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Short Communication

Cutting of oilseed rape regulates agroclimatic indices and thermal efficiencies during different phenological stages

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Oilseed rape *(Brassica napus)* is primarily grown in Asia and Europe during winter and spring seasons. An accurate and timely understanding of the phenology of crops is significant for giving precise productivity forecasts (Liu *et al.,* 2022). It requires the accumulation of a specific amount of heat units to reach various phenological phases such as flowering and physiological maturity. The amount of heat energy accumulated by oilseed rape over time, or GDD is based on the principle that the actual time required by crop plants to reach a particular phenological stage is directly related to temperature ranged between base temperature (below which no growth occurs) and optimum temperature. Cutting of oilseed rape has changed the accumulation of heat units to some extent. Cutting of oilseed rape during early stages helps in escaping early heat stress to the flowering stage under varying climatic conditions. Cutting during early stages and its regrowth utilizes different agroclimatic indices and thermal efficiencies more effectively as compared to uncut crops. Cutting/grazing at the 6-8 leaf stage by sheep for a period of 7 days in mid-winter can delay flowering by 4 days than ungrazed plots (McCormick *et al.,* 2009). Therefore, agro-climatic models based on thermal indices such as growing degree day (GDD), helio-thermal unit (HTU), photo-thermal unit (PTU), and heat use efficiency can be used to understand the phenology and appropriate planting time for cutting and further seed production over spatial and temporal scale (Sreenivas *et al.,* 2010). All earlier studies in contrast to these indices always covered oilseed rape as a single-purpose crop (used for seed) and always looked after delaying sowing which caused a significant loss in yield, and none of the studies has been done for a dual-purpose oilseed rape where these indices were calculated after cutting it at 45 days after sowing without any significant yield reduction. An increase in thermal heat accumulation is expected by cutting and overcoming early seed setting along with the availability of fodder during the lean period of the year. In view of this, the present investigation was carried out to study the effect of cutting oilseed rape sown at different row spacing on phenology and thermal indices of oilseed rape.

The study was carried out at Ludhiana (Lat. 30º 54' N, Long. 75º 48' E, altitude 247-meter amsl) and at Faridkot (Lat. 30º 40' N, Long. 74º 44' E, altitude 200-meter abmsl) western plain zone of Punjab, India. The climate of the area is sub-tropical and semi-arid with hot and dry summers. The experiment was conducted in a randomized complete block design, keeping a combination of cut/uncut oilseed rape sown at a different row spacing of 45 cm and 60 cm. Emergence count was calculated by counting the number of days taken when at least one seedling emerged out of the soil in each row and counted daily until the count became constant and expressed as the number of days taken by the crop for complete emergence. A similar approach was adopted for the initiation and completion of flowering. The physiological maturity of oilseed rape appears when about 85-90% of the siliquae changed their colour from green to pale green, and the seeds in them became hard and brownish-black in colour. Various agroclimatic indices viz. accumulated growing degree days (AGDD), accumulated helio-thermal units (AHTU) and accumulated photothermal units (APTU), and energy use efficiencies viz. heat use efficiency (HUE), photothermal use efficiency (PTUE) and helio-thermal use efficiency (HTUE) were calculated following procedure described by Dar *et al.,* (2018), Dubey *et al.,* (2019), Sharma *et al.,* (2021) and Kumar *et al.,* (2022). Data analyses were performed using R Studio software. Analysis of variance (ANOVA) was used to evaluate the effect of cutting on phenology and seed yield, following the DNMRT test.

Effect of Cutting on crops phenology and seed yield

Crop phenology plays a pivotal role in plants' agronomic and physiological growth. Change in the climatic regime in the trans-Gangetic plain zone of India causes oilseed rape to address the early heat stress during the flowering period. To equip against heat stress, a simple practice of cutting during

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Table 1: Effect of different treatments on initiation and completion of emergence/flowering, physiological maturity, and seed yield

