**Effect of sowing windows and irrigation schedules on growth and productivity of mustard**

**Abstract**

 Rapeseed-mustard is a significant oilseed crop globally as well as in India cultivated primarily for edible oils. Considering the disruptions in the environmental conditions of agro-ecosystems due to climate change, the present field investigation was conducted to evaluate the effect of various sowing windows and irrigation schedules on mustard growth and productivity. Sowing windows and irrigation schedules were evaluated in randomized block design with factorial arrangement and three replications. The results of the present investigation revealed that sowing crop on 20th October resulted the substantially higher plant height (145.7 cm), leaf area index, number of leaves, number of siliquae per plant (234.6), number of seeds per siliqua (13.5), seed (10.35 q/ha), stover yield (30.72 q/ha) and harvest Index (25.23%) at harvest. Similarly, irrigating mustard crop following irrigation schedule based on Penman Monteith modified method resulted in the significantly higher plant height (146.4 cm), leaf area index, number of leaves, number of siliquae per plant (230.7), number of seeds per siliqua (13.7), seed (10.52 q/ha), stover yield (31.02 q/ha) and harvest Index (25.31%) for mustard crop at harvest. Therefore, sowing window of 20th October and irrigation schedule based on Penman Monteith modified method can be recommended for optimized yield levels under conditions of North-western Himalayas of Himachal Pradesh.

**1. Introduction**

 Oilseeds are considerable component of human diet after cereals with substantial contribution as cooking vegetable oils (Tian et al., 2023; Sharma et *al.,* 2025). Rapeseed-mustard is one of the significant oilseed crops cultivated globally for edible oils and protein rich cake (Xiong *et al.,* 2024). Rapeseed mustard has been cultivated globally over an area of 43.5 million hectares with production and productivity of around 91.8 million tons and 2.1 ton/hectare, respectively (FAOSTAT, 2025). India has been a major producer, exporter and importer of rapeseed-mustard at international level (Barik, 2023). In India, rapeseed-mustard occupies a prominent place in edible oilseed value chain after groundnut with cultivation over an area of 8.9 million hectares (FAOSTAT, 2025). The production and productivity for rapeseed and mustard in India stands at 12.6 million tons and 1.43 ton/hectare, respectively (FAOSTAT, 2025). Rapeseed-mustard has been primarily cultivated over an area of Rajasthan, Uttar Pradesh, Haryana, Madhya Pradesh, Gujarat and West Bengal (Kumar and Dhillon, 2023). Rapeseed-mustard is cultivated primarily in winter season as a sole or intercrop.

Tropical countries like India have been highly vulnerable to the issue of climate change with rising temperatures and abnormalities in rainfall driven crop water supply (Mrabet et al. 2022; Bharti et al. 2024). Climate change alters water resources affects crop productivity by as wider extent with more frequent droughts and unfavorable climatic conditions (Rana et al. 2014; Rana et al. 2016; Mrabet et al. 2023). To cope up with the issue of climate change, altering sowing windows can be prominent agronomic intervention influencing the climate to which crop is exposed at various stages (Chandel et al. 2023; Pareek et al. 2023). Varying sowing windows have been advocated to influence crop productivity by a significant manner (Chandel et al. 2022; Thakur et al. 2024). Apart from sowing windows, optimizing irrigation schedules can help crops avoid vulnerability to erratic events of rainfall and meet out water requirement efficiency with substantial productivity (Pareek et al. 2021; Mrabet et al. 2023; Kumar et al. 2024). In a field investigation, Salaria and his co-workers in 2024 advocated that altering sowing windows significant influence crop productivity wherein maximized wheat productivity was observed when crop was sown on 15th October (Salaria et al. 2024a and 2024b). Similarly, Devi et al. 2024 evaluated various sowing windows for their effect over maize productivity wherein sowing the maize crop by 10th June resulted in the highest maize yield levels (Devi et al. 2024). Therefore, the field study was conducted to study the effect of sowing windows and irrigation schedules on mustard growth and productivity under north-western conditions of Himachal Pradesh.

