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MICROMETEOROLOGICAL PARAMETERS AND SEED YIELD OF MUSTARD UNDER OPEN AND POPLAR PLANTATION

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Indian mustard, *Brassica juncea* (L.) Czern. & Coss., is an important oilseed crop, occupying approximately 80% of the total cultivated area under Brassica oilseeds in India. The seeds of *B. juncea* are notable for their nutritional profile, containing 38-46% oil, 4.7-13% linolenic acid, 27% oleic acid, and glucosinolates (180-200 micromoles), along with erucic acid (38-57%)—all of which are beneficial for human health (Kumar, 2012). Among the various annual edible oilseeds cultivated in the country, rapeseed-mustard accounts for 28.6% of the total oilseed production (Shekhawat *et al.*, 2012). In 2020, India produced over 33 million metric tons of oilseeds (Anonymous, 2021). The states of Rajasthan and Uttar Pradesh contribute more than 50% of the national mustard output, totaling approximately 5 million tons. In Punjab, rapeseed-mustard was cultivated on an area of 31,600 hectares, yielding 50,300 tons with an average productivity of 15.95 quintals per hectare during 2020-21 (Anonymous, 2022).

Rapeseed-mustard grows optimally at temperatures below 25°C, provided there is adequate soil moisture throughout the growing season. Its cultivation period, spanning from October to April, coincides with a phase of varying evaporative demand, abundant sunshine, and moderate to high radiation levels. This crop is predominantly grown in tropical and subtropical regions as a *rabi* season crop. It typically requires 25 to 40 cm of rainfall and demonstrates effective photosynthesis at temperatures between 15°C and 20°C. The timing of sowing is a crucial non-monetary factor that significantly influences yield outcomes. The date of sowing affects the phenological development of the crop, as variations in sowing times expose the plants to different thermal environments. Delayed sowing can lead to suboptimal growth and reduced oil content (Akhter *et al*., 2015).

In the context of changing climatic scenarios, researchers advocate for the adoption of agroforestry practices among farmers. Diversifying agriculture by incorporating trees alongside crop cultivation has been suggested as a means to achieve higher profits per unit area sustainably. Poplar trees, known for their rapid growth, ease of planting, and adaptability to various soil types, play a significant role in enhancing farm income. Currently, poplars are primarily cultivated in Uttar Pradesh, as well as in select regions of Punjab and Haryana. Although the integration of mustard cultivation with poplar trees was initiated approximately a decade ago, limited research has been conducted on the effects of poplar plantations on the microclimate, mustard growth, yield, and the incidence of mustard diseases. Understanding how poplar plantations alter the microclimate is crucial for optimizing crop production. This paper presents an experiment focused on micrometeorological parameters and seed yield of mustard under both open conditions and poplar plantation. The findings aim to provide insights into the interactions between poplar trees and mustard cultivation, ultimately contributing to more sustainable agricultural practices.

Two field experiments were conducted simultaneously during the *rabi* season of 2021-22: one in open conditions at the Research Farm of the Department of Climate Change & Agricultural Meteorology, and the other under poplar plantation at the Research Farm of the Department of Forestry and Natural Resources, Punjab Agricultural University (PAU), Ludhiana. The geographical coordinates of Ludhiana are 30°54'N latitude, 75°48'E longitude, with an elevation of 247 meters. This region is characterized by a subtropical climate, featuring hot summers from May to June and cold winters from December to January. Summer temperatures can soar to 45°C, while winter temperatures sharply decline, occasionally dropping to 1-2°C in January, resulting in frost and foggy conditions. The annual average rainfall is approximately 760 mm, with about 80% of this precipitation occurring between June and September. The experiments employed a split-plot design with three replications, incorporating three sowing dates: 10th October (D_1), 5th November (D_2), and 1st December (D_3). Two mustard varieties, PBR-91 and Giriraj, were assigned to the main plots, while nitrogen treatments—N_1 (Recommended N), N_2 (Recommended N + 25%), and N_3 (Recommended N + 50%)—were applied in the subplots. The poplar plantation consisted of six-year-old trees of clone L-48,

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spaced 8 x 2.5 meters apart. Mustard varieties were sown between the rows of the poplar trees.

