Plant height in October 10 sown crop was significantly higher over October 20 sowing in the first crop cycle but both were *at par* in the second crop cycle. The highest number of primary branches was produced in October 10 sowing which got significantly reduced with delay in sowing during both years. In the second crop cycle, maximum number of secondary branches (19.9) was recorded in October 10 sown crop which got reduced by 11.5% in October 20 sowing and 29.1% in

Table 1. Growth and yield attributes of mustard hybrid/variety as influenced by sowing time and spacing

Treatment	Plant height (cm)		Primary branches/ plant		Secondary branches/plant		Siliquae/plant		Siliqua length (cm)		Seeds/siliqua		1,000-seed wt. (g)		Seed wt./ plant (g)	
	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
Sowing date																
October 10	209	217	7.4	7.8	19.5	19.9	297	323	4.56	4.71	13.5	14.2	4.14	4.25	10.81	11.41
October 20	197	208	6.7	7.0	18.3	17.6	272	302	4.27	4.53	12.4	13.4	3.70	3.78	9.35	10.27
October 30	186	187	6.1	6.4	13.0	14.1	218	238	3.86	4.07	10.6	11.4	3.28	3.42	7.62	8.52
SEm±	1.2	3.6	0.1	0.1	0.4	0.4	6.2	5.6	0.05	0.03	0.1	0.1	0.05	0.04	0.18	0.24
CD (P=0.05)	4.5	14.2	0.3	0.6	1.5	1.5	24.2	21.8	0.21	0.13	0.4	0.5	0.19	0.14	0.72	0.95
Variety																
'Kranti'	195	203	6.0	6.5	15.3	15.7	206	235	3.72	3.93	10.9	11.7	3.39	3.52	7.79	9.14
'NRCHB-506'	186	196	6.7	7.2	17.0	17.2	265	286	4.76	4.82	13.1	13.6	3.71	3.82	9.59	10.25
'DMH1'	211	212	7.4	7.6	18.5	18.7	317	342	4.21	4.56	12.5	13.8	4.01	4.11	10.40	10.79
SEm±	2.5	2.1	0.2	0.2	0.4	0.5	5.0	4.0	0.06	0.04	0.2	0.1	0.06	0.05	0.11	0.14
CD (P=0.05)	6.9	6.3	0.5	0.5	1.2	1.5	15.3	12.4	0.21	0.13	0.5	0.3	0.16	0.15	0.36	0.44
Spacing (cm)																
30 × 10	201	210	6.3	6.7	15.9	16.0	239	265	4.11	4.26	11.6	13.0	3.52	3.61	8.36	9.25
45 × 10	197	204	6.4	6.9	16.8	16.9	261	287	4.21	4.44	12.1	13.0	3.65	3.79	9.11	10.06
60 × 10	194	198	7.5	7.6	18.1	18.7	289	311	4.36	4.61	12.7	13.6	3.95	4.04	10.31	10.88
SEm±	2.1	2.5	0.2	0.2	0.4	0.4	5.3	3.3	0.07	0.04	0.1	0.1	0.09	0.07	0.14	0.17
CD (P=0.05)	NS	7.1	0.5	0.6	1.3	1.1	15.1	9.4	0.19	0.12	0.4	0.4	0.26	0.21	0.42	0.50

October 30 sowing. The higher plant height and number of primary and secondary branches in early sowing may be on account of better availability of mineral nitrogen to the plants due to favourable soil temperature which might have resulted in better utilization of carbohydrates to form more protoplasm thereby resulted in more cell division and increased plant vigour. The highest siliquae/plant, siliqua length, seeds/siliqua, 1,000-seed weight and seed weight/plant was recorded in October 10 sowing which got reduced significantly in later sowing on October 20 and October 30 during both the years. The siliquae/plant (297, 323) was recorded maximum in October 10 sowing followed by October 20 (272, 302) and October 30 (218, 238) sowing during 2007-08 and 2008-09 respectively. Thus, siliquae/plant were reduced with every successive delay in sowing after October 10. Similarly, the seeds/siliqua got reduced by 7.8%, 5.3% in October 20 and 21.2%, 19.7% in October 30 sowing after October 10 in the first and second crop year respectively. In general, the value of all the yield contributing characters had significantly lower value under delayed sowing. The number of seeds/siliqua, 1,000-seed weight and seed weight/plant were higher in early sowing which might be due to increased dry matter production and higher translocation of food material for the formation of seed in advanced sowing. Kumar (2003) from Pantnagar, also reported that delayed sowing by 15 days after September 30, up to November 15 resulted in significant reduction in number of branches, siliquae/plant and seed weight/per plant during both the years. Similar findings have also been reported by Rabiee *et al*. (2004), Goyal *et al.*, (2006) and Bhuiyan *et al.* (2008) which supports the findings of the present investigation.

