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Effect of sowing dates on different wheat varieties at Tikapur, Kailali, Nepal

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ABSTRACT

Growth and yield of wheat are affected by variety and sowing dates. Hence a field experiment was carried out at Agronomy Farm, Far Western University in Tikapur, Kailali, Nepal during 2023/24 to study the effect of sowing time and varieties on yield and yield attributing traits of wheat. The experiment was laid out in split plot design comprising four sowing dates viz. 17th November, 27th November, 7th December and 17th December as main plot and three varieties of wheat viz. Vijay, Gautam and Aaditya as sub plot, with three replications. Plant height, spike length, peduncle length, grain per spike, seed length, grain yield and straw yield were significantly higher when sown on 7th December for all the varieties. However, the highest number of effective tillers along with delayed heading, anthesis, maturity and lower grain filling period was observed on 17th November. Aaditya and Vijay produced higher grain yield on 7th December i.e. 4.93 t/ha and 4.25 t/ha, whereas Gautam yielded highest on 17th November with 4.45 t/ha. The last date of sowing produced the lowest grain yield across all the varieties. Similarly, the highest quantity of straw (6.72 t/ha) was observed in Gautam which was statistically at par with Aaditya, followed by Vijay on 7th December. Hence, 7th December for sowing Aaditya and Vijay under Tikapur condition owing to higher yields of both grain and straw whereas 17th November could be suggested for Gautam.

Keywords: Effective tillers, interaction effect, sowing time, senescence period, thousand grain weight

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INTRODUCTION

Wheat (*Triticum aestivum* L.), is the most important cereal crop usually called "bread wheat" or "common wheat" grown on 219 million hectares globally, producing over 760 million tons with an average global yield of 3.47 tons per hectare (FAOSTAT 2022). It is consumed by 35% of the world's population and provides 20% of human calories and protein globally (Poudel and Bhatta 2017). In Nepal, wheat is the third most important staple food crop after rice and maize and the second most important crop of terai region both in terms of area and production. It is grown during the winter season, from 60 to 3,000 masl in Nepal, covering 716,978 ha area under cultivation, with a total production of 2,144,568 tons. Kailali district has the second largest area under wheat cultivation i.e. 34,944 ha after Dhanusha with an average productivity of 3.58 t/ha (MoALD 2023).

Wheat productivity is influenced by various factors like absence of suitable high-yielding varieties, inefficient seed distribution, insufficient fertilizers and pesticides, limited access to irrigation and poor soil management. Farmers also struggle with seed quality, unavailability of seasonal labor, irrigation constraints, disease and pest pressures, and limited access to agricultural machinery (Pandey et al 2017, Subedi et al 2019). Improper sowing dates (Tahir et al 2019) and inappropriate selection of varieties are one of the primary contributors to reduced yields. Late planting exposes wheat to high temperatures during critical growth stages, leading to smaller, lighter grains, and lower yields (Aryal et al 2022). Optimal sowing dates are essential for maximizing wheat yield under these conditions. Early sowing typically increases yield but may not always be economically advantageous, while delayed sowing decreases yield by 0.7% due to late-season heat stress (Ortizet et al 1994). Matching cultivars with appropriate sowing dates based on their flowering and maturity periods is crucial (Flohr et al 2018).

Different wheat varieties respond differently to sowing times and environmental conditions. Recent efforts in Nepal have introduced high-yielding varieties, some suitable for late sowing, to increase wheat yields. Climate and weather significantly influence the variety performance, highlighting the need to identify optimal sowing dates for each variety at different locations. The interaction between variety and sowing date affects grain yield and bread quality, indicating diverse performance among varieties. In Nepal, there is insufficient information on optimal sowing times, limiting farmers' ability to maximize production. Hence, the study aims to assess the phenological and yield attributing characteristics of wheat varieties across different sowing dates to enhance wheat productivity.

MATERIALS AND METHODS

Location

The experiment was laid out at Agronomy Farm of Far Western University, School of Agriculture, Tikapur, Kailali, during November 2023 to April 2024. Geographically, this place is situated in Sudurpashchim province at 28°31'30" North and 81°07'15" East with an elevation of 158 masl. The site had sandy loam soil with neutral pH, 1.03% organic matter content, 0.05% nitrogen, 14.89 kg/ha phosphorus and 121.15 kg/ha potassium.

The Figure 1 showed weather condition throughout the experiment. The minimum and maximum temperature decreased from 17th November to 26th January, then increased until the end of the experiment and the site received a total of 43.81 mm rainfall during the experimental period, which was maximum from 26th February to 6th March. The average maximum and minimum temperatures during the experiment period were 23.67^{o}C and 10.39^{o}C respectively. The site recorded minimum temperature of 7.56^{o}C, 12.04^{o}C & 14.53^{o}C and maximum temperature of 18.77^{o}C, 29.4^{o}C & 31.27^{o}C on first sowing dates. On the last sowing dates, a week prior to anthesis, senescence & maturity, the minimum temperatures were 11.02^{o}C, 14.53^{o}C & 17.7^{o}C and the maximum temperature were 26.41^{o}C, 31.27^{o}C & 35.16^{o}C.

Experimental details

The study was conducted in split-plot design having twelve treatments combination with three replications. There were four sowing dates (November 17, November 27, December 7 and December 17) as main-plot and three varieties (Vijay, Gautam and Aaditya) as sub-plot. The size of each plot was 4 m × 2 m maintaining 1 m and 0.5 m distance between two blocks and two plots respectively.

