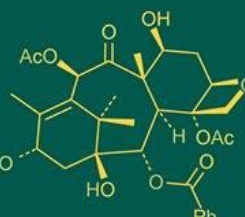


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Puneet Kaur
 Department of Agronomy,
 Punjab Agricultural
 University, Ludhiana, Punjab,
 India

Navneet Kaur
 Department of Forestry and
 Natural Resources, Punjab
 Agricultural University,
 Ludhiana, Punjab, India

Effect of sowing time on phenology and growth of Indian mustard genotypes under poplar-based alley cropping system

Puneet Kaur and Navneet Kaur

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Abstract

A field experiment was conducted during the *rabi* seasons of 2020-21 and 2021-22 at Punjab Agricultural University, Ludhiana, to evaluate the phenological development and growth dynamics of Indian mustard (*Brassica juncea* L.) genotypes under different sowing environments in a poplar-based agroforestry system. A split-plot design was employed with three replications, comprising two cropping systems (poplar+Indian mustard and Indian mustard sole crop) and four sowing times (1st and 15th October, 1st and 15th November) as main plots, and three Indian mustard genotypes (RCH 1, PHR 126, and PBR 357) as sub-plots. Results revealed that phenological stages and growth parameters were significantly influenced by sowing time and cropping system, while genotypic differences were more pronounced at later stages. Early sowing (1st and 15th October) resulted in faster emergence, earlier flowering, and a longer crop duration, leading to increased plant height, dry matter accumulation, and branching. In contrast, delayed sowing (especially on 15th November) caused delayed development due to sub-optimal temperatures during early growth and excessive heat during reproductive stages. Mustard grown in open fields outperformed that grown in poplar alleys due to better light availability and favorable temperature conditions. Shading under poplar trees delayed phenological progression and reduced biomass accumulation. Among the genotypes, PBR 357 consistently exhibited superior growth performance. The findings suggest that early sowing, combined with the use of PBR 357 genotype, plays a pivotal role in enhancing the performance of mustard under poplar-based agroforestry system.

Keywords: *Brassica juncea*, sowing time, phenology, growth, agroforestry, poplar, genotype

Introduction

Rapeseed and mustard, belonging to the Brassicaceae family, are among the major oilseed crops globally, following soybean and oil palm in importance. They exhibit a high seed oil content, typically ranging from 37 to 49%, depending on the genotype. Indian mustard (*Brassica juncea* L.), in particular, is recognized as a "novel food" due to its low glucosinolate content in meal and the absence of erucic acid in its oil, making it comparable in quality to canola (Potts *et al.*, 2003) [21]. Indian mustard is the second most important oilseed crop in India after groundnut, contributing approximately 27.8% to the country's total oilseed production. During the 2021-22 season, it was cultivated over 8.06 million hectares, yielding about 11.75 million tonnes with an average productivity of 1458 kg/ha (Anonymous, 2023) [1]. Despite its significance, India continues to face a shortfall in edible oil production. Although the national target was to achieve 50 million tonnes of oilseed production by 2020 (Parihar *et al.*, 2009) [18], actual production in 2019-20 was estimated at only 34.19 million tonnes. To address this deficit, expanding the area under rapeseed-mustard cultivation is imperative. One potential strategy is to promote intercropping mustard within poplar-based agroforestry systems. This model is especially promising in resource-constrained areas, offering a sustainable alternative to the traditional poplar-wheat rotation. Sowing time plays a pivotal role in determining the length of the growing season and influences the phenological development and growth dynamics of mustard. As a photosensitive crop, rapeseed-mustard responds markedly to variations in sowing time, which affect the prevailing thermal and photoperiodic regimes (Bhagat *et al.*, 2023) [4]. Shifts in sowing time can alter the microclimate experienced by the crop, thereby influencing seedling emergence, branching, flowering, and yield components (Kaur *et al.*, 2018) [11].

Corresponding Author:
Puneet Kaur
 Department of Agronomy,
 Punjab Agricultural
 University, Ludhiana, Punjab,
 India

Timely sowing ensures better alignment between crop development stages and favorable weather conditions, thereby enhancing resource use efficiency (Bhagat *et al.*, 2022) [3].

