AGRICULTURE ARCHIVES

OPEN ACCESS

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Original Research Article
ISSN: 3041-5322
Journal homepage: agriculture.researchfloor.org

Influence of Sowing Date and Cultivar on Growth and Yield Performance of Wheat (*Triticum Aestivum* L.) in the Sahel Savanna, Nigeria

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ABSTRACT

Optimising sowing date and variety selection is critical for enhancing wheat productivity under changing climatic conditions. A two-year field study (2022-2023) was conducted to investigate the interaction effects of sowing dates, varieties, and seasons on phenology, yield components, and grain yield of wheat. The treatments comprised six sowing dates (25th October, 5th November, 15th November, 1st December, 15th December, and 1st January) with two varieties (Borlaug and Norman) across two seasons. Results revealed significant effects of sowing date × variety and sowing date × season interactions on 50% flowering, 1000-grain weight, spikes per m^2, and grain yield. Borlaug sown on 15th November consistently produced the heaviest grains (54.08 g), the highest spike density (430.8 spikes/m^2), and maximum grain yield (34,644 kg ha^{-1} in 2023), followed by Borlaug on 5th November and 15th December. Norman exhibited inferior performance under late sowing (1st January), recording the lowest 1000-grain weight (30.33 g) and yield (1630 kg ha^{-1}). Grain yield declined significantly with delayed planting, primarily due to reductions in spike density, grains per spike, and 1000-grain weight. The findings emphasise that mid-November sowing, particularly with Borlaug, exploits favourable temperature and radiation regimes, ensuring optimal vegetative growth, assimilate partitioning, and yield formation. These results corroborate earlier reports highlighting mid-November sowing as the optimum planting window for wheat in similar agro-ecologies.

Keywords: *Climate resilience, Grain yield, Phenology, Sowing date optimisation, Varietal performance, Wheat.*

1.0 INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the most important cereal crops globally, providing nearly 20% of the calories and protein consumed by humans and ranking second only to maize in total production, with more than 770 million tonnes harvested annually [19]. Wheat is utilised in diverse forms, including bread, pasta, noodles, biscuits, and starch, while its milling by-products, such as bran and middlings, serve as valuable livestock feed ingredients. This dual role in food and feed systems underscores wheat's contribution to global food and nutrition security [6][19]. Its adaptability to a wide range of environments has further established the crop as a central component of agricultural systems worldwide.

Despite its global prominence, wheat production in Sub-Saharan Africa remains low. Nigeria is among the largest wheat importers on the continent, with local production meeting less than 10% of annual demand. This widening supply gap is driven by rapid population growth, urbanisation, and dietary shifts, which continue to increase demand for wheat-based foods [36][32]. Domestic wheat cultivation is concentrated in the northern states, particularly in the Sahel Savanna zone, where ecological conditions permit seasonal production. However, yields in this region remain significantly below global averages due to poor agronomic practices, limited availability of improved cultivars, and environmental stressors.

A major emerging constraint to wheat production in Nigeria's Sahel Savanna is climate change. Rising temperatures, recurrent droughts, and increasing rainfall variability have already begun to undermine wheat productivity across semi-arid regions [38][7]. Heat stress, particularly during anthesis and grain filling stages, shortens growth duration, reduces grain weight, and limits yield potential. Projections suggest that without adaptive strategies, climate change could substantially reduce wheat yields in Sub-Saharan Africa [38]. The Sahel Savanna, characterised by high evapotranspiration and water scarcity, is especially vulnerable to these climatic risks.

Nigeria faces an urgent wheat production challenge, with domestic output falling short of national demand and heavy reliance on imports straining foreign exchange reserves. In the Sahel Savanna, where wheat cultivation is concentrated, productivity remains low due to suboptimal agronomic practices, inappropriate sowing times, and poor cultivar adaptation. Sowing too early or too late exposes wheat to terminal heat and moisture stress, while cultivars lacking adaptability to local agro-ecologies perform poorly under climatic extremes [17][31]. These challenges are further intensified by climate change, which has increased temperature extremes, rainfall irregularities, and drought frequencies in the region [38]. Optimising sowing windows and deploying climate-resilient cultivars therefore represent practical, low-cost strategies with the potential to stabilise yields and strengthen the competitiveness of wheat production in the Sahel.