Photosynthetically active radiation (PAR) levels incident on mustard crops cultivated in both open conditions and under poplar plantation were measured using a Line Quantum Sensor (Model LI-190 SB) at 15-day intervals, beginning 45 days after sowing. Relative humidity within the crop canopy was recorded using a psychron at the same intervals. Canopy temperature was measured at 1430 hours, also at 15-day intervals, from 45 to 135 days after sowing (DAS), utilizing an infrared thermometer (FLUKE-574). At harvest, yield and yield-attributing characteristics were recorded, including the number of siliqua per plant, number of seeds per siliqua, 1000-seed weight, final biomass, seed yield, and straw yield. The data pertaining to seed yield and other yield attributes were statistically analyzed using the CPCS-I software.

The amount of incident solar energy intercepted as a percentage is directly proportional to the incident radiation levels, which vary with changing phenological stages associated with different sowing dates. For mustard sown on 5th November, the incident radiation ranged from 921 to 1323 Watts(W)/m² in open conditions, while it measured between 880 and 1212 W/m² under poplar plantation. In contrast, for crops sown on 10th October, incident radiation values ranged from 1100 to 1215 W/m² in open conditions and from 989 to 1100 W/m² under poplar. For mustard sown on 1st December, total incident radiation varied from 843 to 1575 W/m² in open conditions and from 770 to 1359 W/m² under poplar plantation, as illustrated in Figure 1. Under both growing conditions, the pattern of total incident radiation did not follow a consistent trend and varied with the developmental stages of the mustard crop and the canopy cover of the poplar trees. For mustard sown on 10th October, total incident radiation began to decline 45 days after sowing and continued to decrease until 60 days after sowing. On the other hand, for the crop sown on 1st December, incident radiation increased until harvest in open conditions. The pattern of incident radiation under poplar plantation differed from that in open conditions, primarily due to shading effects from the poplar leaves. Incident radiation was highest in February; thereafter, it declined as the leaf area index of the poplar trees increased. Ultimately, it was determined that open conditions consistently provided more radiation than the poplar plantation throughout the growing season.

In addition to the interception of photosynthetically active radiation (PAR), the crop microclimate is significantly influenced by canopy temperature and relative humidity within the crop. Canopy temperature and relative humidity were measured at 15-day intervals starting 45 days after sowing under both open conditions and poplar plantation. The results indicated that canopy temperature was highest for crops sown on 1st December, followed by those sown on 5th November and 10th October. Canopy temperatures peaked at 135 days after sowing and reached their lowest point at 45 days after sowing in both conditions. Specifically, for the crop sown on 10th October, canopy temperatures recorded were 22.3°C in open fields and 20.9°C under poplar plantation. For the 5th November sowing, temperatures were 24.5°C in open conditions and 22.6°C under poplar. For the crop sown on 1st December, the temperatures measured were 25.8°C in open conditions and 24.5°C under poplar. At 135 days after sowing, canopy temperatures in open conditions were 27.1°C, 28.2°C, and 30.0°C for crops sown on 10th October, 5th November, and 1st December, respectively. Under poplar plantation, these temperatures were 25.9°C, 26.9°C, and 27.8°C for the same sowing dates. The findings indicate that canopy temperatures in open conditions remained up to 3°C higher throughout the growing period compared to