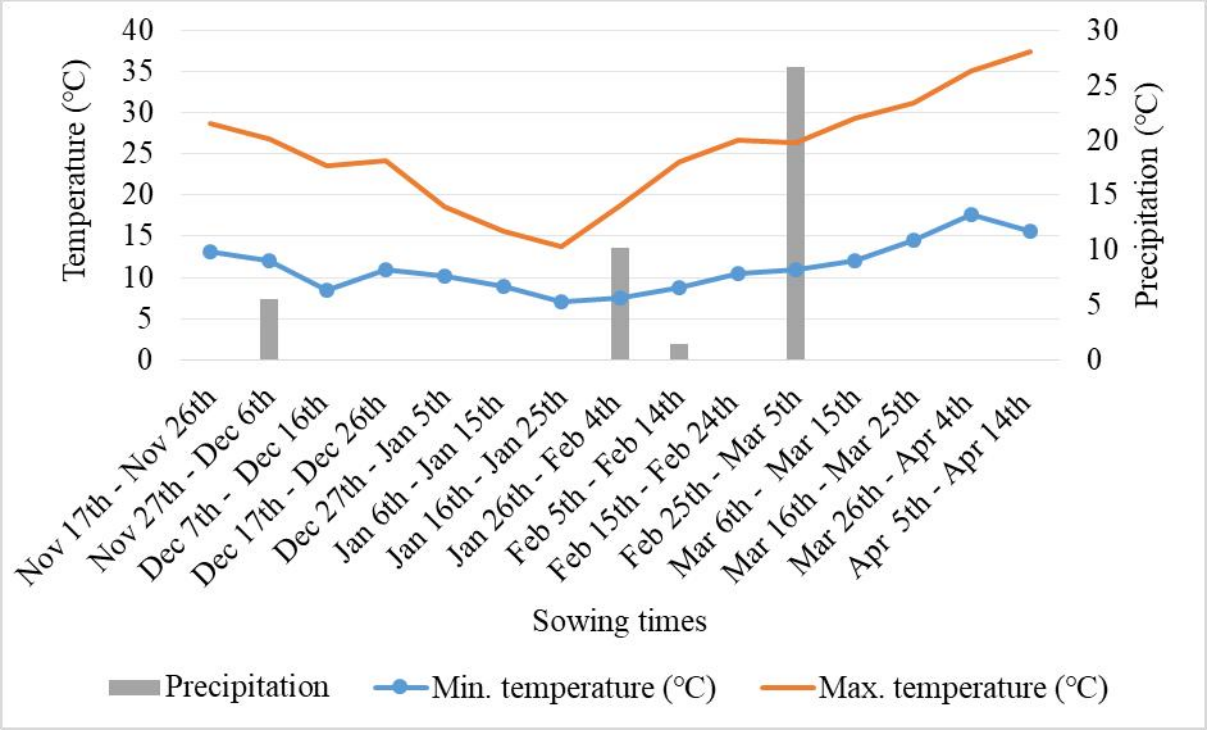

Figure 2. Weather condition during the experiment at Tikapur-01, Kailali, Nepal, 2023/24. (Source: Department of hydrology and meteorology, Babarmahal, Kathmandu, Nepal)

Agronomic practices

The farm yard manure and chemical fertilizers were applied as recommended by Agriculture and Livestock diary, 2080 for Terai area of Sudurpashchim province. A uniform dose of nitrogen (125 kg/ha), phosphorus (50 kg/ha) and potassium (50 kg/ha) through Urea, DAP and MoP were applied to all the treatments. The half quantity of nitrogen and full quantity of phosphorus and potassium were broadcasted in the field during field preparation as basal dose. The rest half dose of nitrogen was top-dressed in two splits, at 21 and 70 days after sowing. Seed sowing was done on 17th November, 27th November, 7th December and 17th December @120 kg/ha seed. Line sowing was done at 25 cm apart row opened through the manually placing at 2-3 cm depth. Flood irrigation was done at 21st DAS, 50th DAS, 70th DAS and 85th DAS in each plot. The crops were harvested manually from 1 m^2 area of each plot where weight of grain adjusted to 12% moisture content, and converted to t/ha.

Data collection and analysis

The data was recorded on biometrical, phenological parameters, yield attributes and yield. The plant height, peduncle length and tiller numbers were recorded as biometrical parameters. Phenological parameters included days to heading, anthesis, senescence based on 50% population and maturity determined by the grain's cracking sound. Yield attributes consisted counting effective tillers, measuring spike length, counting filled grains from ten panicles, and recording seed length, diameter, and weight of 1,000 seeds. Yield was determined by weighing grains from 1 m² area, converting it to t/ha, and adjusting for 12% moisture.

These collected data were statistically analyzed to evaluate differences among sowing dates, wheat genotypes, and their interactions, with mean values calculated and ANOVA performed. Significant differences among treatments were assessed using Duncan's Multiple Range Test

(DMRT) at a 5% significance level, and the data were classified, summarized, and analyzed using MS Excel and R Studio 4.3.0 with the "doebioresearch" package.

RESULTS

Biometric parameters

Plant height

Statistically significant plant height was observed across different sowing dates i.e. 40, 60 and 80 days after sowing (DAS) as shown in Table 1. At 40 DAS, the tallest plant height (40.71 cm) was observed in17th November being statistically at par with 27th November and 7th December, while the shortest plants were obtained in 17th December. By 60 DAS, plants sown in 17th December reached tallest height (68.96 cm), comparable to those sown on 7th December. However, at 80 DAS, the tallest height was observed on 7th December i.e. 100.49 cm, followed by those sown on 17th December and 17th November respectively with the shortest on 27th November, consistently across all the observations except at harvest. During the harvest time, the plant heights were statistically non-significant. Varieties also exhibited significant differences in plant height at all growth stages. At 40 DAS, tallest plants were observed in Gautam i.e. 38.51 cm, similar to Vijay but with shortest plant height in Aaditya. Gautam remained tallest followed by Vijay and Aaditya at 60 and 80 DAS. But at harvest, Gautam had the tallest plants i.e. 109.03 cm, closely followed by Aaditya (108.84 cm) and Vijay (107.29 cm).The study did not show any interaction effects between sowing dates and varieties in plant height at all growth stages, except at harvest. Significant interaction effect between sowing dates and varieties were observed at harvest (Table 2).