Citation: Abdulrahman, A. B, Rabiu, R.T, Abdullahi, A.T, Samaila, A, and Shittu, E. A (2025). Influence of Sowing Date and Cultivar on Growth and Yield Performance of Wheat (*Triticum Aestivum* L.) in the Sahel Savanna, Nigeria.
Agriculture Archives: an International Journal.
DOI: https://doi.org/10.51470/AGRI.2025.4.3.39

Received on: October 05, 2025
Revised on: November 11, 2025
Accepted on: December 06, 2025

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Without clear scientific evidence on the most suitable sowing dates and variety choices, however, Nigeria risks continued reliance on imports and growing vulnerability to food insecurity.

This study is justified by the critical need to increase wheat productivity in Nigeria through evidence-based agronomic interventions. Optimising sowing dates and selecting well-adapted, heat-tolerant cultivars represent practical, cost-effective solutions to mitigate the negative impacts of climate variability on wheat production. Previous research in similar agro-ecologies has demonstrated that appropriate adjustment of sowing time and cultivar choice significantly improves yield stability under stress conditions [14][30]. By providing context-specific recommendations, this study will not only empower farmers in the Sahel Savanna to enhance productivity and resilience but also contribute to Nigeria's broader goal of reducing wheat import dependency and strengthening food security. The study was conceived with the aim of assessing the influence of different sowing dates on the growth performance, phenological development, yield, and yield components of selected wheat cultivars under Sahel Savanna conditions.

2.0 MATERIALS AND METHODS

2.1 Experimental Site

The field experiment was conducted at the Flour Milling Association of Nigeria Research Farm, Ringim Local Government Area, Jigawa State, Nigeria. The site lies within the Sahel Savanna agro-ecological zone, which is characterised by a semi-arid climate with distinct wet and dry seasons. The study was carried out over two consecutive cropping seasons: 2021-2022 and 2022-2023.

2.2 Soil Characteristics

Before sowing each season, composite soil samples were collected from the experimental plots at a depth of 0-30 cm. The samples were analysed for key physical and chemical properties, including soil texture, pH, organic carbon, total nitrogen, available phosphorus, and exchangeable potassium. These analyses provided a baseline for nutrient management and interpretation of crop performance.

2.3 Treatments and Experimental Design

The experiment was arranged as a 2 × 6 factorial in a Randomised Complete Block Design (RCBD) with three replications to account for field variability. Treatments included two wheat cultivars (Norman and Borlaug) and six sowing dates (October 25, November 5, November 15, December 1, December 15, and January 1). Each treatment combination was assigned to a plot measuring 5 m × 3 m, giving a total of 36 experimental units.

2.4 Crop Management

Land Preparation and Sowing

Experimental plots were thoroughly prepared by ploughing and harrowing to create a fine, uniform seedbed, ensuring good seed-to-soil contact for optimal seedling emergence. Wheat seeds were sown using a single-row hand drill at a rate of 100 kg/ha, with uniform planting depth and spacing maintained across plots.

2.5 Fertilizer Application

Nutrient management was based on soil test results and local recommendations for irrigated wheat in the Sahel.

Fertilizer was applied at a rate of 120 kg N, 40 kg P_2O_5, and 40 kg K_2O per hectare. At sowing, NPK (15:15:15) was applied as basal to supply 60 kg N, 40 kg P_2O_5, and 40 kg K_2O. The remaining 60 kg N was top-dressed at the tillering stage using urea.

2.6 Irrigation

Because of the arid environment, supplementary irrigation was essential. Furrow irrigation was used to maintain adequate soil moisture throughout the season. Irrigation scheduling was guided by tensiometer readings and crop water requirements, with particular attention to critical growth stages such as tillering, anthesis, and grain filling.