Therefore, the present investigation was undertaken to evaluate the phenological behavior and growth performance of selected Indian mustard genotypes under varying sowing environments within a poplar alley cropping system. The objective is to identify the optimum sowing time and suitable genotypes that can enhance productivity and sustainability in poplar-based cropping systems.

Materials and Methods

This field trial was conducted at research area of Department of Forestry and Natural Resources, Punjab Agricultural University, Ludhiana, India. The site is located at 30°54' N latitude, 75°45' E longitude, and at an altitude of 247 meters above mean sea level during the *rabi* seasons of 2020-21 and 2021-22. The study was conducted within a poplar-based agroforestry system and in open field conditions (sole crop) which was adjacent to the poplar block plantation. The block plantations comprised poplar trees of the L-47/88 clone, arranged with a spacing of 5 x 4 m, with 5 m wide strip oriented in the north-south direction, featuring 10 trees per row, which were planted in January 2016. The age of poplar plantation was 4 and 5 years in 2020 and 2021, respectively. The experimental design was split plot design with two cropping systems (poplar+Indian mustard and Indian mustard sole crop) and four sowing times (1st October, 15th October, 1st November and 15th November) as main plots and three genotypes (RCH 1, PHR 126 and PBR 357) as sub-plots. The experiment was replicated thrice; with total 72 plots (36 plots under poplar and 36 plots in open field conditions as control).

Indian mustard was sown manually in both open fields and in alleys between poplar rows on four dates: 1st and 15th October, and 1st and 15th November, using a seed rate of 3.75 kg/ha. Fertilization followed the PAU recommended package of practices for *rabi* crops, applying 125 kg N/ha (urea), 30 kg P₂O₅/ha (single super phosphate), and 15 kg K₂O/ha (muriate of potash). Half the nitrogen along with the full dose of phosphorus and potassium was applied at sowing; the remaining nitrogen was top-dressed at 30 days after sowing (DAS). Sowing was done in rows spaced 30 cm apart, and thinning was carried out at 21 DAS to maintain an intra-row spacing of 10-15 cm. Weed control was achieved through two hand weeding at 30 and 45 DAS. Aphid infestation was managed by spraying Rogor 30 EC (dimethoate) at 1.0 L/ha in 250 L (liters) water when pest levels approached the economic threshold (typically in late January). To control white rust, Ridomil Gold was applied at 625 g/ha in 250 L water at 60 and 80 DAS. The crop was harvested at physiological maturity (late March to early April), when over 80% of the siliques had turned yellow. All management practices were uniformly applied across both growing environments.

Results and discussion

Phenological parameters of Indian mustard

Phenological traits of Indian mustard were significantly influenced by cropping system and sowing times, while genotypic variation had minimal effect except at later stages. Seedling emergence and early vegetative growth were delayed under the poplar-based system and with later

sowing. The 15th November sown crop recorded the longest emergence time (10.5 and 10.3 days), while the 1st October sowing showed the fastest emergence (4.4 and 3.6 days). Similarly, the 4-leaf stage was reached earliest under 1st October sowing (9.4 and 8.5 days) and latest under 15th November (15.4 and 15.2 days), with delayed development under poplar conditions compared to open fields.

Flowering and silique initiation were also significantly delayed under later sowing dates and the poplar-based system. The 1st October sown crop initiated flowering 14.5 and 16.4 days earlier than the 1st November sowing, and up to 21 days earlier than the 15th November sowing. Silique initiation followed a similar trend, with the 1st October sowing reaching the stage earliest (68.0 and 71.0 days). Among genotypes, PBR 357 consistently exhibited delayed flowering and silique initiation, while RCH 1 was the earliest. Seed development and physiological maturity were also prolonged under poplar and early sowing. The crop sown on 1st October took the longest time to reach maturity (161.1 and 162.6 days), while delayed sowing shortened the crop duration. Overall, early sowing and open conditions accelerated phenological progression, whereas poplar-based intercropping delayed crop development across all stages.

