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Assessment of yield and yield attributes of wheat varieties under different date of sowing in Madhesh Province of Nepal

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ABSTRACT
Wheat (*Triticum aestivum L.*) contributes to a vital portion of the global food supply and is an economically important crop. Sowing time and suitable varieties are important factors in attaining higher yields. Thus, an experiment was conducted at the Field of CNRM Bardibas in Madhesh Province during the winter of 2023-24 to assess the impact of different sowing dates and wheat varieties. The experiment designed in a split-plot design with two replications, involved three sowing dates (13 December, 23 December, 2 January) as main plot treatment and eight varieties (Banganga, Zinc Gahun 1, Gautam, BL 4341, Borlaug 2020, NL 1386, NL 1349, and BL 4818) as sub-plot. Yield and yield attributes were taken at the time of harvest and during the growing season and then analyzed with Genstat ver. 15.1. The results revealed that sowing time and varieties showed a significant impact on yield and yield attributes. Among tested varieties, the highest yield was recorded in Banganga (3.94 t ha^{-1}), and the least at Borlaug 2020 (2.79 t ha^{-1}) and varied in yield up to 4-20% as compared to late sown. On Interaction (V*S), Banganga planted earlier provided a higher yield (4.59 t ha^{-1}) followed by the same variety planted on 23 December, NL 1349 sown on 13 and 23 December. Banganga on 13 December (51.3 g) showed significantly higher TGW followed by NL 1349 (50.89) and the least in BL 4341 (34.8 g) under late sown. In conclusion, Banganga should be planted earlier to attain higher yields and further research must be carried out in the farmer's field for validation.

Keywords: Date of sowing, variety, wheat, yield

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INTRODUCTION

Wheat (*Triticum aestivum L.*) is 3rd most important staple crop grown around the world. China is the leading producer in 2023-24 with over 137.7 million metric tons volume (*FAOSTAT* 2023). In Nepal, Wheat productivity has increased from 1.89 t ha^{-1} in 2002 to 2.99 t ha^{-1} in 2022 and is today grown in almost 0.76 million hectares, wheat contributes 5.67% to the agricultural GDP of Nepal (MOALD 2023) it further mentions Madhesh province as the food basket of Nepal and produces (628,909 metric tons) of wheat annually which is 29.32% of the National wheat production.

Wheat is a common crop grown after the rice harvest in the Terai setting and after the Maize harvest in the Low hills (Thapa et al 2020). Two primary factors affecting the wheat yield are the appropriate Date of sowing and the Selection of variety. The sowing date of the wheat is influenced by the harvesting date of the rice as the Rice-Wheat cropping pattern is prevalent as the main cropping pattern in Nepal. In most cases, rice is harvested late due to various factors such as the use of late maturing varieties, shortage of labor, and rice harvesters during rice harvesting season (NWRP 2017). The maturity time of the late sown wheat co-occurs with the time of hot desiccating western winds during April to May causing forced ripening of spikes and too tiny grains ultimately resulting in yield reduction (Bastakoti and Poudel 2022). NWRP 2017 states that late-planted wheat is exposed to higher temperatures shortening the reproductive and grain filling periods causing the premature and forced development of wheat grain resulting in Lower grain weight and hence resulting in reduced yield. Early planting of wheat drives seedlings to face higher temperatures which bring about poor root systems affecting the seedling's health and ultimately reducing the yield (Sah et al 2022).

Nepal is the fourth most vulnerable country against climate change and future projections of high temperatures are being made (The World Bank 2013), which can affect the sowing dates of wheat. So, the modification of the sowing dates of the wheat must be done accordingly to obtain an optimum yield.

Among all the productivity factors, variety and sowing date are the most important, economical, and effective factors that can be adjusted to enhance wheat yield (Sah et al 2022). So, research was carried out at the Bardibas Municipality of Madhesh province to find the suitable variety and optimum date of sowing that are to be prioritized.

MATERIALS AND METHODS

Location

The field experiment was conducted starting from December 2023 to April 2024 in the Field of the College of Natural Resource Management, Bardibas (26°56'37"N latitude, 85°53'26"E Longitude and 189 m above mean sea level) to assess the performances of different wheat varieties under different dates of sowing. During the cropping period, the average minimum temperature observed was 14.19^{0}C and the average maximum temperature was 27.213^{o}C. The total amount of precipitation was 29.24 mm and the maximum and minimum relative humidity during the period was recorded 69.88% and 13.56% respectively (Nasa Power 2024).

Experimental details

The experiment was laid out in a Split plot design with 24 treatments comprising 3 different dates of sowing (13 December 2023, 23 December 2023, and 2 January 2024) arranged vertically as the main plot and 8 different varieties (Banganga, Zinc Gahun-1, Gautam, BL 4341, Borlaug 2020, NL 1386, NL 1349, BL 4818) assigned to subplots arranged horizontally. Each treatment was replicated twice. Each subplot of (2m×3m) has 8 rows with 25 cm spacing.