**2. Material and Methods**

The present field investigation was conducted at Research Farm, Department of Agronomy, Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur. The experimental site is situated at 32°06′39.1″ N latitude and 76°32′10.5″ E longitude, at an elevation of 1290 meters above mean sea level in the north-western Himalayas in Kangra district. The experimental site can be characterized agro-climatically with mild summers, severe winters and high rainfall. For the *rabi* cropping season of 2023, the minimum and maximum temperature varied from 2.7 to 11.3°C and 13.7 to 25.9 °C, respectively. Relative humidity varied between 48.0 to 81.7 % during the crop growth period.

The soil at the experimental site was analyzed before sowing of crops. It was observed that the soil at the experimental site was silty clay loam with an acidic pH of 5.6 and soil organic carbon content of 0.60%, whereas the available nitrogen, phosphorus, and potassium content were 273.7 kg ha⁻¹, 24.5 kg ha⁻¹, and 215.2 kg ha⁻¹, respectively.

The present field investigation was conducted in a randomized block design (RBD) with factorial arrangement involving combinations of two dates of sowing and four irrigation regimes, with three replications for each. Two sowing dates involves: First Sowing Date i.e. 42nd SMW (Standard Meteorological Week); Second Sowing Date i.e. 44th SMW (Standard Meteorological Week) and four irrigation regimes included were limited irrigations (2 Irrigations), irrigation scheduling based on Penman Monteith modified, three irrigations, four irrigations. The Trombay Him Palam Mustard-1 variety of mustard was sown with a seed rate of 5 kg/ha and row to plant spacing of 30 x 10 cm, respectively. The mustard variety was sown with all recommended agronomic practices, except the sowing windows and irrigation treatments which were changed as per the experimental design to study their influence on growth and productivity of mustard.

Data on various growth, yield parameters were recorded. The plant height, number of branches per plant, number of siliqua per plant and number of seeds per plant were measured using five randomly tagged plants from net plot area. Test weight is measured by weighing 1000 seed weight manually. Seed and stover yield were calculated from the net plot area wherein entire biomass was harvested, followed by sun drying and threshing. The entire seed and stover yield were converted into q/ha. The recorded data was analyzed using Gomez and Gomez, 1984 based standard protocols for factorial randomized block design (Gomez and Gomez, 1984).

**3. Results and Discussion**

**Growth attributes**

The sowing windows and irrigation schedules significantly affected the mustard plant height, leaf area index and number leaves at different observational stages (Table 1 and 2). Irrigation scheduling based on Penman Monteith modified method resulted in the highest plant height, leaf area index and number of leaves whereas the lowest corresponding values were observed for the limited irrigation regime. Among sowing windows, crop sown on 20th October resulted in the highest plant height, leaf area index and number of leaves at various observational stages whereas delayed sowing of the crop on 4th November lead to the significantly lower plant height, leaf area index and number of leaves. Timely sowing of mustard may have ensured optimal thermal conditions allowing for significantly improved cell division and elongation leading to enhanced plant height of mustard crop (Akhatar et al., 2025). Similarly, optimized photothermal regimes may have elevated meristematic activity leading to increased number of leaves for mustard crop (Wu et al., 2024; Abhimanyu et al. 2025). Contrary to this, delayed sowing may have curtailed the number of growing degree days available for leaf expansion and optimized canopy establishment, resulting to reduced leaf area index and sub-optimal light interception (Abhimanyu et al. 2025).

In a similar field investigation, Kumar and Dhillon in 2023 reported significant effects of sowing windows on mustard plant height with highest plant height for mustard crop sown on 10th October. Similarly, they reported that irrigation schedules substantially influenced mustard yield wherein irrigating mustard crop with 3 irrigations at branching, flowering and siliqua formation resulted in the highest plant height (Kumar and Dhillon, 2023).