Treatments	Locations					
	Ludhiana	Faridkot	Mean	Ludhiana	Faridkot	Mean
	Days taken to initiation of emergence			**Days taken to completion of emergence**		
Oilseed rape sown at 45 cm (cut)	3.46±0.11^{ab}	3.63±0.22^{ab}	3.55±0.18^{a}	7.34±0.33^{ab}	7.63±0.40^{ab}	7.49±0.35^{a}
Oilseed rape sown at 60 cm (cut)	3.43±0.21^{ab}	3.61±0.18^{a}	3.52±0.20^{a}	7.38±0.59^{ab}	7.43±0.57^{ab}	7.41±0.58^{a}
Oilseed rape sown at 45 cm (uncut)	3.51±0.29^{ab}	3.65±0.25^{ab}	3.58±0.26^{a}	7.28±0.19^{b}	7.61±0.22^{a}	7.45±0.20^{a}
Oilseed rape sown at 60 cm (uncut)	3.38±0.27^{b}	3.47±0.18^{ab}	3.43±0.23^{a}	7.36±0.29^{ab}	7.66±0.19^{ab}	7.51±0.24^{a}
Mean	3.45±0.03^{a}	3.59±0.04^{a}		7.34±0.02^{a}	7.58±0.05^{a}	
LSD ($p \leq 0.05$)	Location (A) = NS Treatment (B) = NS, AxB = NS			Location (A) = NS Treatment (B) = NS, AxB = NS		
	Days taken to initiation of flowering			**Days taken to completion of flowering**		
Oilseed rape sown at 45 cm (cut)	89.3±0.78^{c}	91.2±1.01^{ab}	90.2±0.8^{b}	121.3±1.10^{a}	123.6±0.86^{a}	122.4±0.98^{a}
Oilseed rape sown at 60 cm (cut)	91.3±0.93^{bc}	93.3±1.13^{a}	92.3±1.07^{a}	122.6±1.25^{a}	123.2±0.83^{a}	122.9±0.11^{a}
Oilseed rape sown at 45 cm (uncut)	77.4±0.61^{d}	78.2±0.46^{d}	77.8±0.55^{c}	111.0±1.02^{c}	113.7±0.74^{b}	112.4±0.87^{b}
Oilseed rape sown at 60 cm (uncut)	77.4±0.70^{d}	78.8±0.42^{d}	78.1±0.54^{c}	110.9±0.98^{c}	112.1±0.71^{bc}	111.5±0.81^{b}
Mean	83.85±3.75^{b}	85.38±3.99^{a}		116.45±3.19^{b}	118.15±3.05^{a}	
LSD ($p \leq 0.05$)	Location (A) = 0.93 Treatment (B) = 1.32, AxB = NS			Location (A) = 1.22 Treatment (B) = 1.74, AxB = NS		
	Days taken to physiological maturity			**Seed yield (t/ha)**		
Oilseed rape sown at 45 cm (cut)	157.1±0.47^{a}	157.7±0.56^{a}	157.4±0.51^{a}	1.89±0.07^{c}	1.92±0.06^{c}	1.90±0.05^{b}
Oilseed rape sown at 60 cm (cut)	156.7±0.49^{a}	158.0±0.52^{a}	157.3±0.50^{a}	1.83±0.05^{c}	1.87±0.06	1.85±0.06^{b}
Oilseed rape sown at 45 cm (uncut)	147.0±0.51^{bc}	148.3±1.0^{b}	147.6±0.74^{b}	2.38±0.05^{ab}	2.53±0.04^{a}	2.45±0.05^{a}
Oilseed rape sown at 60 cm (uncut)	145.4±0.48^{c}	147.2±0.87^{b}	146.3±0.61^{c}	2.29±0.10^{b}	2.44±0.02^{ab}	2.36±0.05^{a}
Mean	151.55±3.12^{b}	152.8±2.92^{a}		2.10±0.14^{a}	2.19±0.17^{a}	
LSD ($p \leq 0.05$)	Location (A) = 0.82 Treatment (B) = 1.16, AxB = NS			Location (A) = 0.08 Treatment (B) = 0.12, AxB = NS		

the early growth stage of oilseed rape was used which helps in delaying flowering along with getting green fodder during the lean months of October-November and further regrowth for seed production. Oilseed rape when sown at 60 cm row spacing cut for fodder took a maximum number of days for initiation (92.3) and completion (122.9) of flowering while in uncut crops sown at same row spacing, flowering was early by 11 to 14 days (Table 1). A similar delay pattern for flowering was observed under a cut crop of oilseed rape sown at 45 cm row spacing. Physiological maturity was also delayed by almost 10 days when the crop sown at 45 and 60 cm row spacing was cut for fodder at 45 DAS. The delay in flowering undercut treatments was due to the slower regrowth of plants in cooler winter months receiving low sunshine hours. Kirkegaard *et al.,* (2012) grazed oilseed rape using animals at the vegetative stage before buds are visible which delays flowering by 4 days. Cutting reduced the seed yield of oilseed rape by 0.55 t/ha and 0.51 t/ha under 45 and 60 cm sown crops, respectively (Table 1). Reduced yield is compensated by fodder oilseed rape which came out to be very remunerative during the lean months of October and November. The reduction in the seed yield of the oilseed rape was due to slower regrowth of plants facing low temperatures and lower yield contributing components. Grazing before bud elongation reduces the seed yield of winter European canola (*Brassica napus*) (Sprague *et al.,* 2018).

