**Impact of Sowing Dates and Weed Management Strategies on Wheat (*Triticum aestivum* L.) Growth in Northern India**

**Abstract:**

Wheat (*Triticum aestivum* L.) is a globally important grain crop, particularly in India. It is the second largest wheat producer after China, accounting for over 13.5% of world production. Wheat faces challenges including heat stress, weed competition, and diseases, with climate change threatening productivity, especially during grain filling. A study was conducted at Pilikothi Farm, T. D. P. G. College, Jaunpur, Uttar Pradesh, India during *Rabi* seasons 2018-19 and 2019-20. The experiment used a split-plot design with three replications. Main plot treatments included three sowing dates: November 15 (D1), 30 (D2), and December 15 (D3). Sub-plot treatments comprised six weed management practices: weedy check (W1), weed-free (W2), 2,4-DEE at 0.5 kg a.i./ha (W3), Carfentrazone at 0.025 kg a.i./ha (W4), Metsulfuron methyl at 0.004 kg a.i./ha (W5), and Arylex 20.85% + Florasulam 20% (W6). Wheat variety HD 2967 was planted using a seed drill at 100 kg ha-1. Field preparation involved tilling twice, followed by planking. Irrigation was performed as needed. Sowing dates and weed control methods significantly affected dry matter accumulation, crop growth rate (CGR), and relative growth rate (RGR) in wheat. Earlier sowing (November 15) led to higher dry matter accumulation. Hand weeding was most effective, with chemical methods outperforming the weedy check. Arylex 20.85% + Florasulam 20% (W6) was the most effective chemical treatment. CGR was highest for the earliest sowing date across all growth stages. The weed-free treatment showed the highest CGR, while the weedy check had the lowest. W6 and Carfentrazon performed best among chemical treatments. RGR showed no significant differences among sowing dates during early growth stages, but was highest for the earliest sowing date in the final stage (90 DAS-Harvest). Weed control measures had the most pronounced effect on RGR during the final stage. These findings emphasize the importance of early sowing and effective weed management for optimizing wheat growth and productivity, particularly when combining early sowing with appropriate chemical weed control measures, such as W6. The study demonstrates that early sowing dates and effective weed control measures, especially hand weeding and certain chemical herbicides like Arylex 20.85% + Florasulam 20%, significantly enhance dry matter accumulation, crop growth rate, and relative growth rate in wheat crops.

Keywords: - Wheat production, Sowing dates, Herbicides, RGR, CGR

**1. Introduction:**

Wheat (*Triticum aestivum* L.) is a globally significant grain crop that is particularly important in India. The country produced approximately 96.16 million tonnes of wheat from 30.33 million hectares, achieving an average yield of 3171 kg ha-1 (DES, 2020). Uttar Pradesh, a major wheat-producing state, contributed 32.59 million tonnes from 9.50 million hectares (DES, 2020). Globally, India is the second-largest wheat producer after China, accounting for over 13.5% of the world's wheat production (FAO, 2021). Globally, wheat production encounters various obstacles, including both biotic and abiotic factors that substantially affect crop yields. Heat stress is a significant issue affecting as much as 57% of wheat-growing regions in developing nations (Kosina *et al*., 2007). Additional crucial challenges include weed competition and disease, each affecting up to 55% of the wheat-cultivated area (Kosina *et al*., 2007). Climate change and elevated temperatures pose considerable threats to wheat productivity, particularly during the grain-filling phase, at the time of the growing cycle (Newport *et al*., 2020). Increasing temperatures result in yield reductions, notably in eastern and central India (Chatrath *et al*. 2007). The Indo-Gangetic Plains have heightened heat stress, diminished irrigation water resources, and climate-related vulnerabilities (Dhanda et al., 2022).