Peduncle length

Sowing times revealed non-significant effect on peduncle length having the longest recorded on 7th December (24.08 cm), followed by 17th November (23.52 cm), 27th November (22.35 cm) and 17th December (20.87 cm). Similarly, Vijay showed significantly longer peduncle length (24.31 cm), which was statistically at par with Aaditya (23.91 cm). Significantly smallest peduncle length was recorded from Gautam (19.89 cm).

Effective tillers

Effective tillers were significantly influenced by sowing dates having the 16.54% and 10.82% higher tillers when sown on 17th November (276.33) and 7th December (262.78) respectively over those sown on 17th December (237.11). But no significant effect was observed in the number of effective tillers among varieties. However, the highest tillers were recorded in Vijay (262.66), followed by Gautam (253.41), and Aaditya (247) respectively. But no interaction effect was found between sowing time and varieties.

Effective tiller per plant

No significant difference was observed among sowing dates for effective tiller per plant, though the highest was recorded for those sown in 7th December (1.34), followed by those sown in 17th November and 17th December with the lowest on 27th November (1.13). Vijay showed statistically higher tiller per plant as compared to Gautam and Aaditya. Aaditya produced lowest tiller per plant (1.13) which is similar with Gautam. Vijay produced 28.31% and 18.85% higher tiller per plant when compared to Aaditya and Gautam. No interaction effect was recorded between sowing time and varieties on effective tiller per plant.

Table 1. Effect of sowing dates and varieties on plant height at different growth stages of wheat at Tikapur, Kailali

Treatments	Plant height (cm)				Peduncle length (cm)
	40 DAS	60 DAS	80 DAS	At harvest	
Main plot (sowing date)					
17th November	40.71[a]	64.25[ab]	94.65[bc]	109.35	23.52
27th November	39.33[a]	61.19[b]	90.85[c]	108.83	22.35
7th December	38.38[a]	68.14[a]	100.49[a]	109.87	24.08
17th December	32.84[b]	68.96[a]	96.88[ab]	105.50	20.87
$CD_{0.05}$	2.7	4.85	4.27	4.86	7.26
SEm (±)	0.78	1.4	1.23	1.41	2.09
CV (%)	6.19	6.4	3.87	3.89	27.74
F-test	**	*	**	Ns	Ns
Sub plot (varieties)					
Vijay	38.29[a]	65.52[ab]	94.22[b]	107.29[b]	24.31[a]
Gautam	38.51[a]	67.80[a]	98.82[a]	109.03[a]	19.89[b]
Aaditya	36.64[b]	63.58[b]	94.11[b]	108.84[a]	23.91[a]
$CD_{0.05}$	0.97	2.7	1.7	1.09	2.29
SEm (±)	0.32	0.9	0.56	0.36	0.76
F-test	**	*	***	**	**
A:B					
$CD_{0.05}$	1.95	5.41	3.41	2.19	4.58
SEm (±)	0.65	1.8	1.13	0.72	1.53
CV (%)	2.98	4.76	2.06	1.17	11.65
F-test	Ns	Ns	Ns	**	Ns
P value	0.33	0.89	0.41	0.006	0.88
Grand mean	37.81	65.63	95.72	108.39	22.71

Note: CV: Coefficient of Variation; CD: Critical Difference; SEm: Standard Error of the Mean; Ns: Non-significant; *: significant at ≤0.05 level of significance; **: significant at ≤0.01 level of significance; DAS: Days after sowing; Treatment means followed by common letter/letters within the column are not significantly different from each other based on DMRT @ 0.05.

Tiller sterility percentage

The tiller sterility was calculated by subtracting total number of effective tillers from the formed tillers. The dates showed notable differences in tiller sterility, with the highest sterility on 17th December (21.53%) and the lowest on 7th December (10.66%). Though there were no significant differences among varieties, Gautam recorded the highest sterility (16.63%), followed by Aaditya (14.21%) and Vijay (13.29%), with a mean sterility of 14.71%. There were no interaction effects between sowing dates and varieties.

Phenological parameters

Statistically significant differences were observed in all the phenological parameters (days to heading, anthesis, senescence, grain filling period and maturity) for both the factors viz., varieties and sowing dates. The significant interaction effect on phenological parameters was also observed significant except days to senescence. The late sown (17th December) experienced forced heading, anthesis, senescence, grain filing period and maturity. Similarly, the Vijay variety took shortest days to reach heading, anthesis, senescence, grain filing period and maturity when compared to Aaditya and Gautam varieties.

Table 2. Interaction between sowing dates and varieties on plant height on harvesting at Tikapur, Kailali

Sowing dates	**Varieties**		
	Vijay	**Gautam**	**Aaditya**
17th November	107.62^{d-f}	110.96^{ab}	109.48^{b-d}
27th November	109.43^{b-d}	108.58^{b-e}	108.48^{c-e}
7th December	106.67^{ef}	110.87^{a-c}	112.06^{a}
17th December	105.43^{f}	105.72^{f}	105.34^{f}
$CD_{0.05}$	2.18		
SEm (±)	0.72		
CV (%)	1.18		
F-test	**		
P value	0.006		
Grand mean	108.39		

Note: CV: Coefficient of Variation; CD: Critical Difference; SEm: Standard Error of the Mean; Ns: Non-significant; *: significant at ≤0.05 level of significance; **: significant at ≤0.01 level of significance; Treatment means followed by common letter/s are not significantly different from each other based on DMRT at 0.05.

