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Effect of row spacing and intercrops on phenology, growth and productivity of dual purpose canola oilseed rape (*Brassica napus*)

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Abstract

Precise knowledge of timing of phonological development in a crop assists in better management for achieving its potential productivity. Phenology and productivity of canola oilseed rape after cutting for green fodder under different row spacing and intercropping was studied at two locations in Punjab. Field experiment was laid out in randomized complete block design in three replications with 9 treatments comprising cutting of oilseed rape sown at different row spacings (22.5, 30 and 45 cm) for green fodder and cutting of oilseed rape (sown at 45 and 60 cm row spacing) intercropped with Indian mustard and oats. Oilseed rape and Indian rape (as intercrops) were sown in the last week of September whereas, oats was sown as intercrop after cutting of oilseed rape. Oilseed rape was cut for fodder at 45 days after sowing. Flowering of uncut oilseed rape was early by about 12 days in comparison to crop after cutting. Cutting of oilseed rape delayed the maturity of the crop. Uncut oilseed rape attained significantly more plant height at 90 DAS and at maturity than cut crop. At 90 DAS mean plant height of uncut oilseed rape was 3.39 times higher than the crop cut at 45 DAS. However, at maturity, the uncut crop attained 14.8 % more height than crop cut for fodder. Cutting of the oilseed rape at 45 DAS lowered the LAI at 90 DAS and maturity. Oilseed rape sown at wider spacing of 60 cm resulted in higher LAI than oilseed rape sown at 30 cm row spacing. The PAR interception at 90 DAS was 41.9 % higher than that recorded at 45 DAS due to better canopy development. Intercropping with Indian rape reduced the SPAD value of oilseed rape. The maximum oilseed rape equivalent seed yield was obtained in oilseed rape sown at 45 cm row spacing (cut) + Indian rape (3.56 t ha^{-1})) which was statistically at par with oilseed rape sown at 60 cm row spacing (cut) + Indian rape (3.41 t ha^{-1}) but significantly higher than cut and uncut sole crop of oilseed rape (2.22 – 2.71 t ha^{-1}).

Keywords : *Equivalent yield, fodder, Indian rape, leaf area index, oats, oilseed rape, phenology, PAR interception*

Introduction

The current annual production of edible oilseeds in India is only about 35-40 % of the domestic requirements and the deficit is bridged through imports of about 13.45 million tonnes (mt) of vegetable oil worth Rs 81682 crores (Anonymous, 2022). The demand of vegetable oil is further increasing at the rate of 3-5 % against growth in production of about 2 % per annum. Livestock farming contributes significantly to the regular income of the farmers. Green fodders are the cheapest source of carbohydrates, protein, vitamins and minerals for livestock but there is acute shortage of fodder particularly during early winters (September-December). Inadequate availability of fodder and imbalanced nutrition including concentrates are the major reasons for significant reduction in livestock production (Anonymous, 2015; NAAS, 2016).

Oilseed rape (*Brassica napus* L) is also used as green fodder after cutting during the vegetative stage in many countries of the world (Nogueira, 1982; Kirkegaard *et al.,* 2008a; Kirkegaard *et al.,* 2008b; Sprague *et al.,* 2014). It has the ability to regenerate and therefore offers an opportunity for as green fodder during initial period and subsequent growth for production of seed for extraction of oil. Dual purpose (fodder and seed) canola oilseed rape offers green fodder during lean period, quality edible oil (<2% erucic acid and >60% oleic acid) for human consumption and meal (<30 µmolglucosinolatesg^{-1}) for livestock. The inter-row space upto few weeks after cutting of oilseed rape can be utilized for raising short duration compatible crops. The system ensures higher total productivity, efficient use of inputs as well as natural resources and overall higher profitability than the most assured crop *i.e.,* wheat of the region.

Success of such an intensive system depends on optimum spacing and compatible crops and may influence the phenology of crops. Crop phenology plays a crucial role in optimization of various plant processes and development of yield contributing traits (Gayler *et al*., 2002; Mirsch el *et al*., 2005). Knowledge on crop phenology is important for timely application of inputs and crop management practices for achieving potential productivity of crops. Keeping these issues in view, the phenology, growth and system productivity of oilseed rape as influenced by cutting, different row spacing and intercropping were studied.