The selection of wheat planting dates significantly influences wheat production, affecting various aspects of crop growth, development, and yield formation. Studies have demonstrated that grain yield exhibits high sensitivity to planting date, with research indicating a 0.97 ± 0.22% yield reduction for each day that deviates from the optimal planting period (Liu *et al*., 2023). Generally, delayed planting results in lower yields owing to abbreviated growth periods, adverse weather during critical developmental stages, and reduced biomass accumulation (Ahmed & Fayyaz-Ul-Hassan, 2015; Liu *et al*., 2021). Notably, late planting can occasionally enhance certain grain quality parameters such as protein and ash content, particularly under conditions of high temperature and water stress (Ahmed & Fayyaz-Ul-Hassan, 2015). However, this enhancement frequently occurs at the expense of an overall yield reduction. The timing of planting influences the crop's exposure to environmental factors throughout its growth cycle. Earlier planting typically provides exposure of the crop to light and temperature resources during pre-winter growth, whereas later planting may subject the crop to heat stress during grain filling (Dubey *et al*., 2019; Liu *et al*., 2023). These effects can be mitigated by adjusting planting dates to accommodate local climatic conditions and utilizing heat-tolerant varieties (Dubey *et al*., 2019; Kamara *et al*., 2021). In conclusion, optimizing planting date is crucial for maximizing wheat production and quality. The optimal planting window is determined by the local environmental conditions, varietal characteristics, and management practices. Agricultural practitioners and plant breeders should consider these factors to develop strategies that balance yield potential with environmental constraints and quality requirements.

Weed control is as critical as managing other aspects of wheat cultivation, as species such as small-seed canary grass can significantly reduce yields. The economic threshold for weed control is influenced by planting times, with mid-sown wheat requiring 6-7 plants/m2 and late-sown wheat necessitating 2.2-3.3 plants/m2 (Hussain *et al*., 2014). Effective weed management strategies encompass the utilization of competitive cultivars, increased seeding rates, and reduced row spacing, which have demonstrated efficacy in controlling weeds, such as rigid ryegrass (Paynter & Hills, 2009). Notably, increased crop density and uniform spacing could enhance weed suppression. In conclusion, optimizing planting dates and implementing effective weed control measures is essential for maximizing wheat production. Agricultural practitioners should consider local climate conditions, weed pressure, and crop management practices when determining the most appropriate planting dates and weed control techniques for specific regions. In wheat cultivation, the management of weeds through herbicides is essential, as weed infestations constitute one of the most significant biological challenges to wheat crops. Depending on the weed species, population density, and environmental factors, weeds can result in crop yield reductions of up to 100% (Khan *et al*., 2024). Among the various weed control strategies, the application of chemical herbicides remains the most widely adopted method in wheat fields due to its high efficacy and reliability (Hussain *et al*., 2021).

**2. Materials and method:**

A study was conducted at the Pilikothi Farm of T. D. P. G. College, Jaunpur, U. P. during the *Rabi* seasons of 2018-19 and 2019-20. The experiment employed in a split-plot design, with three replications. The main plot treatments consisted of three sowing dates: D1: (November 15), D2: (November 30), and D3: (December 15). The sub-plot treatments encompassed six weed management practices: W1: (weedy check), W2: (weed free), W3: (2, 4 DEE at 0.5 kg a.i./ha), W4: (Carfentrazone at 0.025 kg a.i./ha), W5: (Metsulfuron methyl at 0.004 kg a.i./ha), and W6: (Arylex 20.85% + Florasulam 20%). The climate of Jaunpur district corresponds to the Northern Plain and Central Highlands, including the Aravalli range, characterized by a hot semi-arid eco-region 4.3 and a hot dry ecoregion 9.2. Temperatures range from approximately 4 °C (39 °F) to 44 °C (111 °F), with an average annual precipitation of 1,098 mm (43.2 in). The monsoon typically occurs from mid-June to early October, with 46 annual rain days, 31 of which are during the monsoon season. The district frequently experiences droughts and pest infestations. The experimental field consisted of a sandy clay loam soil. Fertilizers were applied at a rate of 150:60:40 kg N, P2O5, and K2O per hectare. The entire P2O5 and K2O doses were applied as a basal application, while N was distributed in three parts: half as basal and the remainder in two equal portions after the first and second irrigations. Irrigation was performed as required. The field preparation involved tilling twice, followed by planking. Seeding was performed using a seed drill machine after pre-sowing irrigation. The wheat variety HD 2967 was planted according to treatment specifications at a seed rate of 100 kg ha-1.