Days to 50% heading

Early heading was recorded from wheat sown on 17th December (78.89 days), followed by 7th December (81.33 days), 27th November (82.77 days) and 17th November (85.88 days). Among varieties, early heading was recorded on Vijay i.e., 80.50 days, followed by Aaditya (83.91 days) and Gautam (84 days).Table 5 showed significant interaction effect between sowing time and varieties on heading period. Heading period of wheat decreased continuously from 17th November to 17th December. Significantly, Vijay variety was the first to show heading when sown on17th December (77.66 days), which was comparable to 7th December (78.33 days) and 17th December of Aaditya (78.66 days). Gautam and Aaditya variety took the longest duration to reach heading i.e. 86.33 days, when sown on 17th November. December 17 reported earlier heading by 4.34 days, 2.34 days and 0.67 days in Vijay; 6 days, 4.33 days and 2.33 days in Gautam and 7.67 days, 5 days and 4.33 days in Aaditya compared to earlier sowing dates.

Days to 50% anthesis

The earliest anthesis was recorded on those sown in 17th December (80.88 days), followed by 7th December, 27th November and 17th November respectively. December 17th anthesis occurred 7.34 days, 4.56 days and 2.89 days earlier than 17th November, 27th November and 7th December respectively. Vijay (82.33 days) showed the early anthesis compared to Gautam and Aaditya by 3.42 days and 3.17 days. Sowing dates and varieties significantly interacted where December 17 showed early anthesis among varieties. Vijay reached anthesis (79.66

days) earlier on December 17 while Aaditya and Gautam took the longest on November 17. The days to anthesis on wheat sown on November 17 of Vijay, November 27 of Gautam and Aaditya were found to be statistically similar. In Vijay variety, December 17 recorded early anthesis by 1 day, 3.34 days and 6.34 days; 2.67 days, 4.33 days and 6.67 days in Gautam and 4.67 days, 5.64 and 9 days in Aaditya than those sown on other dates.

Table 3. Effect of sowing dates and varieties on effective tillers and tiller sterility percentage of wheat per square meter at Tikapur, Kailali.

Treatments	Effective tillers	Effective tillers per plant	Tiller sterility percentage
Main plot (sowing date)			
17th November	276.33[a]	1.31	14.76[b]
27th November	241.22[b]	1.13	10.66[c]
7th December	262.78[a]	1.34	11.89[c]
17th December	237.11[b]	1.28	21.53[a]
$CD_{0.05}$	19.11	0.16	2.57
SEm (±)	5.52	0.05	0.74
CV (%)	6.52	11.25	15.17
F-test	**	Ns	***
Sub plot (Varieties)			
Vijay	262.66	1.45[a]	13.29
Gautam	253.41	1.22[b]	16.63
Aaditya	247.00	1.13[b]	14.21
$CD_{0.05}$	18.05	0.09	5.25
SEm (±)	6.02	0.03	1.75
F-test	Ns	***	Ns
A:B			
$CD_{0.05}$	36.11	0.18	10.51
SEm (±)	12.04	0.06	3.50
CV (%)	8.20	8.36	41.25
F-test	Ns	Ns	Ns
P value	0.29	0.67	0.64
Grand mean	254.36	1.27	14.71

Note: CV: Coefficient of Variation; CD: Critical Difference; SEm: Standard Error of the Mean; Ns: Non-significant; *: significant at ≤0.05 level of significance; **: significant at ≤0.01 level of significance; DAS: Days after sowing; Treatment means followed by common letter/s are not significantly different from each other based on DMRT @ 0.05.

Grain filling period

Statistically, longer grain filling period was recorded for those sown on 17th November (34.55 days) being 9.44 days, 5.55 days and 1.55 days late when compared to 17th December, 7th December and 27th November respectively. Grain filling period was significantly influenced by sowing dates and varieties (Table 4). Delayed sowing (17th December) shortened the grain filing period whereas Vijay variety sown on December 17 (22.33 days) showed shortest and Gautam (34.33 days)on November 17 the longest grain filling period. Vijay and Aaditya had similar grain filing periodfor November 17 whereas Gautam and Aaditya were statistically at par on November 27. Gautam recordedthe shortest grain filling period on December 7 which was at par to Vijay sown on December 7. December 17 recorded earlier grain filling by 5.33

day, 10 and 11.67 days in Vijay; 2.67 days, 6 and 8 days in Gautam and 3.67 days, 7.67 and 8.67 days in Aaditya compared to those sown on 17th November, 27th November and 7th December.

Table 4. Effect of sowing dates and varieties on phenological parameters at Tikapur, Kailali

Treatments	Days to			
	50% heading	50% anthesis	Grain filling period	Physiological maturity
Main plot (sowing date)				
17th November	84.88[a]	88.22[a]	34.55[a]	132.00[a]
27th November	82.77[b]	85.33[b]	33.00[a]	127.88[b]
7th December	81.33[c]	83.66[c]	29.00[b]	121.77[c]
17th December	78.89[d]	80.88[d]	25.11[c]	116.00[d]
$CD_{0.05}$	0.53	0.44	2.39	1.01
SEm (±)	0.15	0.13	0.69	0.29
CV (%)	0.56	0.46	6.84	0.70
F-test	***	***	***	***
Sub plot (varieties)				
Vijay	80.50[c]	82.33[b]	29.08[b]	122.33[b]
Gautam	84.50[a]	85.75[a]	31.08[a]	125.41[a]
Aaditya	83.91[b]	85.50[a]	31.08[a]	125.50[a]
$CD_{0.05}$	0.53	0.48	0.74	0.48
SEm (±)	0.18	0.16	0.50	0.16
F-test	***	***	***	***
A:B				
$CD_{0.05}$	1.06	0.96	1.47	0.95
SEm (±)	0.35	0.32	0.99	0.32
CV (%)	0.75	0.65	2.79	0.44
F-test	**	**	**	**
P value	0.002	0.001	0.006	0.007
Grand mean	81.97	84.52	30.41	124.41

Note: CV: Coefficient of Variation; CD: Critical Difference; SEm: Standard Error of the Mean; Ns: Non-significant; *: significant at ≤0.05 level of significance; **: significant at ≤0.01 level of significance; DAS: Days after sowing; Treatment means followed by common letter/s are not significantly different from each other based on DMRT @ 0.05.