2.7 Weed Control

Weeds were managed through an integrated approach combining chemical and manual methods. Pendimethalin (1.0 kg a.i.ha^{-1}) was applied one day after sowing as a pre-emergence herbicide. Manual weeding was carried out 40 days after sowing to control late-emerging weeds.

2.8 Pest and Disease Management

Regular field scouting was conducted to monitor insect pests and diseases. When pest or disease incidence reached economic thresholds, appropriate control measures were promptly applied.

2.10 Harvesting

Wheat was manually harvested at physiological maturity, indicated by the yellowing of the flag leaf and peduncle, and grain hardening. Harvesting was performed uniformly across all plots to minimise variability.

2.11 Data Collection and Measurements

Throughout the experiment, data on agronomic and physiological parameters were collected following standard procedures. Phenological data included plant establishment, days to 50% heading, days to 50% flowering, and plant height. Yield components recorded were the number of spikes per square meter, number of grains per spike, spike length, and grain yield (kg/ha).

2.12 Statistical Analysis

All data were subjected to Analysis of Variance (ANOVA) using GenStat (17th edition). Where significant differences were detected ($P < 0.05$), treatment means were separated using the Student-Newman-Keuls (SNK) test.

3.0 RESULTS AND DISCUSSION

3.1 Soil characteristics

The soils at the experimental site across both seasons (2021/2022 and 2022/2023) were dominated by sand particles (61-63%), followed by silt (24-26%) and clay (13-14%). This classifies them as *loamy sand*, a texture typical of Sahelian soils (Table 1). Loamy sand soils are generally well-drained but have low water and nutrient retention, making them vulnerable to drought stress and nutrient leaching, which directly affects wheat productivity [9]. The pH in water (6.47-6.67) suggests slightly acidic soils, which are generally suitable for wheat growth. However, the much lower pH in $CaCl_2$ (4.15-4.22) indicates a tendency toward acidity in the soil's exchange complex, which could reduce nutrient availability, especially phosphorus and micronutrients [34] (Schut and Giller, 2020).

Soil organic carbon (8.70-9.51 g kg^{-1}) was relatively low, reflecting limited organic matter content. This aligns with the widespread issue of declining soil organic matter in Sahelian agroecosystems due to continuous cultivation and limited organic inputs [27]. Low organic carbon is directly linked to reduced soil fertility, poor structure, and low microbial activity.
Similarly, total nitrogen (1.10-1.15 g kg^{-1}) and available phosphorus (5.94-6.08 mg g^{-1}) were very low, confirming that the soils are nitrogen- and phosphorus-deficient. These deficiencies are well-documented as the major yield-limiting factors for cereals, including wheat, in semi-arid regions [11]. Exchangeable bases showed moderate calcium (2.76-3.61 c mol kg^{-1}) and magnesium (1.06-1.13 c mol kg^{-1}) but low potassium (0.10-0.11 c mol kg^{-1}). The cation exchange capacity (CEC) of 5.50-5.90 c mol kg^{-1} was also low, reflecting weak nutrient-holding capacity typical of coarse-textured soils [9].

Table 1: Physical and Chemical properties of the Soils of the Experimental site during 2021/2022 and 2022/2023

Properties	2021/2022	2022/2023
Physical (g kg^{-1})		
Sand	628	616
Silt	256	245
Clay	126	139
Textural class	Loamy sand	Loamy sand
Chemical composition		
pH in water	6.67	6.47
pH ($CaCl_2$)	4.15	4.22
Organic carbon (g kg^{-1})	9.51	8.70
Total Nitrogen (g kg^{-1})	1.15	1.10
Available Phosphorus (mg g^{-1})	6.08	5.94
Exchangeable bases (c mol kg^{-1})		
Mg^{++}	1.13	1.06
Ca^{++}	3.61	2.76
K^{+}	0.11	0.10
Na^{+}	0.13	0.15
Fe^{++}	0.19	0.16
Zn^{++}	3.86	3.79
B^{-}	3.43	3.41
CEC	5.90	5.50