**3. Result:**

**3.1 Dry matter accumulation**

Table 1. presents data on dry matter accumulation, indicating that the timing of sowing and the methods of weed control significantly influenced dry matter accumulation at different observation stages. Generally, sowing earlier led to greater dry matter accumulation compared to later sowing dates. Hand weeding consistently resulted in the highest dry matter accumulation across all sowing dates and periods. Chemical weed control methods varied in effectiveness, typically outperforming the weedy check but not matching the results of hand weeding. The weedy checks consistently showed the lowest dry matter accumulation, underscoring the importance of weed management. In all treatments and sowing dates, dry matter accumulation increased over time. Wheat sown on November 15 recorded the highest dry matter accumulation at all observation stages compared to the other two sowing dates, November 30 and December 15. Among the chemical weed control options, Arylex 20.85% + Florasulam 20% (W6) achieved the highest dry matter at all observation stages, although it was statistically similar to carfentrazone @ 0.025 kg a.i./ha at 60 and 90 DAS and at harvest compared to the other treatments during both years of the study. At 30 DAS, all herbicidal weed control measures were statistically similar in the first year, while in the second year, W6 was comparable to treatments W3 and W4, followed by treatment W5.

**Table 1: Effect of date of sowing and weed control measures on dry matter accumulation (g m2) of wheat at various crop growth stages**

|  |  |
| --- | --- |
| **Treatments** | **dry matter accumulation (g m2)** |
| **30 DAS** | **60 DAS** | **90 DAS** | **At harvest** |
| **2018-19** | **2019-20** | **2018-19** | **2019-20** | **2018-19** | **2019-20** | **2018-19** | **2019-20** |
| **Main Plot: Sowing dates (3)** |
| **D1:** 1st date of sowing (15th Nov) | 77.16 | 79.11 | 270.06 | 276.11 | 1041.90 | 1053.40 | 1105.42 | 1127.21 |
| **D2:** 2nd date of sowing (30th Nov) | 73.21 | 74.90 | 257.14 | 264.31 | 981.93 | 1008.37 | 1055.37 | 1069.13 |
| **D3:** 3rd date of sowing (15th Dec) | 67.02 | 68.58 | 235.25 | 241.14 | 889.05 | 919.96 | 964.16 | 972.33 |
| SEm ± | 1.10 | 1.08 | 3.87 | 3.80 | 14.79 | 14.48 | 15.87 | 15.39 |
| CD (*p=0.05*) | 3.33 | 3.26 | 11.69 | 11.46 | 44.66 | 43.73 | 47.92 | 46.47 |
| **Sub Plot: Weed control measures (6)** |
| **W1:** Weedy check | 68.36 | 69.54 | 205.82 | 215.50 | 784.51 | 822.17 | 852.70 | 858.96 |
| **W2:** Weed free (Two hand weeding) | 81.43 | 83.48 | 284.80 | 289.89 | 1089.22 | 1105.95 | 1163.12 | 1182.16 |
| **W3:** 2,4 DEE @ 0.5 kg *a.i.*/ha Post-em (28 DAS) | 70.99 | 72.79 | 255.22 | 261.21 | 975.12 | 996.55 | 1045.22 | 1060.30 |
| **W4:** Carfentrazon @ 0.025 kg *a.i.*/ha Post-em (28 DAS) | 71.65 | 73.46 | 263.11 | 268.61 | 1005.54 | 1024.77 | 1076.15 | 1092.54 |
| **W5:** Metsulfuron-methyl @ 0.004 kg *a.i.*/ha Post-em (28 DAS) | 69.58 | 71.34 | 248.03 | 254.37 | 947.39 | 970.45 | 1016.82 | 1030.82 |
| **W6:** Arylex 20.85% + Florasulam 20 % Post-em (28 DAS) | 72.77 | 74.60 | 267.93 | 273.53 | 1024.14 | 1043.53 | 1095.86 | 1112.65 |
| SEm ± | 1.06 | 1.06 | 3.70 | 3.68 | 14.15 | 14.05 | 15.18 | 14.93 |
| CD (*p=0.05*) | 3.19 | 3.19 | 11.18 | 11.12 | 42.72 | 42.44 | 45.83 | 45.10 |