Days to physiological maturity

Early maturity was found to be significant on 17th December (116 days) which were 16 days, 11.88 days and 5.77 days earlier for those sown on 17th November, 27th November and 7th December. Sowing time and varieties exhibited significant interaction effect on maturity period, as observed in table 5. December 17 recorded the shortest maturity period across all varieties, with decreasing days to maturity from November 17 to December 17. Vijay on December 7 had a similar maturity with Aaditya on December 17, and Vijay on November 17 was comparable to Gautam and Aaditya on November 27. Likewise, late maturity was observed on November 17 in all varieties. December 17 reported earlier maturity by 5.34, 12, and 18.34 days in Vijay; 6, 12, and 15 days in Gautam; and 6, 11.67, and 15 days in Aaditya compared to earlier sowing dates.

Table 5. Interaction between sowing dates and varieties on phenological parameters of wheat at Tikapur, Kailali

Treatments	Days to			
	50% heading	50% Anthesis	Grain filling period	50% Physiological maturity
1:1	82.00^{d}	86.00^{b-d}	35.00^{ab}	131.00^{b}
1:2	86.33^{a}	89.00^{a}	35.33^{a}	132.66^{a}
1:3	86.33^{a}	89.66^{a}	34.33^{ab}	132.33^{a}
2:1	80.00^{e}	83.00^{e}	32.33^{c}	125.66^{d}
2:2	84.66^{b}	86.66^{b}	33.33^{bc}	129.00^{c}
2:3	83.66^{bc}	86.33^{bc}	33.33^{bc}	129.00^{c}
3:1	78.33^{f}	80.66^{f}	27.66^{e}	119.00^{f}
3:2	82.66^{cd}	85.00^{d}	30.00^{d}	123.00^{e}
3:3	83.00^{cd}	85.33^{cd}	29.33^{d}	123.33^{e}
4:1	77.66^{f}	79.66^{f}	22.33^{g}	113.66^{h}
4:2	80.33^{e}	82.33^{e}	27.33^{e}	117.00^{g}
4:3	78.66^{f}	80.66^{f}	25.66^{f}	117.33^{g}
$CD_{0.05}$	1.06	0.96	1.47	0.95
SEm (±)	0.35	0.32	0.99	0.32
CV (%)	0.75	0.65	2.79	0.44
F-test	**	**	**	**
P value	0.002	0.001	0.006	0.007
Grand mean	82.97	84.52	30.41	124.41

Note: CV: Coefficient of Variation; CD: Critical Difference; SEm: Standard Error of the Mean; Ns: Non-significant; *: significant at ≤0.05 level of significance; **: significant at ≤0.01 level of significance; DAS: Days after sowing; Treatment means followed by common letter/s are not significantly different from each other based on DMRT @ 0.05.

Spike length

7th December recorded statistically longest spike length (13.60 cm), and the shortest spike was on 17th November, which was 12.49%, 6.04% and 2.65% shorter than wheat sown on 7th December, 17th December and 27th November respectively. Among varieties, Gautam was found to superior with significant increase in spike length i.e. 13.93 cm, followed by Aaditya (12.49 cm) and Vijay, with 15.51% and 5.76% smaller spike than Gautam and Aaditya. No interaction effect was perceived between sowing time and varieties on spike length.

Grains per spike

Grains per spike varied significantly across sowing dates and varieties, with the highest grains per spike on 7th December (50.11), followed by 17th November (49.01), 27th November (47.37) and 17th December (45.94) respectively. Statistically, Aaditya (53.61) was found to have 9.16% and 28.84% higher number of grains per spike than Gautam (49.11) and Vijay (41.61). Despite higher significant differences on sowing times and varieties, no any interaction effect was found between them.

Seed length

No significant variations were recorded for sowing times and varieties on seed length.

But numerically the highest seed length for wheat sown on 7th December (6.79 mm), followed by 27th November (6.78mm), 17th December (6.72 mm) and 17th November (6.60 mm) respectively. Aaditya showed longest seed length followed by Gautam and Vijay i.e.

6.73 mm and 6.67mm. Also, no interaction effects were found among the sowing time and varieties on seed length.

Yield attributing traits

Table 6. Yield attributing traits of different sowing dates of wheat varieties at Tikapur, Kailali

Treatments	Spike length (cm)	Grains per spike	Seed length (mm)	Seed diameter (mm)	TGW (g)
Main plot (sowing date)					
17th November	12.09^{c}	47.37^{ab}	6.60	3.51^{a}	47.68^{a}
27th November	12.41^{bc}	49.01^{a}	6.78	3.55^{a}	50.24^{a}
7th December	13.60^{a}	50.11^{a}	6.79	3.46^{a}	49.13^{a}
17th December	12.82^{b}	45.94^{b}	6.72	3.26^{b}	42.02^{b}
$CD_{0.05}$	0.51	2.67	0.19	0.15	3.33
SEm (±)	0.15	0.77	0.06	0.04	0.96
CV (%)	3.47	4.82	2.51	3.73	6.10
F-test	**	*	Ns	*	**
Sub plot (varieties)					
Vijay	11.77^{c}	41.61^{c}	6.67	3.52^{a}	49.96^{a}
Gautam	13.93^{a}	49.11^{b}	6.73	3.36^{b}	45.13^{c}
Aaditya	12.49^{b}	53.61^{a}	6.77	3.45^{ab}	46.71^{b}
$CD_{0.05}$	0.42	1.92	0.09	0.10	1.09
SEm (±)	0.14	0.64	0.03	0.04	0.36
F-test	***	***	Ns	*	***
A:B					
$CD_{0.05}$	0.83	3.84	0.18	0.21	2.17
SEm (±)	0.28	1.28	0.06	0.07	0.73
CV (%)	3.77	4.62	1.55	3.57	2.66
F-test	Ns	Ns	Ns	Ns	Ns
P value	0.12	0.06	0.36	0.93	0.12
Grand mean	12.73	48.11	6.72	3.44	47.27

Note: CV: Coefficient of Variation; CD: Critical Difference; SEm: Standard Error of the Mean; Ns: Non-significant; *: significant at ≤0.05 level of significance; **: significant at ≤0.01 level of significance; TGW: Thousand Grain Weight; Treatment means followed by common letter/s are not significantly different from each other based on DMRT @ 0.05.