Effect of cutting on agroclimatic indices

Maximum AGDD of 1306.0˚C days during initiation of flowering was observed in cut oilseed rape sown at 60 cm row spacing but was at par with 45 cm sown cut oilseed rape. Cut crops of oilseed rape recorded higher AGDD than uncut crops (Table 2). Cutting delayed the physiological maturity by almost 10 days which increases the average of maximum and minimum temperatures as there are a higher number of days to intercept available solar radiation. Cut crop of oilseed rape sown at 45 cm row spacing intercepts higher AGDD at completion of flowering (1501.6 ˚C days) and at physiological maturity (1900.5 ˚C days) as the average of maximum and minimum temperature increases towards maturity due to onset of spring season towards maturity. Wider row spacing allows the leaves of the plants to intercept more solar radiation over a wider surface area which also transits higher AGDD. Wang *et al.,* (2015) reported similar results of intercepting more solar radiations in wider sown crops. A maximum APTU value of 14263.5˚C day hour was recorded during the initiation of the flowering period in the cut treatment of oilseed rape sown at 60 cm row spacing which was also at par with 45 cm sown cut oilseed rape (Table 2). An increase in average maximum and minimum temperature and increase in day length leads to higher APTU values of 16253.5 ˚C day hour and 20601 ˚C day hour at the completion of flowering and physiological maturity, respectively in 45 cm row spacing sown cut crop of oilseed rape. Oilseed rape, sown at 60 cm row spacing accumulated the highest AHTU of 8668.8˚C day hour at the initiation of flowering which increases significantly towards physiological maturity (Table 2). Spacing does not influence the AHTU value at central and western plain zones while cutting increases the AHTU

Table 2: Effect of different treatments on accumulated growing degree day, accumulated photo-thermal units, and accumulated helio-thermal units

Treatments	Locations								
	Ludhiana	Faridkot	Mean	Ludhiana	Faridkot	Mean	Ludhiana	Faridkot	Mean
	Initiation of flowering			Completion of flowering			At physiological maturity		
Accumulated growing degree day (˚C days)									
Oilseed rape sown at 45 cm (cut)	1323.8	1267.7	1295.8	1534.4	1468.8	1501.6	1924.2	1876.7	1900.5
Oilseed rape sown at 60 cm (cut)	1338.3	1273.6	1306.0	1540.1	1462.6	1501.4	1910.3	1876.7	1893.5
Oilseed rape sown at 45 cm (uncut)	1242.1	1186.4	1214.3	1468.0	1398.1	1433.1	1775.5	1721.7	1748.6
Oilseed rape sown at 60 cm (uncut)	1242.1	1192.9	1217.5	1463.8	1385.0	1424.4	1751.2	1707.7	1729.5
Mean	1286.6	1230.2		1501.6	1428.6		1840.3	1795.7	
Accumulated photo-thermal units (˚C day hour)									
Oilseed rape sown at 45 cm (cut)	14465	13858	14161.5	16604	15903	16253.5	20846	20356	20601
Oilseed rape sown at 60 cm (cut)	14611	13916	14263.5	16663	15839	16251	20689	20356	20522.5
Oilseed rape sown at 45 cm (uncut)	13640	13036	13338	15924	15177	15550.5	19178	18615	18896.5
Oilseed rape sown at 60 cm (uncut)	13640	13102	13371	15881	15043	15462	18909	18459	18684
Mean	14089	13478		16268	15490.5		19905.5	19446.5	
Accumulated helio-thermal unit (˚C day hour)									
Oilseed rape sown at 45 cm (cut)	9645.3	7591.9	8618.6	10154	8142.8	9148.4	12932	10656	11794
Oilseed rape sown at 60 cm (cut)	9733.8	7603.8	8668.8	10154	8095.9	9124.9	12793	10656	11724.5
Oilseed rape sown at 45 cm (uncut)	9193.3	7138.5	8165.9	9970.9	7759.7	8865.3	11661	9433.4	10547.2
Oilseed rape sown at 60 cm (uncut)	9193.3	7153.2	8173.2	9955.8	7704.2	8830	11522	9335.1	10428.5
Mean	9441.4	7371.8		10058.7	7925.6		12227.0	10020.1	

Table 3: Effect of different treatments on heat use efficiency, photo-thermal use efficiency, and helio-thermal use efficiency