**3.2 Crop Growth Rate**

The table presents data on Crop Growth Rate (CGR) measured in grams per square meter per day (g m2 day-1) for three different sowing dates across two growing seasons (2018-19 and 2019-20). The CGR was measured at three growth stages: 30-60 days after sowing (DAS), 60-90 DAS, and 90 DAS to harvest. The results indicate that earlier sowing dates (D1: 15th Nov) consistently yielded higher CGR values compared to later sowing dates (D2: 30th Nov and D3: 15th Dec) across all growth stages and both seasons. The differences in CGR between sowing dates were statistically significant, as evidenced by the standard error of mean (SEm ±) and critical difference (CD) values provided. The most substantial differences in CGR were observed during the 60-90 DAS period, with values ranging from 21.79 to 25.73 g m2 day-1 in 2018-19 and 22.63 to 25.91 g m2 day-1 in 2019-20. These findings suggest that early sowing has a positive impact on crop growth rate in the studied crop.

The weed control measures had a significant impact on the Crop Growth Rate (CGR) of the crop across both growing seasons. The weed-free treatment (W2) consistently showed the highest CGR values across all growth stages, demonstrating the importance of effective weed management. In contrast, the weedy check (W1) exhibited the lowest CGR, highlighting the detrimental effects of weed competition on crop growth. Among the chemical weed control measures, Arylex 20.85% + Florasulam 20% (W6) and Carfentrazon (W4) performed well, with CGR values close to those of the weed-free treatment. The 2,4-DEE (W3) and Metsulfuron-methyl (W5) treatments also showed improved CGR compared to the weedy check, but were slightly less effective than W6 and W4. These results underscore the importance of selecting appropriate weed control measures to optimize crop growth and productivity.

**Table 2: Effect of date of sowing and weed control measures on crop growth rate (CGR) of wheat at various crop growth stages**

|  |  |
| --- | --- |
| **Treatments** | **Crop Growth Rate (g m2 day-1)** |
| **30-60 DAS** | **60-90 DAS** | **90 DAS-Harvest** |
| **2018-19** | **2019-20** | **2018-19** | **2019-20** | **2018-19** | **2019-20** |
| **Main Plot: Sowing dates (3)** |
| **D1:** 1st date of sowing (15th Nov) | 6.43 | 6.57 | 25.73 | 25.91 | 2.50 | 2.46 |
| **D2:** 2nd date of sowing (30th Nov) | 6.13 | 6.31 | 24.16 | 24.80 | 2.45 | 2.03 |
| **D3:** 3rd date of sowing (15th Dec) | 5.61 | 5.75 | 21.79 | 22.63 | 2.12 | 1.75 |
| SEm ± | 0.09 | 0.09 | 0.36 | 0.36 | 0.04 | 0.03 |
| CD (*p=0.05*) | 0.28 | 0.27 | 1.10 | 1.08 | 0.12 | 0.10 |
| **Sub Plot: Weed control measures (6)** |
| **W1:** Weedy check | 4.58 | 4.87 | 19.29 | 20.22 | 2.27 | 1.23 |
| **W2:** Weed free (Two hand weeding) | 6.78 | 6.88 | 26.81 | 27.20 | 2.46 | 2.54 |
| **W3:** 2,4 DEE @ 0.5 kg *a.i.*/ha Post-em (28 DAS) | 6.14 | 6.28 | 24.00 | 24.51 | 2.34 | 2.13 |
| **W4:** Carfentrazon @ 0.025 kg *a.i.*/ha Post-em (28 DAS) | 6.38 | 6.50 | 24.75 | 25.21 | 2.35 | 2.26 |
| **W5:** Metsulfuron-methyl @ 0.004 kg *a.i.*/ha Post-em (28 DAS) | 5.95 | 6.10 | 23.31 | 23.87 | 2.31 | 2.01 |
| **W6:** Arylex 20.85% + Florasulam 20 % Post-em (28 DAS) | 6.51 | 6.63 | 25.21 | 25.67 | 2.39 | 2.30 |
| SEm ± | 0.09 | 0.09 | 0.35 | 0.34 | 0.04 | 0.03 |
| CD (*p=0.05*) | 0.27 | 0.26 | 1.05 | 1.03 | 0.11 | 0.10 |

**3.3 Relative Growth Rate**

The relative growth rate (RGR) of the crop was influenced by different sowing dates across various growth stages. During the initial growth period (30-60 DAS), no significant differences in RGR were observed among the three sowing dates in both years. Similarly, during the 60-90 DAS period, RGR remained statistically similar across sowing dates. However, during the final growth stage (90 DAS-Harvest), significant differences emerged. The earliest sowing date (15th November) consistently showed the highest RGR in both years (0.0027 and 0.0023 g g-1 day-1), followed by the second sowing date (30th November), while the latest sowing (15th December) resulted in the lowest RGR. This trend suggests that earlier sowing dates may provide more favourable conditions for crop growth during the later stages of development, potentially due to better utilization of environmental resources.