Plant height was significantly influenced by varieties. Among the varieties, hybrid 'DMH-1' recorded the highest plant height which was significantly superior to hybrid 'NRCHB-506' and variety 'Kranti' during both the years. The highest number of primary and secondary branches per plant was recorded in hybrid 'DMH-1' followed by hybrid 'NRCHB-506' and variety 'Kranti' which might be due to genotype response and capability of higher dry matter production. Hybrid 'DMH-1' produced the highest number of branches (25.9, 26.3) which were 8.9, 7.7% higher over NRCHB 506 and 21.5, 18% over 'Kranti' during 2007 and 2008 respectively. Number of siliquae /plant and 1000-seed weight were significantly higher in hybrid 'DMH-1' in comparision to hybrid 'NRCHB-506' and variety 'Kranti'. Total number of siliquae/plant varied from 206 ('Kranti') to 317 ('DMH-1') in the first crop season and from 235 to 342 in the second crop season. Hybrid

'NRCHB-506' had significantly higher siliqua length followed by hybrid 'DMH-1' and 'Kranti' during both years and the same trend was observed for number of seeds/siliqua in the first year which indicated interdependence of both characters as well. However, number of seeds/siliqua was similar in both the hybrids in the second crop season. The significant improvement in various yields attributes of mustard hybrids over 'Kranti' may be attributed as inherent variation due to their superior genetic make up. The varietal difference in several yield attributes has also been reported by Razzaque *et al.* (2007).

Spacing also significantly affected various yield attributes of mustard. Crop sown at wider spacing 60 × 10 cm produced significantly higher number of primary and secondary branches at harvest, number of siliquae/plant, siliqua length, number of seeds/siliqua, 1,000-seed weight and seed weight/plant over 45 × 10 cm and 30 × 10 cm during both the years except siliqua length in first year. There was non-significant difference due to spacing on plant height in the first crop cycle. Spacing of 30 × 10 cm recorded significantly higher plant height over 60 × 10 cm in second year but statistically similar to 45 × 10 cm spacing. The highest number of secondary branches was recorded in 60 × 10 cm spacing (18.1,18.7) which got significantly reduced in 45×10cm (16.8,16.9) and 30 × 10 cm (15.9,16.0) in the first and second year respectively. However, number of secondary branches were at par in spacing 45 × 10 cm and 30 × 10 cm in both years. Total number of siliquae/plant was significantly higher in wider spacing of 60 × 10 cm (289, 311) which was 10.4, 8.7% higher than 45 × 10 cm spacing and 20.6, 17.3% higher over 30 × 10 cm spacing during both years respectively. The number of seeds/siliqua, 1,000-seed weight and seed weight/plant were higher under wider spacing (60 ×10 cm) because of higher translocation of assimilates for the formation of seeds and higher siliqua length. All these factors, on account of increased growth parameters, resulted in better reproductive growth and caused increase in various yield parameters. The improvement in yield attributes with wider spacing was also reported by Chaniyara *et al.* (2002).