Materials and Methods

The field study was conducted during 2020-21, under irrigated conditions, at the research farm of the Punjab Agricultural University, Ludhiana and Regional Research Station, Faridkot in India. The soil of the experimental field was loamy sand and sandy loam, neutral in pH (7.12, 7.65) and EC (0.52, 0.50 dS m^{-1}), low in available N (159, 232 kg ha^{-1}), high in available P (25, 40 kg ha^{-1}) and low in available K (110, 353 kg ha^{-1}) at Ludhiana and high at Faridkot, respectively. The study comprising 9 treatments was conducted in randomized block design with three replications. Treatments comprised T_1: Oilseed rape at 22.5 cm row spacing (cutting followed by removal of alternate rows), T_2: Oilseed rape at 30 cm row spacing (cutting of alternate rows), T_3: Oilseed rape at 30 cm row spacing (cutting followed by removal of alternate rows), T_4: Oilseed rape at 45 cm row spacing (cut) + one row of oat after cutting of oilseed rape, T_5: Oilseed rape at 45 cm row spacing (cut) + one row of Indian rape (simultaneous sowing), T_6: Oilseed rape at 60 cm row spacing (cut) + one row of Indian rape (simultaneous sowing), T_7: Oilseed rape at 45 cm row spacing (cut), T_8: Oilseed rape (uncut) at 45 cm row spacing, T_9: Oilseed rape (uncut) at 60 cm row spacing.

The varieties used were GSC 7 of canola oilseed rape, TL 17 of Indian rape and OL 12 of oats. The oilseed rape along with Indian rape (as intercrop) was sown on September 25, 2020 at Ludhiana and on September 28, 2020 at Faridkot. Oats was intercropped in oilseed rape after cutting of oilseed rape for green fodder. Application of 50 kg N, 30 kg $P_2O_5^{-1}$ and 15 kg K_2O ha^{-1} was made at sowing and another dose of 50 kg N ha^{-1} was applied to oilseed rape after its cutting of green fodder. In the intercropping systems, recommended doses of nutrients were applied to crops on area basis. Oilseed rape was cut for green fodder at 45 days after sowing (DAS). One cutting of oats was also taken for fodder at 45 DAS. Plot size was 5.0 m × 3.6 m.

Observations were recorded on number of days required for initiation and completion of flowering and maturity of oilseed rape, plant height, leaf area index, chlorophyll content, interception of photosynthetically active radiation at 45 DAS, 90 DAS and maturity. Chlorophyll content in leaves was recorded with SPAD 502 plus Chlorophyll Meter. Line quantum sensor (Model LJ-191-SA) was used to measure the PAR. This line quantum sensor measures quantum (photons) response through wavelength range of 400 to 760 nm for photosynthetic photon flux density (PPFD). Sun scan canopy analyzer CI-110/CI- 120 was used for recording LAI. Yields of different crops were converted into oilseed rape equivalent (seed) yield on the basis of prevailing price of the green fodder (Rs 2000/- per tonne), seed/grain ((Rs 46500 for oilseed rape and Indian rape and Rs 15000 for oats per tonne) and stover (Rs 1150 for oilseed rape and Indian rape and Rs 2150 for oats per tonne). The oilseed rape equivalent yield (OREY, t ha^{-1}) was calculated by the following formula:

$$\text{OREY} = \text{Seed yield of oilseed rape} + \frac{\text{Yield of intercrop (component crops)} \times \text{Price of intercrop}}{\text{Price of oilseed rape}}$$

Results and Discussion

Phenology

Oilseed rape sown at Faridkot took significantly more number of days for initiation (86 days) and completion (118 days) of flowering and maturity (152 days) than that sown at Ludhiana (85, 116 and 151 days, respectively) (Table 1). For initiation of flowering, oilseed rape sown at 45 cm row spacing (cut) + one row of Indian rape (T_5) took significantly more number of days (98) than its intercropping with oats (T_4) which took 96 days. Flowering initiation of sole crop of oilseed rape cut for fodder (T_7) was early by 6 to 8 days in comparison to its flowering initiation in the intercropping with Indian rape (T_5) and oats (T_4). However, cutting of oilseed rape at 45 DAS (T_7) significantly delayed the initiation of flowering (by about 12 days) than uncut crop (T_8) which took 78 days.

Similarly intercropping of one row of Indian rape with oilseed rape at 45 cm (T_5) or 60 cm (T_6) row spacing and with oats at 45 cm spacing (T_4) significantly delayed completion of flowering (124 days) by about 12.4 days and physiological maturity (158 days) by about12 days in comparison to the uncut crop (T_8 and T_9) irrespective of spacing and cutting of alternate rows. However, differences in number of days required for completion of flowering and maturity of oilseed rape sown as sole crop (cut) or as intercrop (cut) were inconspicuous. Number

Table 1: Effect of row spacing, cutting of oilseed rape and intercropping on phenology and plant height of oilseed rape