Seed diameter

Seed diameter was significantly larger for those sown on 27th November (3.55 mm), which was statistically similarto17th November (3.51 mm) and 7th December (3.46 mm). Statistically, seeds of Vijay had the largest diameter (3.52 mm), followed by Aaditya (3.45 mm) and Gautam (3.36 mm) respectively. The interaction effect of sowing time and varieties on seed diameter was found to be non-significant.

Thousand grain weight

Sowing dates as well as varieties significantly affected thousand grain weight, with the highest weight observed for seeds sown on 27th November (50.24 g), which was similar to weights from 7th December (49.13 g) and 17th November (47.68 g). In the same way, Vijay

had the boldest grain weighing (49.96 g) compared to the other varieties. No interaction effect between sowing dates and varieties was observed.

Yield

Table 7. Grain yield, straw yield and harvest index of different sowing dates of wheat varieties

Treatments	Grain yield (t/ha)	Straw yield (t/ha)	Harvests Index
Main plot (sowing date)			
17th November	4.05[a]	5.91	0.41[a]
27th November	4.02[a]	6.11	0.40[a]
7th December	4.37[a]	6.59	0.40[a]
17th December	3.49[b]	6.28	0.36[b]
$CD_{0.05}$	0.39	0.83	0.02
SEm(±)	0.11	0.24	0.007
CV (%)	8.44	11.55	5.36
F-test	**	Ns	**
Sub plot (varieties)			
Vijay	3.80[b]	5.70[c]	0.40[a]
Gautam	3.96[ab]	6.72[a]	0.37[b]
Aaditya	4.19[a]	6.26[b]	0.40[a]
$CD_{0.05}$	0.25	0.38	0.02
Sem(±)	0.08	0.13	0.006
F-test	*	***	**
A:B			
$CD_{0.05}$	0.49	0.77	0.04
SEm(±)	0.17	0.26	0.01
CV (%)	7.22	7.10	5.52
F-test	**	Ns	Ns
P value	0.008	0.77	0.07
Grand mean	3.98	6.22	0.39

Note: CV: Coefficient of Variation; CD: Critical Difference; SEm: Standard Error of the Mean; Ns: Non-significant; *: significant at ≤0.05 level of significance; **: significant at ≤0.01 level of significance; Treatment means followed by common letter/s are not significantly different from each other based on DMRT @ 0.05.

Grain yield

The significant effect was found among sowing dates and varieties where the results indicated that the highest grain yield was achieved on 7th December (4.37 t/ha), over those sown on 17th November (4.05 t/ha), 17th November (4.02 t/ha) and 17th December (3.49 t/ha). Significantly, Aaditya yielded the highest quantity (4.19 t/ha), outperforming Gautam (3.96 t/ha) and Vijay (3.80 t/ha) by 5.81% and 10.26%, respectively.

Statistically, there was significant interaction between varieties and date of sowing in terms of grain yield. Aaditya was found to be superior of all varieties with 4.93 t/ha when sown on December 7, followed by Gautam on November 17 (4.45 t/ha) and Vijay on December 7 (4.25 t/ha).

Table 8. Interaction effect of grain yield of wheat varieties at different sowing dates at Tikapur, Kailali.

Sowing dates	Varieties		
	Vijay	**Gautam**	**Aaditya**
17th November	3.53^{ef}	4.45^{ab}	4.18^{bc}
27th November	4.09^{b-d}	3.89^{c-f}	4.09^{b-d}
7th December	4.25^{bc}	3.93^{b-e}	4.93^{a}
17th December	3.35^{f}	3.56^{d-f}	3.55^{d-f}
A:B			
SEm (±)	0.17		
CV (%)	7.22		
F-test	**		
P value	0.008		
Grand mean	3.98		

Note: CV: Coefficient of Variation; CD: Critical Difference; SEm: Standard Error of the Mean; Ns: Non-significant; *: significant at ≤0.05 level of significance; **: significant at ≤0.01 level of significance; Treatment means followed by common letter/s are not significantly different from each other based on DMRT @ 0.05.

The minimum yield was observed on December 17 in Vijay variety (3.35 t/ha). The yield of Vijay on December 7 increased by 26.87%, 20.39% and 3.91% than the seeds sown on December 17, November 17 and November 27 respectively. Likewise, Gautam sown on November 17 showed increase in yield by 25%, 14.40% and 13.23% than those sown on December 17, November 27 and December 7. Likewise, Aaditya sown on December 7 yielded by 38.87%, 20.54% and 17.94% than those sown onDecember 17, November 27 and November 17. Sowing and varieties showed significant interaction effect on grain yield.

Straw yield

Sowing times had no significant effect whereas varieties showed significant straw yield. However, 7th December (6.59 t/ha) reported the highest straw yield followed by 17th December (6.28 t/ha), 27th November (6.11 t/ha) and 17th November (5.91 t/ha). The Gautam (6.72 t/ha) produced significantly highest straw yield followed by Aaditya (6.26 t/ha) and Vijay (5.70 t/ha) which was 17.89% and 7.35% higher than Vijay and Aaditya. Increase in straw yield might be due to increased plant height (r=0.39). Sowing time and varieties showed no interaction effect on straw yield.

Harvest index

The significant variation on HI was observed among sowing times and varieties. Statistically the lowest harvest index was observed on 17th December (0.36) followed by 7th December (0.40) which was comparable with 17th November and 27th November. Likewise, Aaditya and Vijay noted with identical HI of 0.40 while Gautam had 0.37. However, no interaction effect was recorded between sowing time and varieties on harvest index.