Seed yield

October 10 sown crop produced the highest seed yield and harvest index during both the years. Successive delay in sowing caused significant reduction in yield, thus October 30 sown crop proved to be the lowest yielder during both the years. The decrease in seed yield in October 20 and October 30 sowing dates over October 10 sowing was to the tune of 8.7 and 29.2% in the first and 10.1 and 29.3% in the second crop year, respectively. Moreover, maximum and minimum temperature attained comparatively lower values under delayed sowing during various phases which came to the lowest level in October 30 sowing, due to which the duration of reproductive phase was markedly reduced, resulting in reduced seed yields. The hybrid 'DMH-1' recorded significantly highest seed yield. The higher seed yield in 'DMH-1' might be correlated to higher number of primary and secondary branches, number of siliquae/plant and 1,000-seed weight. The 'DMH-1'

Table 2. Effect of sowing time and spacing on yield, quality parameters and economic returns of mustard hybrid/variety

Treatment	Yield (t/ha)		Harvest Index (%)		Oil yield(t/ha)		Gross return (×10³ ₹/ha)		Net return (×10³ ₹/ha)		Net B:C ratio	
	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
Sowing date												
October 10	1.82	1.93	23.0	22.9	0.75	0.80	30.95	34.81	20.28	24.13	1.88	2.25
October 20	1.66	1.73	22.3	22.2	0.68	0.71	28.25	31.27	17.58	20.60	1.64	1.92
October 30	1.29	1.36	20.8	21.7	0.53	0.56	21.92	24.62	11.25	13.94	1.05	1.30
SEm±	0.02	0.02	0.1	0.3	0.01	0.01	0.38	0.38	0.38	0.38	0.04	0.04
CD (P=0.05)	0.10	0.08	0.5	NS	0.04	0.03	1.52	1.49	1.52	1.49	0.14	0.14
Variety												
'Kranti'	1.32	1.40	21.9	21.9	0.54	0.58	22.37	25.33	12.14	15.11	1.19	1.48
'NRCHB-506'	1.68	1.74	22.4	22.7	0.69	0.72	28.60	31.48	17.70	20.58	1.62	1.88
'DMH1'	1.77	1.88	21.8	22.3	0.73	0.78	30.17	33.88	19.27	22.98	1.76	2.10
SEm±	0.03	0.02	0.2	0.2	0.01	0.01	0.53	0.42	0.53	0.42	0.05	0.04
CD (P=0.05)	0.10	0.07	NS	NS	0.04	0.03	1.64	1.30	1.64	1.29	0.15	0.20
Spacing (cm)												
30 × 10	1.67	1.80	21.9	22.2	0.69	0.74	28.51	32.43	17.61	21.52	1.61	1.96
45 × 10	1.62	1.69	22.2	22.5	0.67	0.69	27.62	30.43	16.94	19.75	1.58	1.84
60 × 10	1.47	1.54	21.9	22.2	0.61	0.64	25.01	27.84	14.56	17.38	1.38	1.66
SEm±	0.02	0.03	0.3	0.2	0.01	0.01	0.41	0.44	0.41	0.44	0.04	0.04
CD (P=0.05)	0.07	0. 07	NS	NS	0.03	0.03	2.10	1.28	1.20	1.27	0.11	0.12

(34.9 and 33.7%) and 'NRCHB-506' (27.8 and 24.3%) recorded higher seed yield over 'Kranti' in the first and second crop year, respectively. Generally, cultivation of hybrid cultivars derived from inbred lines improves seed yield considerably. Sodhi *et al*. (2006) reported a yield advantage of about 30% in hybrid 'DMH-1' over the best national and regional varieties in multi-site trials conducted in the north-western states of India. The varietal differences in seeds yield has also been reported by Dehghani *et al*. (2008).

Sowing at 30 × 10 cm spacing recorded significantly higher seed yield over wider spacings during both the years but was *at par* with 45 × 10 cm in the first crop season. Spacing 45 × 10 cm also recorded significantly higher seed yield over 60 × 10 cm spacing during both the years. Harvest index showed non significant effect due to different varieties and spacing. This may be due to the similar increment in seed and stover yield at different spacings. The improvement in yield attributes with wider spacing failed to compensate for the lower number of plants per unit area. However, lower value of various yield attributes under narrow row spacing resulted in increased seed yield which might be due to higher plant population which led to competition for nutrients and light and also increased the total nutrient uptake for plant and assimilates for seed development. Similar results were also obtained by Anal *et al*. (2002) and Kumar *et al*. (2004).