The implementation of weed control measures significantly influenced the Relative Growth Rate (RGR) of the crop across different growth stages and sowing dates. During the initial growth period (30-60 DAS), the RGR showed minimal variation among different sowing dates, ranging from 0.0418 to 0.0419 g g-1 day-1 in 2018-19 and 0.0417 to 0.0420 g g-1 day-1 in 2019-20. However, as the crop progressed to the 60-90 DAS stage, a slight increase in RGR was observed, with values ranging from 0.0443 to 0.0450 g g-1 day-1 in 2018-19 and consistently at 0.0446 g g-1 day-1 in 2019-20 across all sowing dates. The most pronounced effect of weed control measures on RGR was evident during the final growth stage (90 DAS-Harvest), where a significant decline in RGR was observed. The earliest sowing date (15th Nov) maintained the highest RGR of 0.0027 and 0.0023 g g-1 day-1 in 2018-19 and 2019-20, respectively, while the latest sowing date (15th Dec) showed the lowest RGR of 0.0020 and 0.0018 g g-1 day-1 for the respective years. These findings suggest that effective weed control measures, particularly when combined with earlier sowing dates, can positively influence the crop's RGR, especially during the critical later stages of growth.

**Table 3 : Effect of date of sowing and weed control measures on Relative Growth Rate (RGR) of wheat at various crop growth stages**

|  |  |
| --- | --- |
| **Treatments** | **Relative Growth Rate (g g-1 day-1)** |
| **30-60 DAS** | **60-90 DAS** | **90 DAS-Harvest** |
| **2018-19** | **2019-20** | **2018-19** | **2019-20** | **2018-19** | **2019-20** |
| **Main Plot: Sowing dates (3)** |
| **D1:** 1st date of sowing (15th Nov) | 0.0418 | 0.0417 | 0.0450 | 0.0446 | 0.0027 | 0.0023 |
| **D2:** 2nd date of sowing (30th Nov) | 0.0419 | 0.0420 | 0.0447 | 0.0446 | 0.0024 | 0.0020 |
| **D3:** 3rd date of sowing (15th Dec) | 0.0419 | 0.0419 | 0.0443 | 0.0446 | 0.0020 | 0.0018 |
| SEm ± | 0.00070 | 0.00070 | 0.00074 | 0.00074 | 0.00004 | 0.00003 |
| CD (*p=0.05*) | NS | NS | NS | NS | 0.0001 | 0.0001 |
| **Sub Plot: Weed control measures (6)** |
| **W1:** Weedy check | 0.0367 | 0.0377 | 0.0442 | 0.0441 | 0.0021 | 0.0015 |
| **W2:** Weed free (Two hand weeding) | 0.0417 | 0.0415 | 0.0447 | 0.0446 | 0.0022 | 0.0022 |
| **W3:** 2,4 DEE @ 0.5 kg *a.i.*/ha Post-em (28 DAS) | 0.0427 | 0.0426 | 0.0447 | 0.0446 | 0.0023 | 0.0021 |
| **W4:** Carfentrazon @ 0.025 kg *a.i.*/ha Post-em (28 DAS) | 0.0434 | 0.0432 | 0.0447 | 0.0446 | 0.0023 | 0.0021 |
| **W5:** Metsulfuron-methyl @ 0.004 kg *a.i.*/ha Post-em (28 DAS) | 0.0424 | 0.0424 | 0.0447 | 0.0446 | 0.0024 | 0.0020 |
| **W6:** Arylex 20.85% + Florasulam 20 % Post-em (28 DAS) | 0.0434 | 0.0433 | 0.0447 | 0.0446 | 0.0032 | 0.0025 |
| SEm ± | 0.00070 | 0.00070 | 0.00074 | 0.00074 | 0.00004 | 0.00003 |
| CD (*p=0.05*) | 0.0021 | 0.0021 | NS | NS | 0.0001 | 0.0001 |