Treatment	Initiation of flowering			Completion of flowering			Physiological maturity			Plant height at 45 DAS (cm)			Plant height at 90 DAS (cm)			Plant height at maturity (cm)		
	LDH	FDK	Mean	LDH	FDK	Mean	LDH	FDK	Mean	LDH	FDK	Mean	LDH	FDK	Mean	LDH	FDK	Mean
T1	78	79	79	110	112	111	145	145	145	36	31	33	156	162	159	206	208	207
T2	78	79	79	110	111	111	145	146	146	37	32	34	156	161	159	206	208	207
T3	78	79	78	111	111	111	145	146	145	37	31	34	156	160	157	205	207	206
T4	95	97	96	122	124	123	158	158	158	36	31	34	45	50	48	180	185	183
T5	98	99	98	125	126	125	159	159	159	36	31	34	43	48	46	177	182	179
T6	97	97	97	123	124	123	158	159	159	36	32	34	44	49	46	178	182	180
T7	89	91	90	121	124	122	157	158	157	36	32	34	45	50	47	179	183	181
T8	77	78	78	111	114	113	147	148	148	37	31	34	159	162	161	209	211	210
T9	78	79	78	111	112	112	145	147	146	36	32	34	158	162	160	207	210	208
LSD ($p \leq 0.05$)	2	2	2	1	2	2	2	2	2	NS	NS	NS	3	2	2	11	7	4

LDH: Ludhiana, FDK: Faridkot

of days taken for initiation of flowering (78-79 days) and completion of flowering (111-112 day) in uncut oilseed rape sown at 60 cm (T_9) or 45 cm (T_8) row spacing, 22.5 cm (T_1) or 30 cm (T_2) row spacing (cutting of alternate row for fodder) was at par (Table 1). Cutting of oilseed rape delayed the flowering due to slower regrowth of plants under low temperature conditions during winter months. However further delay in flowering under intercropping treatments may be ascribed to lesser space available for growth and reduced availability of sunlight to oilseed rape plants when intercropped with highly competitive Indian rape and oats plants. Kirkegaard *et al.* (2012) in Australia observed that grazing of oilseed rape at vegetative stage before buds were visible delayed flowering by 4 days whereas grazing at flower opening stage caused delay of 26 to 30 days. Sprague *et al.* (2018) also reported that grazing of oilseed rape delayed initiation and completion of flowering. Cutting after bud elongation prevented the leaf growth and biomass and reduced the assimilate supply to developing siliquae (Kirkegaard *et al.,* 2008a). Partial loss of vigour, time required for overcoming cutting shock, sub optimal temperatures slowed down the vegetative and reproductive growth and delayed phenological development of the crop. In Pakistan also, topping/cutting delayed maturity of oilseed rape (Khan *et al.,* 2007) and chickpea (Khan *et al.,* 1998) in comparison to uncut crop.

Growth

Plant height increased with crop growth up to maturity (Table 1). Increase in plant height between 45 DAS (34 cm) to 90 DAS (159 cm) was much more than the period between 90 DAS to maturity (208 cm). Plant height at 45 DAS was more at Ludhiana (36 cm) than at Faridkot (31 cm) whereas at 90 DAS and maturity, crop attained more plant height at Faridkot (112 cm, 197 cm, respectively) than Ludhiana (107 cm, 194 cm, respectively). At 45 DAS, plant height of oilseed rape was not influenced by different treatments. At 90 DAS mean plant height (159 cm) of uncut oilseed rape (T_8) was 3.4 times higher (by 47 cm) than the crop cut at 45 DAS (T_7). However, at maturity, the uncut crop (T_8) attained 14.8 % more plant height than the crop cut for fodder (T_7) which attained height of 181 cm.

Leaf area index (LAI) of oilseed rape increased with crop growth up to 90 DAS and decreased thereafter up to maturity (Table 2). However, LAI of uncut sole oilseed rape (T_8) at maturity was higher than at 45 DAS. In case of intercropped and sole cut crop of oilseed rape, LAI at 45 DAS and at maturity was almost similar. Mean maximum leaf area index (LAI) at 45 DAS (1.5), 90 DAS (4.7) and at