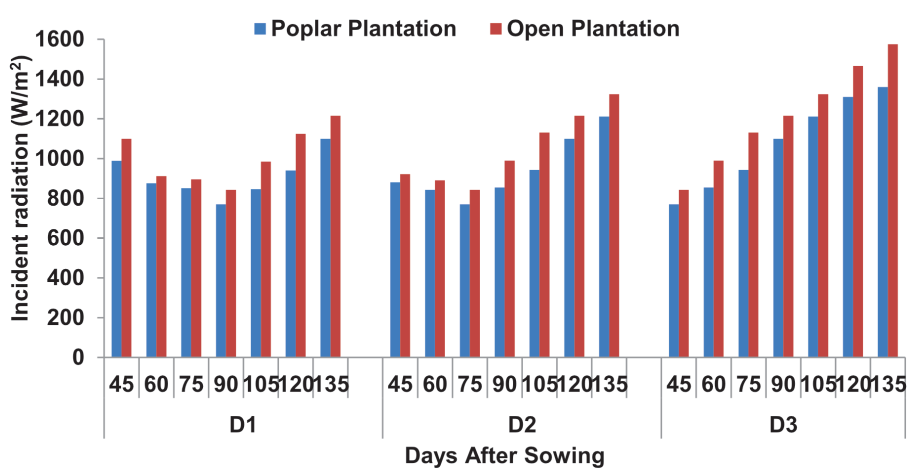

Fig. 1. Comparison of incident radiation in open fields and poplar plantations across different sowing dates

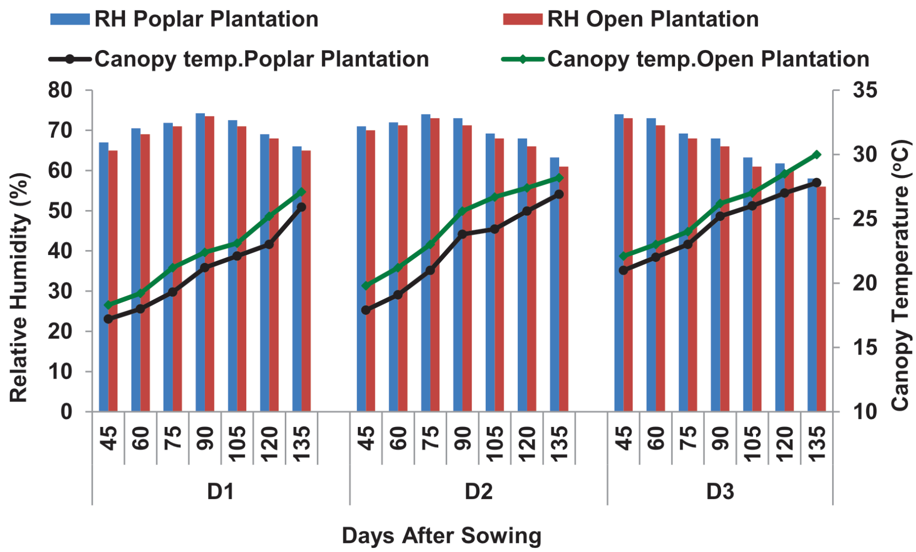

Fig. 2. Comparison of canopy temperature and relative humidity in open fields and poplar plantations across different sowing dates

those under poplar plantation. This difference can be attributed to the canopy cover of the poplar trees, which created significantly cooler microclimate conditions, as illustrated in Figure 2.

Comparing the different sowing dates, the relative humidity within the crop canopy was highest for the October 10th sowing (68.9%), followed closely by the November 5th sowing (68.6%) and the December 1st sowing (65.0%). Under poplar plantation, a similar trend was observed, with relative humidity levels of 70.2% for the October 10th sowing, 70.1% for the November 5th sowing, and 66.7% for the December 1st sowing, indicating slightly elevated humidity in this environment. Maximum relative humidity inside the canopy was recorded at 90 days after sowing, reaching 73.5% in open conditions and 74.3% under poplar plantation. On the other hand, minimum relative humidity was observed at 135 days after sowing, measuring 65.0% in open conditions and 66.1% under poplar plantation for the October 10th sowing. For the November 5th sowing, peak relative humidity occurred at 75 days after sowing, with a minimum recorded at 135 days after sowing in both growing conditions. Similarly, for the December 1st sowing, the highest relative humidity was measured at 60 days after sowing, with the lowest values recorded at 135 days after sowing in both open and poplar plantation environments. It was determined that the relative humidity within the crop canopy remained higher under poplar plantation, attributed to the slightly lower temperatures in this environment compared to open conditions.