**Table 1. Effect of sowing windows and irrigation schedules on plant height and leaf area index of mustard**

|  |  |  |
| --- | --- | --- |
| **Treatment** | **Plant height (cm)** | **Leaf area index** |
| 30 DAS | 60 DAS | 90 DAS | 120 DAS | 150 DAS | At harvest | 30 DAS | 60 DAS | 90 DAS | 120 DAS | 150 DAS |
| **Date of sowing** |
| 20th October | 8.7 | 33.2 | 121.8 | 141.0 | 143.2 | 145.7 |  0.39 | 1.70 |  2.52  | 3.77 | 1.81 |
| 4th November | 8.5 | 31.3 | 119.3 | 139.5 | 141.5 | 143.6 | 0.38 | 1.61 |  2.40 | 3.62 | 1.72 |
| SE(m)± | 0.1 | 0.4 | 0.6 | 0.6 | 0.6 | 0.6 | 0.01 | 0.02 | 0.03 | 0.04 | 0.02 |
| CD (p=0.05) | NS | 1.3 | 1.8 | 1.8 | 1.8 | 1.9 | NS | 0.05 |  0.08 | 0.12 | 0.06 |
| **Irrigation scheduling based on ET Method** |
| Limited irrigation two) | 8.4 | 30.7 | 118.5 | 137.7 | 139.3 | 141.8 |  0.37 | 1.56 | 2.28 | 3.50 | 1.63 |
| Irrigation scheduling (Penman Monteith modified) | 8.7 | 33.6 | 122.2 | 141.1 | 144.7 | 146.4 | 0.40  |  1.72 | 2.56 | 3.80 | 1.84 |
| Three irrigations | 8.6 | 32.1 | 120.3 | 139.2 | 142.8 | 144.9 | 0.39 |  1.67  |  2.48 |  3.70 |  1.78 |
| Four irrigations | 8.7 | 32.8 | 121.0 | 139.8 | 143.2 | 145.5 | 0.40  | 1.68 |  2.51 | 3.76 | 1.80 |
| SE(m)± | 0.1 | 0.5 | 0.7 | 0.7 | 0.7 | 0.7 | 0.01 | 0.02 |  0.03 | 0.04 | 0.02 |
| CD (p=0.05) | NS | 1.6 | 2.0 | 2.0 | 2.1 | 2.2 | NS | 0.06 |  0.09 | 0.13 | 0.06 |

**Table 2. Effect of sowing windows and irrigation schedules on number of leaves**

|  |  |  |
| --- | --- | --- |
| **Treatment** | **Number of leaves at flowering** | **Number of leaves at Harvesting** |
| **Date of sowing** |
| 20th October | 34.0 | 3.3 |
| 4th November | 31.3  | 3.0 |
| SE(m)± | 0.6 | 0.1 |
| CD (p=0.05) | 1.9 | 0.2 |
| **Irrigation scheduling based on ET Method** |
| Limited irrigation (two) |  29.5 |  2.9 |
| Irrigation scheduling based on Penman Monteith modified | 34.6 | 3.4 |
| Three irrigations | 32.7 | 3.2 |
| Four irrigations | 33.7 | 3.3 |
| SE(m)± |  0.7 | 0.1 |
| CD (p=0.05) | 2.2  | 0.2 |

**Yield attributes**

The sowing windows and irrigation schedules significantly affected the number of siliquae per plant, seeds per siliqua and test weight for mustard crop (Table 3). Substantially higher number of siliquae per plant (230.7), seeds per siliqua (13.7) and test weight (4.5 g) was recorded for the irrigation schedule based on Penman Monteith modified method, whereas limited irrigation regime following only 2 irrigation applications resulted in considerable reduction in number of siliquae per plant (217.0), seeds per siliqua (12.8) and test weight (3.9 g) for the mustard crop. For sowing dates, crop sown on 20th October resulted in the highest the number of siliquae per plant (234.6), seeds per siliqua (13.5) and test weight (4.4) for mustard crop whereas delayed sowing i.e., by 4th November led to substantial reduction in mustard yield attributes i.e., number of siliquae per plant (225.1), seeds per siliqua (12.9) and test weight (4.1 g).