maturity (1.9) was observed in oilseed rape (uncut) sown at 60 cm row spacing (T_9). At 45 DAS, crop sown at wider spacing as sole crop registered more LAI due to better canopy development in comparison to its intercropping. Lowest LAI at 45 DAS (1.3), 90 DAS (2.1) and maturity (1.4) was recorded for oilseed rape sown at 30 cm row spacing and removal of alternate rows after cutting for fodder (T_3), oilseed rape at 60 cm row spacing (cut) + Indian rape (T_6) and oilseed rape at 45 cm row spacing (cut) + oat (T_4), respectively. Cutting of the oilseed rape at 45 DAS resulted in lower LAI due to lesser regrowth of the crop after cutting. Oilseed rape sown at wider spacing of 60 cm (T_9) attained higher LAI than oilseed rape sown at 30 cm row spacing ($T_{2/}$T3). Leaf is the site for photosynthesis. Higher the leaf area of crop more will be interception of solar radiation which aids in higher dry matter accumulation in crops. The LAI indicates the size of the assimilatory system of the crop. Pawar (2016) reported higher LAI of oilseed rape with row spacing of 90 cm as compared to 60 cm row spacing because of better aeration and solar radiation interception. Sarkar *et al.* (2011) reported higher LAI of rapeseed (*Brassica campestris*) grown as sole crop than in the intercropping system due to absence of inter specific competition in sole crop.

Interception of photosynthetically active radiation (PAR) increased with crop growth up to 90 DAS and decreased thereafter up to maturity (Table 2). However, irrespective of the treatment, PAR interception at maturity was higher than that recorded at 45 DAS. The PAR interception was only slightly more at Ludhiana than at Faridkot at 45 DAS and vice versa at 90 DAS and maturity. Oilseed rape sown at 22.5 cm row spacing and removal of alternate rows after cutting for fodder (T_1) recorded mean maximum PAR interception at 45 DAS (53 %), while maximum PAR interception at 90 DAS (89%) and maturity (62%) was registered in case of oilseed rape sown at 45 cm row spacing and cut + oat (T_4).

At 45 DAS, lowest PAR interception (51%) was recorded in cut treatment of oilseed rape sown at 45 cm row spacing (T_7), at 90 DAS in oilseed rape sown at 30 cm row spacing where cutting was followed by removal of alternate rows i.e. T_3 (83 %) and at maturity in oilseed rape sown at 60 cm row spacing (cut) + one row of Indian rape i.e. T_6 (55 %). Interception of PAR indicates the photosynthetic efficiency of the crop canopy which helps in better utilization of growth resources for better growth and development of the crop. Reduced subsequent growth of oilseed rape after cutting primarily due to reduced duration of the crop in case of sole crop and short stature,

Table 2: Effect of row spacing, cutting of oilseed rape and intercropping on leaf area index on interception of photosynthetically active radiation (PAR) at different growth stages

Treatment	Leaf area index									Interception of PAR (%)								
	45 DAS			90 DAS			At maturity			45 DAS			90 DAS			At maturity		
	LDH	FDK	Mean	LDH	FDK	Mean	LDH	FDK	Mean	LDH	FDK	Mean	LDH	FDK	Mean	LDH	FDK	Mean
T1	1.4	1.3	1.3	4.2	4.2	4.2	1.7	1.7	1.7	54	52	53	87	88	88	62	63	62
T2	1.4	1.3	1.3	4.7	4.3	4.5	1.8	1.8	1.8	53	52	52	84	86	85	56	57	57
T3	1.3	1.3	1.3	4.8	4.5	4.7	1.8	1.9	1.7	53	52	53	83	82	83	56	56	56
T4	1.4	1.4	1.4	2.3	2.2	2.2	1.4	1.4	1.4	52	51	51	89	89	89	61	62	62
T5	1.4	1.4	1.4	2.3	2.2	2.2	1.4	1.4	1.4	53	52	52	89	88	88	57	57	57
T6	1.5	1.4	1.4	2.2	2.1	2.1	1.4	1.4	1.4	52	51	52	87	88	87	54	55	55
T7	1.4	1.4	1.4	2.3	2.2	2.2	1.4	1.4	1.4	51	50	51	86	88	87	61	61	61
T8	1.4	1.4	1.4	4.5	4.2	4.3	1.8	1.9	1.8	52	51	51	88	89	88	60	61	61
T9	1.5	1.5	1.5	4.9	4.6	4.7	1.9	1.9	1.9	52	51	52	85	87	86	54	56	56
LSD	0.06	0.04	0.04	0.4	0.3	0.3	0.1	0.1	0.1	2	1	1	2	2	1	3	2	2

($p \leq 0.05$)

Table 3: Effect of row spacing, cutting of oilseed rape and intercropping on SPAD value of oilseed rape and oilseed rape equivalent yield