The statistical analysis of yield and yield attributes indicated that early sowing (10th October) resulted in higher yields and improved yield characteristics compared to later sowing dates (5th November and 1st December) (Table 1). Among the sowing dates, the variety PBR-91 consistently produced higher yields than Giriraj. Across all sowing dates and for both varieties, the N_3 treatment (recommended N + 50%) yielded the most, followed by N_2 (recommended N + 25%) and N_1 (recommended N). The highest seed yield, biomass yield, straw yield, and key yield attributes—such as the number of siliqua per plant, seeds per siliqua, and 1000-seed weight—were recorded for the early sowing date (10th October), followed by the 5th November and 1st December sowings. According to Singh (2016), the sowing date significantly influenced the number of siliqua per plant, with the first sowing date yielding the highest counts, followed by the subsequent dates. Gopale *et al.* (2022) similarly reported that delays in sowing resulted in decreased siliqua counts, seeds per siliqua, and test weight. The crop sown on 10th October had the highest number of seeds per siliqua, with decreasing numbers for the 5th November and 1st December sowings, attributed to elevated temperatures during the siliqua filling stage for late-sown crops. Among the varieties, PBR-91 produced a greater number of seeds per siliqua than Giriraj. Langangmeilu *et al.* (2023) also noted that delayed sowing led to stunted growth, premature ripening, and substantial yield reductions, primarily due to increased temperatures during the grain-filling period and soil moisture depletion.

Regarding fertilizer treatments, the N_3 treatment produced a significantly higher number of siliqua per plant compared to N_2 and N_1 in both growing conditions. Dixit *et al.* (2023) observed that nitrogen application (30 to 90 kg/ha) significantly improved growth, yield attributes, and overall yield compared to treatments

Table 1. Yield and yield attributing characteristics of mustard varieties under different treatments in open fields and poplar plantations

Treatments	Siliqua/ plant (#)		Seeds/ siliqua (#)		1000 seed weight (gm)		Final biomass (q/ha)		Seed yield (q/ha)		Straw yield (q/ha)	
	Open	Poplar	Open	Poplar	Open	Poplar	Open	Poplar	Open	Poplar	Open	Poplar
Date of sowing												
10th October	285.33	260.33	11.01	10.17	3.6	3.4	98.38	78.17	17.93	15.81	80.45	62.36
5th November	213.77	188.77	10.98	10.05	3.5	3.2	77.38	62.22	16.27	14.01	61.11	48.21
1st December	192.00	167.00	10.90	9.95	3.3	3.2	66.92	51.92	13.77	11.57	53.15	40.35
Variety												
PBR-91	239.56	214.56	11.11	10.28	3.5	3.3	82.24	65.73	16.79	14.56	65.45	51.17
Giriraj	221.19	196.19	10.83	9.83	3.4	3.2	79.56	62.48	15.20	13.03	64.36	49.45
CD ($p \leq 0.05$)	7.66	8.5	0.16	0.13	NS	NS	2.8	4.45	1.6	1.35	1.4	1.8
Nitrogen levels												
N_1 (Recommended Nitrogen)	221.00	196.00	10.81	9.79	3.2	3.2	79.87	62.92	15.25	13.05	64.62	49.87
N_2 (Recommended Nitrogen+25%)	231.78	206.78	10.92	10.02	3.3	3.3	80.67	63.67	16.02	13.82	64.65	49.85
N_3 (Recommended Nitrogen+50%)	238.33	213.33	11.19	10.36	3.5	3.4	82.17	65.72	16.71	14.53	65.46	51.19
CD ($p \leq 0.05$)	3.66	6.3	NS	NS	NS	NS	0.9	1.25	2.9	0.55	0.48	0.98