Significant effects of sowing windows and irrigation schedules was reported on number of siliquae per plant and seeds per siliqua for mustard during a field investigation conducted by Kumar and Dhillon in 2023. They reported that sowing crop on 20th October and irrigating mustard crop with 3 irrigations at branching, flowering and siliqua formation resulted in the highest number of siliqua per plant and seeds per siliqua at harvest (Kumar and Dhillon, 2023).

**Yield levels**

The sowing windows and irrigation schedules significantly affected the seed and stover yield for mustard crop (Table 3). Substantially higher seed (10.52 q/ha) and stover yield (31.02 q/ha) was recorded for the irrigation schedule based on Penman Monteith modified method, whereas limited irrigation regime following only 2 irrigation applications resulted in considerable reduction in seed (9.45 q/ha) and stover yield (28.92 q/ha) for the mustard crop. Among sowing windows, crop sown on 20th October resulted in the highest seed (10.35 q/ha) and stover yield (30.72 q/ha) whereas delayed sowing of the crop i.e., on 4th November lead to the significantly reduced seed (9.66 q/ha) and stover yield (29.78 q/ha) for mustard crop. Increments in seed and stover yield of mustard crop with optimized sowing windows and irrigation schedules was also reported by Kumar and Dhillon in 2023. Substantial increase in seed and stover yield levels for mustard crop cultivated under irrigation schedule based on Penman Monteith modified method and crop sowing by 20th October can be attributed to corresponding positive significant response for growth attributes such as plant height, number of leaves, leaf area index and yield attributes such as number of siliquae per plant, seeds per siliqua and test weight for the mustard crop. Among growth parameters especially, higher number of leaves and leaf area index may have improved crop’s photosynthetic potential with increased leaf expansion, better canopy establishment, and improved leaf orientation.

No significant interactions were reported for sowing windows and irrigation schedules in terms of mustard seed and stover yield. Similarly, no significant effects were reported for sowing windows and irrigation schedules on harvest index of mustard crop.

**Table 3. Effect of sowing windows and irrigation schedules on yield attributes and yield levels of mustard crop**

|  |  |  |
| --- | --- | --- |
| **Treatment** | **Yield attributes** | **Yield levels** |
| **Number of Siliquae/plant** | **Number of seeds/siliqua** | **Test weight (g)** | **Seed yield (q/ha)** | **Stover yield (q/ha)** | **Harvest Index (%)** |
| **Date of sowing** |
| 20th October |  234.6  | 13.5  | 4.4 | 10.35 | 30.72 | 25.23 |
| 4th November | 225.1 | 12.9 | 4.1 | 9.66 | 29.78 | 24.59 |
| SE(m)± | 2.4 | 0.2 | 0.1 | 0.10 | 0.24 | 0.25 |
| CD (p=0.05) | 7.3 | 0.4 | 0.2 | 0.30 | 0.73 | NS |
| **Irrigation scheduling based on ET Method** |
| Limited irrigation (two) | 217.0 | 12.8 | 3.9 | 9.45 | 28.92 | 24.63 |
| Irrigation scheduling based on Penman Monteith modified | 230.7 | 13.7 | 4.5 | 10.52 | 31.02 | 25.31 |
| Three irrigations | 222.5 | 13.3 | 4.2 | 10.00 | 30.33 | 24.81 |
| Four irrigations | 225.7 | 13.5 | 4.3 | 10.23 | 30.72 | 24.98 |
| SE(m)± | 2.8 | 0.2 | 0.2 | 0.11 | 0.28 | 0.29 |
| CD (p=0.05) | 8.4 | 0.6 | 0.5 | 0.34 | 0.85 | NS |

**4. Conclusion**

Based on the present field investigation, it can be concluded that sowing the mustard crop by 20th October can result in optimized yield levels under conditions of north-western Himalayas of Himachal Pradesh. Similarly, Penman Monteith modified method-based irrigation schedule can be considered to the best for improved yield levels of mustard crop. Therefore, crop sowing on 20th October and Penman Monteith modified method-based irrigation schedule can be recommended for mustard crop sowing under north-western conditions of Himachal Pradesh.

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