Interaction effect

Interaction effect of sowing dates and varieties on seed yield was found significant (Table 4) during both the years. In the first year, maximum seed yield was observed in hybrid 'DMH-1' on October 10 over October 20, but both the dates had similar effect on this hybrid in the sec-

Table 3. Interaction effect of date of sowing and varieties on seed yield t/ha of mustard hybrid/variety

Sowing date	Variety 2007-08			Variety 2008-09		
	'Kranti'	'NRCHB-506'	'DMH-1'	'Kranti'	'NRCHB-506'	'DMH-1'
October 10	1.46	1.95	2.05	1.59	2.05	2.16
October 20	1.36	1.73	1.90	1.42	1.77	2.03
October 30	1.13	1.37	1.37	1.21	1.43	1.46
		SEm±	CD (P=0.05)	SEm±	CD (P=0.05)	
To compare sowing date at same or different variety		0.039	0.130	0.050	0.162	
To compare variety at same or different sowing date		0.040	0.125	0.054	0.167	

Table 4. Effect of sowing time and spacing on nutrient uptake by mustard hybrid/variety

Treatment	N-uptake (kg/ha)				P-uptake (kg/ha)				K-uptake (kg/ha)			
	Seed		Stover		Seed		Stover		Seed		Stover	
	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09
Sowing date												
October 10	60.3	63.3	25.4	24.1	10.7	10.8	14.9	14.6	17.6	18.2	114.3	113.9
October 20	55.9	57.9	25.2	24.0	10.4	10.4	15.2	13.8	16.3	16.6	110.9	107.5
October 30	44.1	46.2	22.5	20.4	8.5	8.6	14.0	12.9	12.9	13.3	96.1	87.6
SEm±	0.8	0.8	0.5	0.5	0.1	0.1	0.5	0.6	0.2	0.2	1.8	2.6
CD (P=0.05)	3.1	3.3	1.8	2.1	0.4	0.4	NS	NS	0.8	0.8	6.9	10.1
Variety												
'Kranti'	45.1	47.7	21.4	20.5	9.6	9.8	13.9	13.8	13.3	13.8	92.0	89.7
'NRCHB-506'	56.2	57.8	25.1	23.0	10.4	10.3	15.0	14.1	16.6	16.7	109.6	105.4
'DMH-1'	60.0	62.0	26.6	25.1	10.6	11.0	15.2	14.5	17.0	17.5	119.6	114.1
SEm±	1.0	0.7	0.3	0.7	0.2	0.2	0.3	0.3	0.3	0.2	1.9	1.9
CD (P=0.05)	3.0	2.1	0.9	1.9	0.5	0.5	0.9	NS	0.9	0.5	6.0	5.9
Spacing (cm)												
30 × 10	56.9	60.5	26.5	25.4	10.6	10.9	16.9	16.1	16.7	17.4	116.8	112.6
45 × 10	54.6	56.1	24.7	22.7	9.1	9.9	14.9	14.1	16.0	16.1	108.0	102.2
60 × 10	48.7	50.8	21.9	20.4	8.9	8.9	12.7	12.1	14.3	14.6	96.4	94.4
SEm±	0.8	0.8	0.4	0.5	0.2	0.2	0.2	0.3	0.2	0.2	1.8	1.3
CD (P=0.05)	2.3	2.4	1.2	1.4	0.5	0.4	0.6	0.8	0.7	0.6	5.1	3.7

ond year. Hybrid 'NRCHB-506' was similar to 'DMH-1' when sown in October 10, but significant difference was recorded in both the hybrids when sown on October 20. Significant reduction in seed yield of 'Kranti' when delayed by October 30 and both the hybrids at all the dates of sowing.

Quality Parameters

The oil yield/ha was also affected by sowing dates because it is the result of seed yield and oil content and both of these components were influenced by plant growth and yield contributing attributes. The oil yield was maximum in October 10 sown crop and reduced by 1.01% in the first crop cycle and 1.42% in the second crop cycle on October 20 sown crop, respectively. This was associated with the reduction in oil content as well as seed yield under delayed sowing. Rabiee *et al.* (2004), also reported higher oil yield per hectare in early sowing.