The delay in seedling emergence under late sowing conditions can be attributed to declining temperatures and reduced sunshine hours. In the present study, the crop sown on 15th November took significantly longer to emerge compared to earlier sowing dates (1st October to 1st November), as mean temperatures during the first 10 days after sowing dropped progressively from 26.3 °C to 16.0 °C in 2020-21 and from 28.7 °C to 17.2 °C in 2021-22. These temperatures fall below the optimal range of 24-28 °C required for mustard germination and seedling emergence (Kumar and Rana, 2013) [13]. Similar delays due to lower temperatures in late sowing have been reported for *B. napus* (Kaur *et al.*, 2018) [11], *B. carinata* (Singh and Dhingra, 2003; Singh, 2016) [23, 25], and *B. juncea* (Patel *et al.*, 2004) [20].

Delayed sowing also significantly influenced the phenological development of mustard. The late-sown crop experienced slower growth and delayed flowering due to lower temperatures in December and January, consistent with findings by Singh *et al.* (2014) [24] and Patel *et al.* (2013) [19]. These cooler conditions extended the vegetative phase, while higher temperatures and increased sunshine from mid-February onwards hastened crop maturity, reducing the reproductive period. This trend aligns with earlier reports by Dhaliwal (2002) [7], Nanda *et al.* (1999) [17], and Robertson *et al.* (2004) [22], who noted shortened growth durations in mustard under delayed sowing. Gupta *et al.* (2017) [9] also observed that increased temperatures during the reproductive phase hasten seed development, leading to early physiological maturity in mustard cultivars. Under the poplar-based agroforestry system, mustard exhibited delayed phenological stages compared to open-field conditions. This delay is primarily due to the altered microclimate under the poplar canopy, which results in lower temperatures and reduced photosynthetically active radiation (PAR), as also reported by Bhardwaj *et al.* (2021) [5] in onion, Banoo (2021) in *Cucurbita* spp., and Kaur *et al.* (2024) [10] in garden peas. The shading effect of trees in agroforestry systems slows the accumulation of thermal units necessary for crop development, thereby delaying phenological events.

Growth Parameters of Indian mustard

Plant height of Indian mustard showed a consistent increase from 30 to 90 DAS across all treatments. Sowing time significantly influenced plant height, with the 1st and 15th October sowings recording taller plants than the 1st and 15th November sowings. This can be attributed to more favorable growing conditions during early sowing, such as optimal temperature and better solar radiation (Kumar and Rana, 2013) [13]. The cropping system also played a critical role; plants grown under sole cropping recorded significantly higher plant height than those intercropped with poplar, likely due to the shading effect and altered microclimatic conditions under the tree canopy (Bhardwaj *et al.*, 2021) [5]. Among genotypes, PBR 357 exhibited superior height at 90

DAS, whereas PHR 126 and RCH 1 remained statistically comparable.

Dry matter accumulation (DMA) increased substantially with crop age, displaying a typical sigmoid growth trend. The 15th October sowing registered the highest DMA, closely followed by the 1st October sowing, while the 15th November sowing recorded the lowest, reflecting the adverse impact of delayed sowing. Sole cropping consistently resulted in higher biomass accumulation compared to the poplar-based system, attributable to enhanced light interception and photosynthetic efficiency (Boomiraj *et al.*, 2010) [6]. Genotype PBR 357 accumulated more dry matter than the other two genotypes, indicating its superior growth potential.

Table 1: Effect of sowing time on phenological stages of Indian mustard genotypes sown under poplar and open conditions during 2020-21 (Y1) and 2021-22 (Y2)