**4. Discussion:**

Different sowing dates significantly affect dry matter accumulation in wheat at various growth stages, with implications for overall crop performance and yield. Early sowing generally leads to increased dry matter accumulation before silking, while late sowing results in higher accumulation after silking (Cirilo & Andrade, 1994). This shift in dry matter partitioning can have substantial effects on grain yield. Delayed sowing tends to decrease cumulative incident radiation during the vegetative period, but may increase crop growth rate due to higher radiation use efficiency and percent radiation interception (Cirilo & Andrade, 1994). However, late sowings often decrease crop growth rate during grain filling, negatively impacting kernel weight and number (Cirilo & Andrade, 1994; Liu et al., 2021). Interestingly, the effects of sowing date on dry matter accumulation can vary depending on latitude and environmental conditions. At higher latitudes, delayed sowing leads to decreased effective accumulated temperature and solar radiation, resulting in reduced dry matter accumulation (Zhang et al., 2022). The relationship between sowing date and dry matter accumulation is not always linear, as some studies have found that yield and dry matter initially increase with delayed sowing before declining (Zhou et al., 2016). In conclusion, optimal sowing dates for maximizing dry matter accumulation and yield depend on various factors, including local climate, latitude, and cultivar characteristics. Understanding these relationships is crucial for developing effective crop management strategies to optimize wheat production under different environmental conditions (Dubey et al., 2019; Liu et al., 2021).

Herbicidal weed management can significantly impact the dry matter accumulation of wheat crops through various mechanisms: Effective weed control using herbicides can enhance wheat biomass production by reducing competition for resources. By eliminating weeds, herbicides allow wheat plants to access more nutrients, water, and light, leading to increased dry matter accumulation. However, the timing and method of herbicide application can influence its effectiveness and impact on wheat growth. Post-emergence herbicide applications have been found to be generally more effective than pre-emergence applications in controlling weeds, regardless of tillage intensity **(Streit et al., 2003)**. This suggests that proper timing of herbicide application can optimize weed control and potentially enhance wheat dry matter accumulation. Broad-leaved weed herbicides can significantly impact dry matter accumulation in wheat crops, primarily through their effects on weed control and crop-weed competition. The application of broad-leaved weed herbicides can lead to reduced weed biomass, which in turn allows for increased dry matter accumulation in wheat. For instance, (Gerhards & Oebel, 2006) reports that herbicide use against broad-leaved weeds in winter cereals resulted in reductions of 6-81% in herbicide application, while maintaining weed control efficacy between 85% and 98%. This high level of weed control suggests that the wheat crop would face less competition for resources, potentially leading to increased dry matter accumulation. Interestingly, the timing of herbicide application can play a crucial role in its effectiveness and impact on wheat dry matter accumulation. (Carey & Kells, 1995) indicates that when postemergence herbicide applications were made to weeds 10 cm or less in height, weed interference did not reduce corn height or grain yield. However, when applications were delayed until weeds were 15 cm tall or higher, corn height and grain yield were reduced even with nearly complete weed control. This suggests that early herbicide application is critical for maximizing crop dry matter accumulation. In conclusion, while broad-leaved weed herbicides can effectively control weeds and potentially increase wheat dry matter accumulation, factors such as application timing, weed density, and environmental conditions play significant roles in determining the overall impact on the wheat crop. Proper management of these factors is crucial for optimizing the benefits of herbicide use on wheat dry matter accumulation.

**5. Conclusion:**

In conclusion, this study highlights the critical importance of optimal sowing dates and effective weed management strategies in maximizing wheat productivity. Early sowing consistently resulted in higher dry matter accumulation and improved crop growth rates, particularly during the later stages of development. The weed-free treatment demonstrated the highest crop growth rates across all stages, underscoring the significant impact of weed competition on wheat performance. Among chemical weed control measures, Arylex 20.85% + Florasulam 20% and Carfentrazone showed promising results, approaching the effectiveness of hand weeding. These findings emphasize the need for integrated approaches that combine timely sowing with appropriate weed control methods to optimize wheat yields. Future research should focus on refining these strategies to address specific environmental conditions and cultivar characteristics, ultimately enhancing wheat production in diverse agricultural settings.

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