Table 9. Correlation coefficient between different parameters under selection of wheat at Tikapur, Kailali

	GY	**GPS**	**PH**	**PL**	**ET**	**TS%**	**DA**	**GFP**	**DM**	**SY**
GY	1									
GPS	0.52**	1								
PH	0.64***	0.39*	1							

	GY	GPS	PH	PL	ET	TS%	DA	GFP	DM	SY
PL	0.29	0.01	0.33*	1						
ET	0.26	-0.19	0.2	0.06	1					
TS%	-0.34*	-0.1	-0.28	-0.14	-0.34*	1				
DA	0.41*	0.43*	0.54**	0.03	0.34*	-0.27	1			
GFP	0.37*	0.3	0.47**	0.2	0.25	-0.38*	0.82***	1		
DM	0.36*	0.26	0.46**	0.12	0.34*	-0.34*	0.91***	0.95***	1	
SY	0.29	0.43*	0.39*	-0.23	-0.13	0.08	0.05	-0.05	-0.13	1

Note: GY: Grain yield (t/ha); PH: Plant height; ET: Effective tiller; TS%: Tiller sterility percentage; PL: Peduncle length; GpS: Grain per Spike, SY: Straw yield; DS: Days to senescence; GFP: Grain filling period; DM: Days to maturity. Treatment means followed by common letter/s are not significantly different from each other based on DMRT @ 0.05. Grain yield showed significant positive correlation with plant height (r=0.64), grain per spike (r=0.52), grain filling period (r=0.37), days to anthesis (r=0.41), days to maturity (r=0.36), indicating increase these parameters played vital role to increase in yield whereas tiller sterility percentage (r=-0.34) showed negative correlation with grain yield.

Relationship between grain yield and other parameters

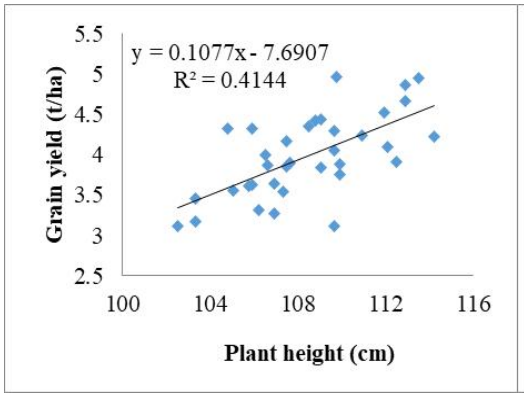

Figure 2. Relationship between grain yield and plant height

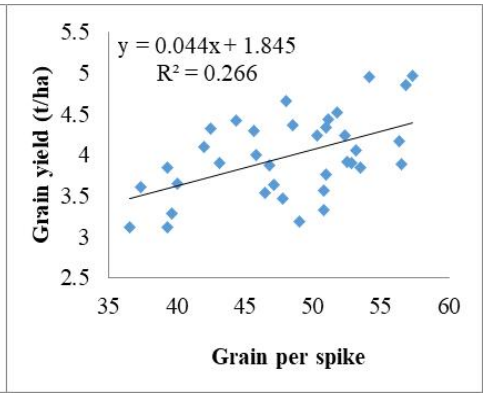

Figure 3. Relationship between grain yield and grain per spike

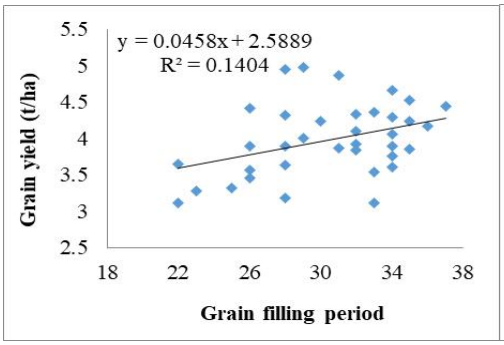

Figure 4. Relationship between grain yield and grain filling period

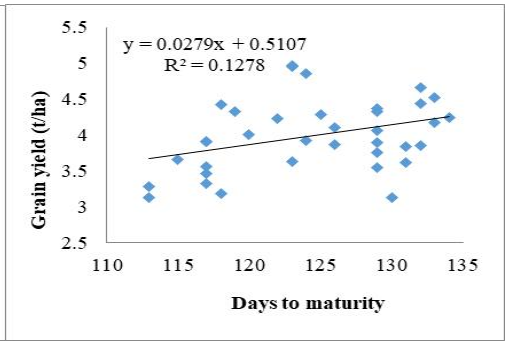

Figure 5. Relationship between grain yield and days to maturity

DISCUSSION

The study revealed significant variation in plant heights of wheat, when sown at varying dates especially at 40, 60 and 80 days after sowing (DAS). But no significant variation was observed in plant height during harvest. Early sown wheat exhibited taller plant heights due to the weather condition favoring the growth of wheat plants, than those sown late. In line with our findings, Sial et al (2005) reported poor development of plant organs and the transfer

of resources from source to sink, under delayed sowing condition. The findings of our research also align with that by Hassan et al (2014) and Jat et al (2013). But in contradictory to our results, Yadav et al (2017) and Verma et al (2016) reported no significant effect of sowing time on plant height. Varieties also exhibited significant effect on plant height at all growth stages and peduncle length. Variation in plant height among different varieties might be due to inherent genetic differences responding differently to different environment condition (Rajbanshi et al 2024), which contributed greatly to the length of peduncle (r=33). Genetic factors such as the plant growth potential, response to nutrients, hormonal factors and adaptability to environmental conditions might have contributed to these differences in height among the genotypes. Similar findings were reported by Madhu et al (2018). But in contrast to the findings of this research, Verma et al (2016) reported insignificant effect of variety on plant height. The significant interaction effect among varieties and sowing dates, as in our study, was also observed by Madhu et al (2018) and Hossin (2014).Dates of sowing non-significant and varieties has significant effect on peduncle length.