Hybrid 'DMH-1' recorded significantly higher oil yield over varieties 'NRCHB-506' and 'Kranti' during 2008-09, but 'DMH-1' was *at par* with 'NRCHB-506' during 2007-08. Hybrid 'NRCHB-506' had significantly higher oil yield over 'Kranti' during both the years. Varietal differences in oil content and oil yield were also reported by Das *et al.* (1998).

Oil yield was found to be highest in 30 × 10 cm level during both the years. Although, oil content was higher in wider spacing, but differences were non-significant. However, higher seed yield at spacing of 30 × 10 cm and 45 × 10 cm resulted in the higher oil yield. This may be due to higher plant population at these spacing over 60 × 10 cm level. These results have been supported by Singh and Prasad (2003).

Economics

The result of the present study showed that gross return, net return, and B:C ratio were markedly higher when sowing time was October 10 in comparison to October 20 and October 30 due to higher yield at same cost of cultivation during both the years. Hybrid 'DMH-1' produced significantly higher gross return over 'Kranti' but was at par with hybrid 'NRCHB-506' during both the years. Hybrid 'DMH-1' recorded significantly higher net return (₹19.27×10^3/ha) over 'Kranti' (12.14×10^3/ha) and statistically similar value with 'NRCHB-506' (17.69×10^3/ha) during first crop year but all the varieties had significant differences during second year. Benefit cost ratio were higher in 2008 in comparision to 2007. Statistically, hybrid 'DMH-1' (1.76) and 'NRCHB-506' (1.62) had similar B:C ratio but they were significantly higher over 'Kranti' (1.19) during 2007. Significant difference was recorded among varieties for B:C ratio in the second crop cycle and 'DMH-1' obtained maximum value (2.10). Spacing 30 × 10 cm fetched highest gross return, net return and B:C ratio over 60 × 10 cm and statistically similar effect with spacing 45 × 10 cm in the first year.

Nutrient uptake

October 10 sown crop had significant increase in the uptake of N, P and K in seed over October 30 during both the years and followed the trend of seed yield. In the first year, October 10 and October 20 were *at par* with each other for N uptake by stover, P uptake by seed and K uptake by stover. Sowing dates had non-significant effect on phosphorus uptake by stover during both years. Bhatnagar (1999) also reported that nitrogen uptake decreased considerably with delayed sowing and the highest nitrogen uptake was recorded in October 10 sowing which supports the findings of present research, although genotypes were different.

All the varieties were significantly different for N,P and K uptake by seed and stover at harvest, and significantly higher amount was recorded in hybrid 'DMH-1' followed by 'NRCHB-506' and 'Kranti'. Hybrids 'DMH-1' and 'NRCHB-506' both had significantly higher phosphorus uptake by seed and stover over 'Kranti' but remained *at par* with each other during both the years except phosphorus uptake by stover during 2008 where difference in phosphorus uptake were non-significant. However, Hybrid 'DMH-1' had higher phosphorus uptake in comparision to other varieties. Potassium uptake of seed by 'NRCHB-506' and 'DMH-1' were *at par,* but significantly higher over variety 'Kranti' during 2007. Kumar (2003) also reported that nutrient uptake of rapeseed-mustard were significantly affected by varieties which was similar to current findings.

Sowing at spacing 30 × 10 cm recorded significantly higher nitrogen, phosphorus and potassium uptake by seed and stover over 45 × 10 cm and 60 × 10 cm spacing during both the years, except nitrogen and Potassium uptake by seed that remained *at par* with 45 × 10 cm spacing during 2007. The nutrient uptake is the function of dry matter and nutrient content. Higher plant density led to higher dry matter and production which led to higher nutrient uptake by plants.

It is concluded that sowing of mustard on October 10 with the introduction of new hybrid 'DMH-1' at a spacing of 45 × 10 cm can achieve higher productivity and better economic returns from mustard in Western U.P and plain/*tarai* zone of Uttarakhand.

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