Table 2 shows establishment percentage, Days to 50% flowering, Days to 50% heading and Days to maturity of wheat as influenced by sowing date, variety and season during 2022/2023 dry season. Results shows that sowing date significantly influenced establishment percentage, flowering, and heading, but not maturity. The highest establishment percentage was recorded with wheat sown on December 1st (153.4%), while the lowest was with January 1st sowing (126.2%). This indicates that delaying sowing into January exposes wheat to suboptimal germination conditions, likely due to higher soil temperatures and reduced moisture availability [18]. Similar findings have been reported in the Sahel and semi-arid regions, where delayed planting reduces stand establishment and subsequent yield potential [29].
For phenological traits, wheat sown on December 15th recorded the longest duration to flowering (68.92 days), while January 1st sowing flowered significantly earlier (62.75 days). This reduction in duration under late sowing reflects the heat stress-induced acceleration of phenological development, as crops adjust to complete their life cycle before terminal drought and high temperatures [21]. Heading followed a similar pattern, with significantly shorter durations in late sowing (57.25 days in January) compared to early November sowings (61-62 days).
Days to maturity were not significantly (P > 0.05) affected by sowing date, suggesting that while flowering and heading respond strongly to thermal regimes, final crop duration may be buffered by varietal adaptation and management practices.
However, the trend showed slightly longer maturity in October sowing (114.5 days) compared to January sowing (110.1 days), consistent with the thermal time accumulation theory [16].
Variety had a significant (P <0.001) effect on all phenological traits. Norman exhibited longer duration to 50% flowering (71.92 days), 50% heading (65.56 days), and maturity (119.67 days) compared to Borlaug (61.64, 54.92, and 104.42 days, respectively). These results suggest that Norman is a late-maturing genotype with a longer growth cycle, whereas Borlaug is early-maturing and thus better suited for environments prone to late-season heat stress. Longer phenological phases in Norman could allow for greater biomass accumulation, but under Sahelian heat stress, this may expose the crop to terminal drought, thereby reducing yield stability [12]. Interestingly, establishment percentage did not differ significantly between varieties, implying that genotypic differences were more expressed in growth duration than in emergence vigor. This aligns with the findings of [10] [35], who reported that wheat varietal responses in West Africa are mainly driven by thermal and photoperiod sensitivity.
There were no significant (P > 0.05) differences between seasons for flowering, heading, or maturity, although establishment percentage tended to be higher in 2023 (151.3%) than in 2022 (129.7%). The higher establishment in 2023 may reflect more favorable early-season soil moisture conditions. Seasonal variations in Sahelian climates are common, often influencing wheat establishment and yield stability [38].

Table 2: Establishment percentage, Days to 50% flowering, Days to 50% heading and Days to maturity of wheat as influenced by sowing date, variety and season during 2022 and 2023

Treatment	Establishment percentage (%)	Days to 50% flowering (#)	Days to50% Heading (#)	Days to Maturity (#)
Sowing date (SD)				
25th October	129.6bc	64.50c	59.17b	114.5
5th November	149.2ab	68.25ab	61.25a	111.8
15th November	146.7ab	67.67b	61.00a	112.4
1st December	153.4a	68.58ab	61.75a	111.9
15th December	137.8abc	68.92a	61.00a	111.6
1st January	126.2c	62.75d	57.25c	110.1
P of F	0.026	<.001	<.001	0.881
SE±	6.56	0.403	0.531	2.436
Variety (V)				
Borlaug	142.1	61.64b	54.92b	104.42b
Norman	138.9	71.92a	65.56a	119.67a
P of F	0.561	<.001	<.001	<.001
SE±	3.79	0.232	0.307	1.407
Year (Y)				
2022	129.7	66.03	60.25	110.11
2023	151.3	67.53	60.22	113.97
P of F	0.054	0.380	0.979	0.304
SE±	3.70	0.948	0.668	1.990
Interaction				
SD x V	0.147	0.004	0.542	0.798
SD x Y	0.142	0.247	0.972	0.632
V x Y	0.218	1.000	0.230	0.122
SD x V x Y	0.957	0.004	0.542	0.742

Means followed by the same letter(s) in the column within a treatment group are not significantly different at 5% level of probability using SNK