Treatments	SPAD chlorophyll value						Oilseed rape equivalent yield(t ha^{-1})		
	45 DAS			90 DAS					
	LDH	FDK	Mean	LDH	FDK	Mean	LDH	FDK	Mean
T1	41.3	42.5	41.9	42.6	44.9	43.8	2.65	2.76	2.71
T2	40.4	42.7	41.5	41.5	43.8	42.7	2.47	2.63	2.55
T3	40.9	42.5	41.7	42.4	44.4	43.4	2.56	2.71	2.64
T4	40.6	42.9	41.8	38.6	40.3	39.5	2.32	2.45	2.39
T5	41.0	41.7	41.4	38.2	38.9	38.5	3.47	3.65	3.56
T6	40.7	41.5	41.1	37.3	38.5	37.9	3.33	3.49	3.41
T7	40.4	42.5	41.4	42.1	44.8	43.4	2.23	2.20	2.22
T8	41.2	42.5	41.8	41.3	43.4	42.4	2.38	2.53	2.45
T9	41.1	42.6	41.9	42.0	44.2	43.1	2.29	2.44	2.36
LSD ($p \leq 0.05$)	NS	NS	NS	1.4	2. 6	1.6	0.31	0.23	0.18

lower biomass production and harvesting of intercrops such as Indian rape and oat resulted in lesser coverage of the ground in comparison to uncut sole crop of oilseed rape and therefore resulted in lower PAR interception at 90 DAS and maturity. Priya (2019) reported that PAR interception increased up to 90 DAS and then declined upto maturity due to senescence of the crops in comparison to sole crop in chickpea based intercropping systems. Pawar (2016) reported similar results in *Brassica napus* and *Pisum sativum* intercropping.

Irrespective of the treatments, SPAD value at Faridkot was higher (42.4, 42.6) than that at Ludhiana (40.9, 40.7) at both 45 DAS and 90 DAS (Table 3). At 45 DAS, differences among treatments for SPAD values were inconspicuous. At 90 DAS, SPAD values (mean 42.4 - 43.8) of uncut crop (irrespective of row spacing and cutting of alternate rows) were significantly higher than intercropped oilseed rape cut for fodder (37.9 -39.5).

However, SPAD value (43.4) of sole oilseed rape (cut) crop was similar to uncut crop. Higher SPAD value in leaf indicates higher photosynthetic efficiency of the crop which influences the vegetative and reproductive growth of plants. Lower SPAD value under intercropping systems might be due to lower interception of solar radiation for oilseed rape particularly in case of its intercropping with Indian rape. Competition of nutrients with intercrops might also have led to lower amount particularly of nitrogen available to oilseed rape.

Yield

Oilseed rape equivalent yield (OREY) was influenced by different planting pattern and intercropping systems (Table 3). The maximum OREY (3.56 t ha^{-1}) was obtained from oilseed rape sown at 45 cm row spacing (cut) + Indian rape (T_5) which was statistically at par with oilseed rape sown at 60 cm row spacing (cut) + Indian rape i.e. T_6 (3.41 t ha^{-1}) but significantly higher than all other treatments (2.22 – 2.71 t ha^{-1}). The lowest OREY (2.22 t ha^{-1}) was obtained from sole crop of oilseed rape (cut) sown at 45 cm row spacing (T_7) which was at par with sole crop of oilseed rape (uncut) sown at 60 cm row spacing i.e. T_9 (2.36 t ha^{-1}) and oilseed rape sown at 45 cm row spacing (cut) + oats sown after cutting of oilseed rape i.e. T_4 (2.39 t ha^{-1}).Cutting of oilseed rape though supplied green fodder resulted in significantly lower seed yield in comparison to uncut crop. The lower price of green fodder also resulted in lower total income and OREY yield. Less than optimum population in case of oilseed rape sown at wider spacing resulted in its lower seed yield in comparison to recommended row spacing of 45 cm. Though intercropping of oilseed rape with Indian rape also resulted in significantly lower seed yield of oilseed rape, additional seed yield of Indian rape as well as green fodder yield of oilseed rape resulted in highest OREY.

Conclusion

Poor vegetative growth and delay in onset of reproductive growth phase of oilseed rape after cutting impeded the attainment of physiological maturity by slowing down the regrowth process of the crop. Flowering and maturity of oilseed rape after cutting were delayed by about 12 days in comparison to uncut crop. Cutting of the oilseed rape at 45 DAS resulted in lower plant height, LAI and SPAD values than uncut crop. Wider row spacing (60 cm) resulted in higher LAI as compared to closer sown (30 cm). The PAR interception at 90 DAS was 42 % higher

than that recorded at 45 DAS. Intercropping of oilseed rape sown at 45 cm or 60 cm row spacing (cut) with Indian rape resulted in significantly higher oilseed rape equivalent yield (3.56 t and 3.41 t ha^{-1}) which was significantly higher than all other treatments (2.22 – 2.71 t ha^{-1}).

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