#: Number

without nitrogen. Application of 90 kg N/ha resulted in the highest values for growth and yield attributes. All yield and yield attributes were notably lower under poplar plantation compared to open conditions, primarily due to reduced accumulated photothermal units caused by shading from the poplar trees. However, the trends remained consistent: early sowing (10th October) consistently yielded higher results than the later sowing dates, with PBR-91 outperforming Giriraj and the N_3 treatment producing the highest yields across all conditions. Test weight (1000-seed weight) was highest in the 10th October sown crop, followed by those sown on 5th November and 1st December, benefiting from favorable weather conditions during the siliqua filling period. PBR-91 also exhibited a higher test weight than Giriraj, and among fertilizer treatments, N_3 demonstrated the greatest test weight across both growing conditions. Supporting this, Keivanrad and Zandi (2012) studied the effects of nitrogen levels on Indian mustard under various planting geometries, noting that the highest number of seeds per siliqua (17.32) was recorded in the N_5 treatment (200 kg/ha), followed by N_4 (150 kg/ha), N_3 (100 kg/ha), N_2 (50 kg/ha), and the lowest in the N_1 treatment (control). Kumar *et al.* (2013) found that mustard grown without eucalyptus trees yielded a higher number of siliqua per plant (371.05) compared to those grown under eucalyptus (84.2). Similarly, the seeds per siliqua were also higher in crops grown without eucalyptus (14.5±1.63) than those grown under its canopy (9.5±1.63). The seed yield was comparatively lower in mustard grown under eucalyptus. Singh (2016) noted that the 7th October sowing produced the greatest test weight compared to later sowing dates (17th and 27th October). Kaur *et al.* (2021) concluded that the Indian mustard cultivars PBR-357 and Giriraj, when supplied with 150 kg N, achieved the highest yield attributes and yields, highlighting that higher nutrient levels help mitigate tree-crop competition for resources.

The findings from the experiments highlight the critical influence of sowing date, variety, and nitrogen application on the yield and yield attributes of Indian mustard (*Brassica juncea*). The results consistently demonstrate that early sowing (10th October) yields superior outcomes compared to later dates (5th November and 1st December). This trend aligns with previous research, which indicates that timely sowing maximizes the crop's exposure to favourable conditions during critical growth stages, ultimately enhancing yield characteristics such as the number of siliqua per plant and seeds per siliqua. Among the tested varieties, PBR-91 outperformed Giriraj, reinforcing the notion that selecting high-yielding varieties can significantly impact overall productivity. The application of nitrogen also played a pivotal role, with the N_3 treatment (recommended N + 50%) yielding the most across all conditions. This finding supports the premise that adequate nutrient supply is vital for optimizing growth and yield, as corroborated by studies showing significant improvements in yield attributes with increased nitrogen levels. The environment of poplar plantations, while providing some benefits, such as increased humidity, ultimately resulted in lower yields compared to open conditions. This reduction can be attributed to shading effects that limit photosynthetically active radiation and accumulated photothermal units. However, the overall trends remained consistent, with early sowing consistently producing higher yields regardless of the growing conditions.

In summary, these results highlight the importance of strategic agronomic practices, including selecting optimal sowing dates, choosing high-yielding varieties, and ensuring sufficient nitrogen application to enhance the productivity of Indian mustard. Further research into the interactions between these factors could provide deeper insights into maximizing yields under varying climatic and agronomic conditions.

In conclusion, this study highlights the significant impact of sowing date, variety selection, and nitrogen application on the yield and yield attributes of Indian mustard (*Brassica juncea*). Early sowing (10^{th} October) consistently produced the highest yields, demonstrating the importance of timely planting to optimize crop performance. The variety PBR-91 outperformed Giriraj, emphasizing the role of cultivar choice in achieving superior productivity. Additionally, higher nitrogen levels, particularly in the N_3 treatment, positively influenced yield outcomes across all conditions. While poplar plantations offered some microclimatic benefits, they ultimately led to lower yields due to shading effects. These findings highlight the necessity for integrated agronomic strategies to enhance mustard production, with potential implications for sustainable agricultural practices in similar climatic regions.

Authors' contribution

Conceptualization of research work and designing of experiments (SKS, NK); Execution of field experiments and data collection (BK); Analysis of data and interpretation (BK, SKS, NK); Preparation of manuscript (BK, SKS, NK)

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