The interaction between sowing date and variety on days to 50% flowering was significant and shown in Table 3. Results revealed that Norman significantly (P <0.01) took more days to reach 50% flowering, particularly when sown from 5th November to 15th December, compared other interaction combinations. This indicates that Norman has a longer growth duration and stronger sensitivity to photoperiod and temperature, whereas Borlaug flowered earlier across all sowing windows, reflecting its shorter life cycle. The three-way interaction of SD × V × Y on days to 50% flowering (Table 3) further showed that seasonal variability slightly influenced flowering time, with crops in 2023 generally requiring more days to flower than in 2022. Such variation is linked to differences in temperature and rainfall distribution, which are known to regulate wheat phenology in semi-arid environments [12][38].

Norman's prolonged flowering under optimal sowing windows (mid-November to December) may enhance biomass accumulation and yield potential but increases its exposure to terminal heat and water stress if sowing is delayed. In contrast, Borlaug's early flowering makes it more suitable for flexible sowing, particularly under early or late planting, supporting yield stability under Sahelian climate variability [18][16].

Table 3: Sowing date x Variety interaction on Days to 50% flowering of wheat during 2022 and 2023 combined effect

Treatment	Variety	
	Borlaug	Norman
Sowing date		
25th October	60.17e	68.83b
5th November	62.50d	74.00a
15th November	62.33d	73.00a
1st December	62.83d	74.33a
15th December	63.17d	74.67a
1st January	58.83e	66.67c
SE±	0.569	

Means followed by the same letter are not significantly different at 5% level of probability using SNK

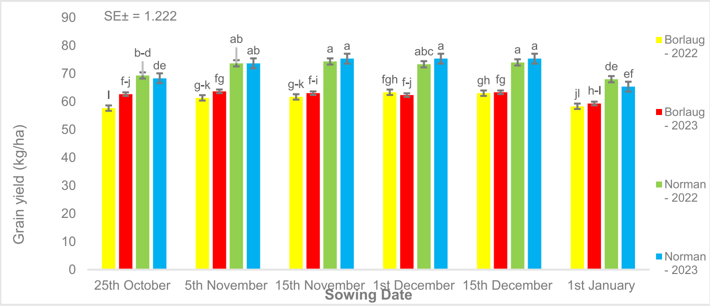

Figure 1: Sowing date x Variety x Year interaction on Days to 50% flowering of wheat during 2022 and 2023 seasons

Means followed by the same letter(s) are not significantly different at 5% level of probability using SNK

3.2 Plant height (cm)

Table 4 indicates that plant height was significantly ($P < 0.001$) influenced by sowing date and variety, but not by season. The tallest plants were recorded on 15th November, while 25th October and 1st January sowings produced the shortest. This suggests that mid-November planting provided optimum temperature and photoperiod conditions for vegetative growth. Norman consistently recorded taller plants than Borlaug, reflecting varietal differences in growth habit. These results agree with [8], who observed that optimum sowing windows enhance wheat stature, while delayed planting reduces growth due to terminal heat stress.

3.3 Number of spikes m^{-2}

The number of spikes per unit area differed significantly ($P < 0.001$) across sowing dates and varieties. 15th November planting produced the highest spike population, while both early (25th October) and late (1st January) sowings resulted in fewer spikes (Table 4). This reduction is likely due to suboptimal tillering temperatures and shortened vegetative phases in late sowing. Borlaug outperformed Norman in spike density, suggesting its superior tillering ability. These findings are consistent with [16], who reported that tiller survival and spike density are key yield determinants under optimal sowing windows.

3.4 Spike length (cm)

Spike length was also maximized under 15th November sowing, with reduced values under both early and late plantings (Table 4). The favorable thermal regime during this period likely prolonged assimilate partitioning to reproductive structures, increasing spike elongation. Norman exhibited longer spikes than Borlaug, reflecting inherent genetic potential. Similar findings were reported by [5] and corroborated by [3], were late sowing accelerated senescence, reducing spike development.