Treatments	Number of days											
	Seedling emergence		Early vegetative phase (4 leaf stage)		Flowering initiation		Siliqua initiation		Seed development		Physiological maturity	
	Y1	Y2	Y1	Y2	Y1	Y2	Y1	Y2	Y1	Y2	Y1	Y2
Cropping system												
Poplar + Indian mustard	7.5	7.0	12.7	12.1	59.8	58.8	79.1	81.1	94.3	95.4	145.8	148.4
Indian mustard sole crop	6.9	6.4	11.5	10.9	56.3	55.4	75.4	77.9	90.0	91.3	143.1	144.1
CD (p=0.05)	0.4	0.3	0.3	0.4	1.0	1.0	1.1	1.0	0.9	0.8	0.9	0.7
Sowing time												
1 st Oct	4.4	3.6	9.4	8.5	48.6	46.6	68.0	71.0	84.9	88.4	161.1	162.6
15 th Oct	5.2	4.2	10.0	9.2	52.8	50.9	73.4	75.6	92.7	92.9	153.1	154.8
1 st Nov	8.8	8.7	13.4	13.3	63.1	63.0	81.7	84.0	96.7	97.2	138.5	140.0
15 th Nov	10.5	10.3	15.4	15.2	67.7	67.9	85.9	87.4	94.3	94.8	125.1	127.6
CD (p=0.05)	0.6	0.5	0.4	0.5	1.5	1.4	1.5	1.5	1.3	1.2	1.3	1.1
Genotypes												
RCH 1	7.4	6.9	12.0	11.3	57.8	56.8	76.8	79.0	91.9	93.0	143.9	145.5
PHR 126	7.1	6.6	12.0	11.5	57.9	56.8	77.0	79.2	91.8	93.0	144.1	145.8
PBR 357	7.2	6.6	12.2	11.8	58.6	57.7	78.0	80.3	92.8	94.0	145.3	147.4
CD (p=0.05)	NS	NS	NS	NS	0.6	0.7	0.9	0.7	0.8	0.9	0.6	0.9

The number of primary and secondary branches per plant also increased with early sowings (1st and 15th October) producing significantly more branches than late sowings. Crops grown under open conditions outperformed those under the poplar canopy in terms of branching, indicating

better resource availability and growth environment. Although differences among genotypes were not statistically significant, PBR 357 consistently recorded higher values across both seasons.

Table 2: Effect of sowing time on plant height of Indian mustard genotypes sown under poplar and open conditions

Treatments	Plant height (cm)					
	30 DAS		60 DAS		90 DAS	
	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
Cropping system						
Poplar + Indian mustard	13.4	12.1	82.3	75.9	121.3	112.6
Indian mustard sole crop	15.9	16.2	95.5	93.8	151.4	150.8
CD (p=0.05)	0.7	0.6	2.6	2.7	5.1	5.7
Sowing time						
1 st Oct	15.9	16.0	99.8	96.9	151.7	145.8
15 th Oct	15.8	15.2	96.6	93.4	146.1	141.7
1 st Nov	14.2	13.4	82.6	78.4	129.1	124.8
15 th Nov	12.7	12.0	76.7	70.7	118.6	114.6
CD (p=0.05)	1.0	0.9	3.7	3.8	7.2	8.0
Genotypes						
RCH 1	14.7	14.0	87.8	83.1	136.2	131.4
PHR 126	14.6	14.2	87.6	83.8	131.8	127.2
PBR 357	14.6	14.3	91.4	87.6	141.1	136.5
CD (p=0.05)	NS	NS	3.4	2.6	7.0	7.2

The results on growth parameters of Indian mustard clearly indicate that sowing time significantly influenced plant height, dry matter accumulation, and branching pattern.

Early sowing on 1st and 15th October produced significantly taller plants, greater dry matter accumulation, and more secondary branches per plant compared to crop sown on 1st

and 15th November. These results indicate that early sowing provides favorable conditions for active cell division, efficient nutrient uptake, and vigorous plant development. The warm temperatures and ample sunlight during October promote physiological processes such as meristematic growth and stem elongation, contributing to enhanced vegetative performance. In contrast, crops sown later in the season are exposed to lower temperatures, which delay seedling emergence and hinder early growth. Similar findings were reported by Keerthi *et al.* (2017) ^[12] and Kumar *et al.* (2017) ^[15], who observed a reduction in plant height with delayed sowing, emphasizing the crop's sensitivity to temperature fluctuations during the initial growth stages.