Effective tillers were pointedly influenced by sowing dates. Lower number of effective tillers per square meter was due to delayed planting, with approximately 67.22 tillers dying between stem elongation and flowering. Early sowing i.e., on 17th November produced more fertile tillers which might be due to a longer vegetative period (Pyare et al 2015 and Acharya et al 2022). While, varieties exhibited non-significant effect on effective tillers which may be due to limited genetic diversity and uniform environmental conditions limiting the expression of these genetic differences. Contrary to this, previous studies by Chauhan et al (2020) and Shah et al (2022) reported statistically significant effect of varieties on number of effective tillers. Delayed sowing significantly increased tiller sterility due to colder temperatures, shorter days as observed from the figure 2 and reduced soil warmth, which hindered the tiller development. These unfavorable conditions might have limited the uptake of nutrients, increasing the plant stress, leading to higher tiller sterility in late sown dates. But these findings contradict with that reported by Marasini et al (2016).

Both the sowing dates and varieties significantly affected days to heading and days to anthesis, which is in line with that reported by Baloch et al (2012) and Mumtaz et al (2015) The varieties showed varying time of anthesis due to differences in genetic factors controlling growth rates and developmental stages and their response to various environmental cues, such as temperature and photoperiod, influencing the timing of flowering. The longer grain filling period of early sown (17th November) wheat was aided by the prolonged low temperature. Also, increased plant height and longer peduncle length extend the grain filling period by improving the plant's ability to support and access resources. Positive correlation of grain filling period with plant height (r=0.47), days to anthesis (r=0.82) and peduncle length (r=0.20), is also evidenced in this study. Late sown (17th December) crops were exposed to relatively higher temperatures during early period leading to faster aging, which reduced grain filling duration. These findings are in accordance with Aryal et al (2022). Gautam and Aaditya took longest grain filling period (31.08 days) compared to Vijay (2.08 days). Different varieties had different grain filling periods due to their genetic differences influencing their growth rate, stress tolerance, and developmental timing (Bhattarai et al 2017). Early sowing experienced delayed maturity due to exposure of varying temperatures, while late sowing typically results into shortened maturity phase. These findings corroborate with those by Sah et al (2022) and Akhter et al (2015). Different varieties possess different maturity times due to distinct genetic traits which affect the length of time required to reach physiological maturity resulting in noticeable variations in maturity duration among various varieties, as is reported by Yadav et al (2018) and Mumtaz et al (2015).

Date of sowing and varieties had significant effect on both spike length and grains per spike. The longer spike length in early sown dates might be due to an extended growing season allowing plants more time to grow and develop with access of optimal temperature conditions, as is reported by Khokhar et al (2010) and Kamrozzaman et al (2016). Bhattarai et al (2017) and Sah et al (2022) also reported significant effect of wheat varieties on spike length. Dolferus et al (2011) reported that abiotic stress like increasing temperature reduces grain numbers, while Fischer (2011) emphasized that 10-15 days prior to anthesis is crucial for grain number formation. The limited days available for grain development, due to delayed heading have been reported by Acharya et al (2017), Shirinzadeh et al (2017). Early sowing increased the grains per spike by providing more time for grain formation and crop escape post anthesis drought (Aryal et al 2022). The variation in number of grains per spike for varieties is controlled by the genetic factors (Acharya et al 2017 and Bhattarai et al 2017).

Seed diameter differed significantly in wheat sown at different dates, due to differences in temperatures during the ripening. The exposure of wheat crop to higher temperatures during grain development, under late sown conditions might have reduced the dry matter in the grains, as is evidenced from the values of thousand grain weight, which is also reported by Pyare et al (2015) and Gupta et al (2017). The heat stress reduced the grain-filling period, leading to smaller, underdeveloped seeds due to increased respiration, decreased photosynthesis and nutrient uptake. Vijay's superior grain weight is likely due to its genetic traits, such as improved photosynthetic efficiency, nutrient uptake and optimal hormonal regulation enhancing grain development. The findings of this study align with the findings by Yadav et al (2018) and Khokhar et al (2010).

Significantly higher yield of wheat when sown on 7th December was due to higher number of effective tillers per plant, lower tiller sterility, increased number of grains per spike, thousand grain weight and greater seed diameter as shown in table 3 and 6. Delayed sowing resulted in the lowest yield due to higher tiller sterility, fewer grains per spike and lesser value of thousand grain weight, which has also been reported by Sah et al (2022) and Aryal et al (2022). The higher grain yield of Aaditya variety is attributed to more grains per spike, longer grain-filling period, and greater seed length. Varieties differ in yield attributing traits resulting in significant variation in yields. Significant influence of varieties on grain yield has also been reported by Verma et al (2016), Shirpurkar et al (2007) and Mumtaz et al (2015). Sah et al (2022) reported similar results, while Jat et al (2013) found early sowing on November 20 led to higher straw yield due to increased plant height and dry matter accumulation.

CONCLUSION

The study demonstrated significant effect of both the sowing dates and varieties of wheat at Kailali district. Both the variety Vijay and Aaditya yielded the highest amount of grain when sown on December 7th, providing evidence that a slight delay in sowing these wheat varieties can also increase yield in the current context. But in case of Gautam, the performance was the best when sown on 17th November as compared to other dates, indicating that this variety should be sown earlier Vijay and Aaditya. All the varieties tested in the study exhibited lower grain yield when sown late i.e. on 17th December, due to increase in temperature forcing the grains to mature fast. The results highlighted the importance of selecting both the appropriate sowing time and variety for maximizing the yield of wheat.

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Authors' Contributions
Devraj Rajbanshi designed and conducted this research, and was responsible for data collection and preparation of manuscript. Binod Bohara, Archana Chaudhary, Priyanka Rasali, and Sangita Gaha Magar helped with setting up the field experiment, data collection and manuscript writing. Raksha Sharma guided for effective research design, reviewed and finalized the manuscript.

Conflicts of Interest
The authors have no relevant conflict of interests.

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