Number of seeds per spike

Sowing on 15th November significantly increased grain number per spike, while early and very late planting (25th October and 1st January) reduced this parameter (Table 3). Heat stress during anthesis in late planting likely impaired fertilization and kernel set. Interestingly, there was no significant varietal or seasonal effect, suggesting that spike fertility was more responsive to environmental conditions than genotype. Comparable outcomes were observed by [25] and further supported by [22], who noted that reproductive success in wheat is most sensitive to sowing date around flowering.

3.5 1000-grain weight (g)

Grain weight showed clear sowing date and variety effects. The 5th November sowing produced the heaviest grains, while 1st January planting had the lowest. The reduction in late sowing is attributable to the shortened grain-filling duration under elevated temperatures, reducing assimilate accumulation per kernel. Borlaug recorded slightly higher grain weight than Norman, highlighting genetic differences in assimilate translocation. These results align with [25] and confirm the more recent findings of [23], who emphasized the role of extended grain-filling period in achieving higher test weights.

3.6 Grain yield (kg ha^{-1})

The combined influence of growth and yield attributes culminated in maximum yield under 15th November sowing (12,013 kg ha^{-1}), followed by 5th November and 15th December. Early planting (25th October) and very late sowing (1st January) significantly reduced yield, mainly due to reduced spike density, kernel number, and grain weight. Borlaug significantly outyielded Norman, despite Norman's taller plants and longer spikes, suggesting Borlaug's advantage lies in higher spike density and heavier grains. These findings are consistent with [24] and reinforced by recent studies [13] [20], which confirm that yield gains under optimal sowing dates are linked to cumulative improvements in growth duration, assimilate partitioning, and grain-filling efficiency.

Table 4: Plant height, Number of spike m^{-2}, Spike length, Number of seeds per spike, 1000 seed weight and Grain yield of wheat as influenced by sowing date, variety and season during at 2022-2023 dry season

Treatment	Plant height (cm)	Number of spikes ms^{-2}	Spike length (cm)	Number of seeds $spike^{-1}$	1000 grain weight (g)	Grain yield (Kg ha^{-1})
Sowing date (SD)						
25th October	84.38c	244.5c	7.792c	90.2bc	35.12d	2166c
5th November	89.67ab	349.3b	8.833b	100.1b	51.33a	8261ab
15th November	90.71a	406.5a	9.833a	125.9a	41.92c	12013a
1st December	87.96ab	339.9b	9.125b	107.3b	45.62b	1930c
15th December	87.38b	323.2b	8.833b	105.8b	42.62c	7974ab
1st January	83.12c	246.7c	7.833c	79.6c	31.25e	3679bc
P of F	<.001	<.001	<.001	<.001	<.001	0.002
SE±	0.990	9.24	0.1830	5.81	0.555	1908.5
Variety (V)						
Borlaug	81.22b	337.2a	8.444b	103.8	42.51a	8999a
Norman	93.18a	299.5b	8.972a	99.2	40.11b	3009b
P of F	<.001	<.001	<.001	0.334	<.001	<.001
SE±	0.572	5.34	0.1057	3.36	0.320	1101.9
Year (Y)						
2019	85.90	312.1	8.556	41.5	40.51	2965.
2020	88.50	324.6	8.861	161.4	42.11	9042
P of F	0.384	0.640	0.305	0.405	0.955	0.168
SE±	1.662	16.15	0.1581	81.02	1.194	2024.4
Interaction						
SD x V	0.109	0.016	0.499	0.934	0.009	0.019
SD x Y	0.496	0.061	0.473	0.040	0.004	0.029
V x Y	0.506	<.001	0.101	0.884	0.879	<.001
SD x V x Y	0.623	0.058	0.653	0.927	0.158	0.024

Means followed by the same letter(s) in the column within a treatment group are not significantly different at 5% level of probability using SNK

Interaction Effects

The interaction between sowing date and variety on spike density and grain yield (Table 5) revealed that Borlaug sown on 15th November recorded the highest number of spikes/m^2 and yield, while very early (25th October) and very late sowing (1st January) in both varieties significantly reduced spike density. This could be attributed to favorable climatic conditions in November, which enhanced tillering and spike formation, consistent with the reports of [26]. On the other hand, 15th November sowing in 2020 significantly yielded more spike density compared with rest of the interaction combination. The superior performance in mid-November sowing aligns with the findings of [1], who noted that optimal sowing dates ensure maximum utilization of radiation and moderate temperatures during critical growth stages.