Delayed sowing, especially beyond early November, exposed the crop to sub-optimal thermal conditions during early growth and excessive heat during the reproductive phase, which negatively impacted growth and dry matter

accumulation. Keerthi *et al.* (2017) ^[12] and Kumar *et al.* (2017) ^[15] similarly reported significant reductions in plant height and biomass with delayed sowing. Lakra *et al.* (2018) ^[16] also observed a consistent decline in growth with each week's delay in sowing from late October to late November. Early sowing led to better vegetative establishment, more branching, and higher DMA due to prolonged growth duration. In contrast, high temperatures (36.0-41.5 °C) during reproductive stages in late-sown crops accelerated senescence and curtailed biomass production (Kumar *et al.*, 2022; Dudhade *et al.*, 1996; Singh *et al.*, 2002; Tyagi, 2017) ^[14, 8, 26, 27]. Notably, dry matter was reduced by 9.37% and 17.6% in crops sown on 4th and 19th November, respectively. Branching was similarly affected, with fewer secondary branches in late-sown crops due to stress conditions, as also observed by Bhagat *et al.* (2022) ^[3] in *B. napus*.

Table 3: Effect of sowing time on dry matter accumulation (g/m²) of Indian mustard genotypes sown under poplar and open conditions

Treatments	Dry matter accumulation (g/m ²)					
	30 DAS		60 DAS		90 DAS	
	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
Cropping system						
Poplar + Indian mustard	15.01	11.52	76.63	67.97	429.53	415.64
Indian mustard sole crop	19.89	20.36	89.55	91.32	471.04	469.97
CD (p=0.05)	0.95	1.08	4.65	4.15	14.29	12.89
Sowing time						
1 st Oct	17.18	16.02	89.63	86.13	477.18	469.00
15 th Oct	21.38	20.39	100.90	98.28	525.31	514.75
1 st Nov	16.67	15.20	74.74	71.29	419.97	415.07
15 th Nov	14.57	12.15	67.11	62.88	378.69	372.40
CD (p=0.05)	1.34	1.52	6.57	5.87	20.20	18.23
Genotypes						
RCH 1	16.98	15.38	80.40	76.57	440.30	431.44
PHR 126	17.31	15.82	82.95	80.04	451.79	443.72
PBR 357	18.07	16.62	85.93	82.32	458.76	453.27
CD (p=0.05)	0.88	0.89	2.81	2.99	14.46	13.44

Table 4: Effect of sowing time on number of branches per plant of Indian mustard genotypes sown under poplar and open conditions

Treatments	Primary branches (no.)		Secondary branches (no.)	
	2020-21	2021-22	2020-21	2021-22
Cropping system				
Poplar + Indian mustard	4.83	4.37	9.60	8.57
Indian mustard sole crop	5.84	5.61	11.90	11.85
CD (p=0.05)	0.19	0.22	0.59	0.54
Sowing time				
1 st Oct	6.06	5.81	12.40	11.70
15 th Oct	5.84	5.42	11.73	10.96
1 st Nov	4.87	4.53	9.72	9.36
15 th Nov	4.57	4.22	9.15	8.83
CD (p=0.05)	0.27	0.30	0.83	0.76
Genotypes				
RCH 1	5.28	4.90	10.41	9.78
PHR 126	5.33	4.99	10.76	10.20
PBR 357	5.40	5.10	11.08	10.64
CD (p=0.05)	NS	NS	0.53	0.55

Conclusion

The present investigation demonstrated that sowing time and cropping system exert significant influence on the phenological development and growth performance of Indian mustard in a poplar-based agroforestry system. Early sowing, particularly on 1st and 15th October, was found to be optimal for enhancing vegetative growth, biomass

accumulation, and timely attainment of phenological stages. In contrast, delayed sowing, especially beyond 1st November, led to prolonged emergence, delayed flowering, and reduced dry matter accumulation due to unfavorable thermal conditions during critical growth phases. The poplar-based agroforestry system, while offering a sustainable land-use option, introduced microclimatic

modifications such as reduced light intensity and lower temperatures, which delayed phenological events and limited growth compared to open field conditions. Among the tested genotypes, PBR 357 exhibited superior adaptability and growth performance across environments, making it a promising choice for poplar-based intercropping systems. Overall, the findings underscore the importance of optimizing sowing time and selecting suitable genotype to improve growth in poplar-mustard intercropping system. Early sowing ensures better synchronization of crop growth with favorable environmental conditions, while genotypes like PBR 357 can help overcome the growth constraints posed by agroforestry system.

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