Treatments	Locations								
	Ludhiana	Faridkot	Mean	Ludhiana	Faridkot	Mean	Ludhiana	Faridkot	Mean
	Initiation of flowering			Completion of flowering			At physiological maturity		
Heat use efficiency (kg/ha/ ºC/day)									
Oilseed rape sown at 45 cm (cut)	1.69	1.76	1.72	1.46	1.52	1.49	1.16	1.19	1.18
Oilseed rape sown at 60 cm (cut)	1.57	1.66	1.62	1.36	1.44	1.40	1.09	1.12	1.10
Oilseed rape sown at 45 cm (uncut)	1.91	2.13	2.02	1.62	1.81	1.71	1.34	1.47	1.41
Oilseed rape sown at 60 cm (uncut)	1.84	2.04	1.94	1.57	1.76	1.67	1.31	1.43	1.37
Mean	1.64	1.79		1.40	1.54		1.15	1.23	
Photo-thermal use efficiency (kg/ha/ ºC/day hour)									
Oilseed rape sown at 45 cm (cut)	0.15	0.16	0.15	0.13	0.14	0.14	0.11	0.11	0.11
Oilseed rape sown at 60 cm (cut)	0.14	0.15	0.14	0.13	0.13	0.13	0.10	0.10	0.10
Oilseed rape sown at 45 cm (uncut)	0.17	0.19	0.18	0.15	0.17	0.16	0.12	0.14	0.13
Oilseed rape sown at 60 cm (uncut)	0.17	0.19	0.16	0.14	0.16	0.15	0.12	0.13	0.12
Mean	0.15	0.16		0.13	0.14		0.32	0.11	
Helio-thermal use efficiency (kg/ha/ ºC/day hour)									
Oilseed rape sown at 45 cm (cut)	0.23	0.29	0.26	0.22	0.27	0.25	0.17	0.21	0.19
Oilseed rape sown at 60 cm (cut)	0.22	0.28	0.25	0.21	0.26	0.24	0.16	0.20	0.18
Oilseed rape sown at 45 cm (uncut)	0.26	0.35	0.31	0.24	0.33	0.29	0.20	0.27	0.24
Oilseed rape sown at 60 cm (uncut)	0.25	0.34	0.30	0.23	0.32	0.28	0.20	0.26	0.23
Mean	0.23	0.30		0.21	0.28		0.17	0.22	

value. Longer sunshine hours help in accumulating more heat units which increased the AHTU value in oilseed rape sown at 45 cm row spacing during completion of flowering (9148.4˚C day hour) and at physiological maturity (11794˚C day hour).

Effect of cutting on thermal efficiencies

The highest heat use efficiency was observed in the uncut crop of oilseed rape sown at 45 cm row spacing of 2.02 kg/ ha/ ºC/day at the initiation of flowering, 1.71 kg/ha/ ºC/day at the completion of flowering, and 1.41 kg/ha/ ºC/day at physiological maturity (Table 3). The uncut crop of oilseed rape sown at 45 cm row spacing recovered highest PTUE at initiation of flowering (0.18 kg/ha/ ºC/day), completion of flowering (0.16 kg/ha/ ºC/day), and at maturity (0.13 kg/ha/ ºC/day) (Table 3). Uncut oilseed rape, sown at 45 cm row spacing utilizing maximum available bright sunshine hours which simulated the highest HTUE of 0.31 kg/ha/ ºC/day at the initiation of flowering. HTUE decreases towards the completion of flowering (0.29 kg/ha/ ºC/day) and physiological maturity (0.24 kg/ha/ ºC/day) as actual sunshine hours decrease as the crop faces cooler winter months (Table 3). Cutting of oilseed rape reduced the different efficiencies due to the reduction in regrowth of the plants during cooler winter temperatures. Due to this, there was a reduction in yield parameters contributing towards lower seed yield which reduces thermal efficiencies as a lower number of seeds was produced from the same amount of accumulated growing degree days. With the delay in sowing, there was a reduction in HUE, PTUE, and HTUE as there was a reduction in yields with the delay in sowing (Kumar *et al.*, 2014). Similar results were observed in research as by cutting there was a delay in flowering by 12 days which indirectly delays the sowing time, in other words, causing a reduction in thermal efficiencies.

CONCLUSION

The study showed that cutting oilseed rape protects the crop from early heat stress by delaying the flowering of the crop by 12-14 days resulting in a climate-resilient agroecosystem. Agroclimatic indices showed a positive response towards cutting as crops get almost 10 more growing days to assimilate more solar radiation towards reproductive sinks. Thermal efficiencies showed a marginal low in cut crops, but these can be compensated by the fodder yield during the lean winter months. Cutting helps defend against early heat stress and provides extra fodder along with seed yield.

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