Table 5: Sowing Date x Variety on Number of spikes ms^{-2} and Grain yield of wheat

Treatment	Borlaug	Norman	Borlaug	Norman
Sowing date	Number of spikes ms^{-2}		Grain yield (Kg ha^{-1})	
25th October	238.5e	238.5e	2055b	2276b
5th November	381.7b	381.7b	13467a	3056b
15th November	430.8a	430.8a	19678a	4348b
1st December	373.5b	373.5b	3781b	3576b
15th December	347.8bc	347.8bc	12805a	3143b
1st January	250.8e	250.8e	2206b	1654b
SE±	13.07		269.1	

Means followed by the same letter(s) are not significantly different at 5% level of probability using SNK

Table 6 presents significant interaction of sowing dates and variety and SD x Year on 1000 grain weight, where Borlaug sown on 15th November produced the heaviest grains, closely followed by Norman on the same date, while the lowest grain weight was recorded in Norman sown on 1st January. This indicates that optimum sowing time, particularly mid-November, favored grain filling, while late sowing exposed plants to terminal heat stress, reducing assimilate translocation to grains. Similar findings were reported by [39] [28], who observed that mid-November sowing produced heavier grains compared to late planting.

On the other hand, sowing on and 15th November x 2020 significantly had the heaviest 1000 seeds compared with rest of the interaction combination which indicates that optimum sowing time provided favorable temperature and radiation during the grain-filling period, which directly influenced assimilate partitioning into seeds. Grain weight is highly sensitive to the duration of grain filling, which depends on both genotype and environmental conditions at critical stages of development. According to [33], timely sowing aligns anthesis and grain filling with favorable thermal regimes, ensuring efficient photosynthate translocation. Similarly, [22] reported that mid-November sowing maximized kernel weight by avoiding terminal heat stress common in late sowings and cold stress in early sowings.

The superiority of the 2020 season further underscores the influence of seasonal variation. Adequate rainfall distribution and moderate temperatures in 2020 may have extended the grain-filling duration, leading to heavier kernels. This agrees with [37], who highlighted that seasonal weather variations significantly affect 1000-grain weight through their impact on source-sink dynamics. Furthermore, [2] observed that wheat sown in optimal windows achieves not only higher yields but also improved grain quality parameters such as test weight and 1000-grain weight.

Table 6: Sowing date x Variety on 1000 grain weight and Sowing date x Year interaction on 1000 grain weight

	Variety		Year	
Treatment	Borlaug	Norman	2019	2020
Sowing date				
25th October	36.50f	33.75g	35.67d	34.58d
5th November	41.42de	42.42cde	39.92c	43.92b
15th November	54.08a	48.58b	49.42b	53.25a
1st December	47.08b	44.17c	44.17b	47.08b
15th December	43.83cd	41.42e	42.75bc	42.50bc
1st January	32.17gh	30.33h	31.17	31.33
SE±	0.785		1.194	

Means followed by the same letter(s) are not significantly different at 5% level of probability using SNK

The sowing date × year interaction (Table 7) further confirmed that 15th November 2023 produced the highest spike density and grain yield, while 25th October and 1st January sowing in both years gave the lowest yields. The superior performance in mid-November sowing aligns with the findings of [24] and [2], who noted that optimal sowing dates ensure maximum utilization of radiation and moderate temperatures during critical growth stages.

Table 7: Sowing date x Year interaction on Number of spikes per meter^{-2} and Grain yield of wheat

Treatment	2022	2023	2022	2023
Sowing date	Number of spikes per meter^{-2}		Grain yield (Kg ha^{-1})	
25th October	37.2d	143.2cd	1739d	2593d
5th November	46.2d	154.0bc	3067cd	13456ab
15th November	54.2d	197.7a	4511bcd	19515a
1st December	40.0d	174.7ab	3537cd	3820d
15th December	40.7d	171.0b	3228cd	12720abc
1st January	31.0d	128.2d	1709d	2150d
SE±	81.37		417.8	

Means followed by the same letter(s) are not significantly different at 5% level of probability using SNK

Figure 2 present a significant sowing date × variety × year interaction on grain yield, where Borlaug sown on 15th November 2023 achieved the highest yield, followed by Borlaug on 5th November and 15th December 2023. Norman consistently produced lower yields, indicating varietal differences in adaptability. Late sowing significantly reduced yields due to fewer spikes/m^2, lighter grains, and shorter grain-filling periods, corroborating the reports of [4].

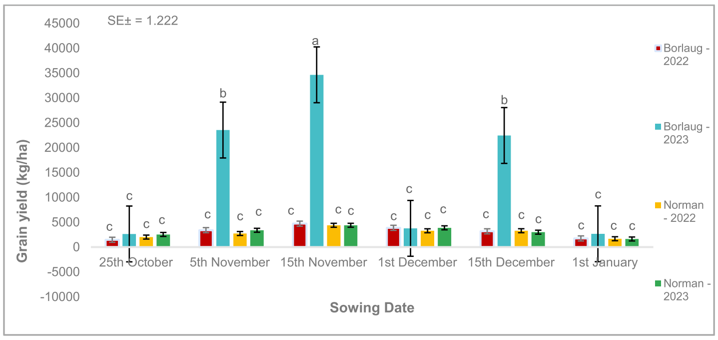

Figure 2: Sowing Date x Variety x Year interaction on grain yield of wheat

Means followed by the same letter(s) are not significantly different at 5% level of probability using SNK

The variety × year interaction on number of spike (Table 8) showed that Borlaug produced more spikes/m^2 than Norman, especially in 2023 in comparison with other interaction combination, suggesting better adaptability and tillering potential. This agrees with [33] who highlighted that timely sowing enhances productive tiller formation, which strongly correlates with yield.

Table 8: Variety x Year on Number of Spikes per m^2

Treatment	Year	
	2022	2023
Variety		
Borlaug	313.9ab	360.5a
Norman	310.4ab	288.7b
SE±	17.01	

Means followed by the same letter(s) are not significantly different at 5% level of probability using SNK

The sowing date × variety × year interaction on spikes/m^2 (Figure 3) revealed that Borlaug sown on 5th and 15th November 2023 recorded the highest spike density, while Norman sown on 1st January recorded the lowest.

This further emphasizes the critical role of mid-November sowing in achieving maximum yield potential, as confirmed by [15]. These findings underscore the importance of timely sowing in synchronizing crop growth with favorable microclimatic conditions, thereby sustaining wheat productivity in challenging environments.

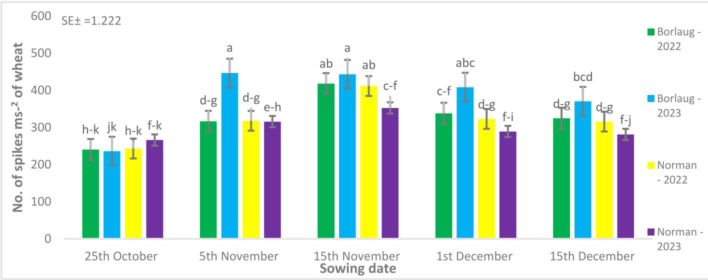

Figure 3: Sowing date x Variety x Year interaction on Number of spikes ms^{-2} of wheat

Conclusion and Recommendation

Sowing date and varietal choice profoundly influence wheat yield performance. Mid-November sowing, especially with Borlaug, maximized yield components and grain productivity, whereas late sowing beyond December severely reduced yields. Therefore, timely sowing between 5th-15th November using high-yielding varieties such as Borlaug is strongly recommended to sustain wheat productivity under semi-arid environments. Future studies should integrate climate-smart practices and genotype evaluation to further enhance resilience and productivity under shifting climatic patterns.

Competing Interests

Authors have declared that no competing interests exist.

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