Crop management practices

The field was ploughed twice 5 days before the sowing date. Line sowing is practiced with the row spacing of 25 cm and was sown on three different dates of sowing, the first sowing was done on December 13 taken as early sowing. The second sowing was conducted on 23

December for normal sowing and late planting was done on 2 January 2024. A fertilizer dose of 60:30:30 kg NPK ha^{-1} through Urea, Di-ammonium phosphate, and muriate of potash was applied. Half of nitrogen dose and full P and K doses were applied at the time of sowing and half of the remaining nitrogen dose was applied at the time of flowering. Data on phenological, morphological, and yield-attributing traits such as plant height, number of leaves, leaf area, effective tillers per $meter^2$, length of the spike, grains per spike, TGW, grain yield, biological yield, and Harvest index were taken. All data were analyzed at a probability level <0.05 by using GenStat (15^{th} edition).

Biometrical characters

The plant height of the crop is measured by the measuring tape in centimeters. A total of 10 random samples from the second row were taken from each plot and averaged to get the data of a plot. For the Leaf area index, measurement of the length and width of the flag leaf was done and the formula LAI=Length*width*0.75 (Chanda & Singh 2002) was used. LAI for 10 plants in the plot was taken and then averaged. Ten spikes from the 7^{th} row of the plot were taken and then the length of the spike was measured with the help of a 30 cm Scale and averaged to get data for the length of a spike of that plot.

Yield and yield attributes

Effective tillers per m^2 were taken by counting the no of tillers from the second row of 3m length and then calculated. After the maturity of the crop 10 spikes from the 7^{th} row were selected randomly and then harvested and threshed separately for different plots. The total number of grains in those ten spikes was counted and averaged for that plot to get grains per spike. Thousand grain weight was calculated by counting the thousand grains and weighing them in the electrical balance (±0.1 gm). Every plot was harvested separately and weighed for the biological yield. The harvesting is carried out and grain yield is also known. The harvest index for the plot was calculated by the formula

$$HI=\frac{Grain\ yield}{Biological\ yield} * 100$$

Phenological characters: Phenological characters were observed through regular field visits. Days to heading were noticed based on the threshold: 50% of the anther having at least one anther burst, Days to flowering are calculated by observing the plot with more than a 50% spike in the flowering stage. Days to maturity were checked by biting the grain, if the seed is hard then it is mature. Fifty percent of the plant in a plot must attain this stage to be called a matured plot.

Statistical analysis: All the collected data were entered in MS Excel 2013 and further subjected to analysis of variance. GenStat (ver. 15.1.) was used for data analysis with a 5% level of significance.

RESULTS

Effect of different sowing dates on different phenological characters

The effect of different sowing dates on different phenological characters of wheat varieties is presented in Table 1. The study revealed that sowing dates significantly influenced the phenological development of wheat varieties ($p<0.05$). Wheat sown on 13 December took the longest duration to reach heading (69.62 days), flowering (74.69 days), and maturity (107.44 days). Delaying sowing reduced phenological duration consistently across all varieties, with the 2 January sowing leading to the shortest crop cycle. Similar findings were reported by

(Sah et al 2022), who observed accelerated development and reduced maturity periods under delayed sowing due to increased thermal accumulation. Among varieties, NL 1349 had the highest days to heading (70.67) and flowering (75.83), while Banganga matured the earliest (100 days). This indicates that genotypic differences strongly influence thermal time requirements, a trend also supported by (Singh 2021).

Table 1. Effect of different sowing dates on different phenological characters at CNRM Bardibas, Mahottari, 2023-2024

Treatments	Days to heading	Days to flowering	Days to Maturity
Factor A (Date of sowing)			
13 December 2023	69.62[a]	74.69[a]	107.44[a]
23 December 2023	68.19[b]	73[b]	104.69[b]
2 January 2024	66.50[c]	71.44[c]	100.44[c]
SEM (±)	0.219	0.108	0.191
LSD(<0.05)	1.336*	0.659**	1.162**
Factor B (Varieties)			
Banganga	66.33	71	100
Zinc Gahun 1	67.33	73.33	106.67
Gautam	67	71.67	101.33
BL 4341	68.67	73.33	101.50
Borlaug 2020	68.17	72.83	108.67
NL 1386	68.17	72.67	102.67
NL 1349	70.67	75.83	106.33
BL 4818	68.50	73.67	106.33
SEM (±)	0.356	0.304	0.457
LSD(<0.05)	1.046***	0.839***	1.344***
A*B	Ns	Ns	2.238
CV (%)	1.3	1.0	1.1

Note: NS= Non-significant; Significant at 5% level of significance ""; highly significant at 1% level of significance "**"; very highly significant at 0.1% level of significance "***"*

Effect of different sowing dates on biometric character

The effect of different sowing dates on the plant height of wheat varieties is presented in Table 2. Plant height was influenced significantly by genotype but not by sowing date, aligning with findings by (Khosravi et al 2010), who attributed plant height to genetic characteristics and environmental adaptability. The tallest variety was NL 1349 (96.99 cm), followed by BL 4341 and BL 4818. Zinc Gahun 1 recorded the shortest plants (81.35 cm). Leaf area index (LAI), though statistically non-significant, showed a decreasing trend with delayed sowing. LAI dropped by approximately 25% in wheat sown on 2 January compared to early sowing, likely due to poor leaf expansion and canopy development under higher temperatures. Banganga exhibited the highest LAI (2.67), suggesting better photosynthetic potential. These results are consistent with (Gupta et al 2017), who found that early sowing enhances canopy development.

Table 2. Effect of different sowing dates on Plant height of different varieties on different days of sowing at CNRM Bardibas, Mahottari, 2023-2024

Treatment (Plant height (cm))	30 DAS	60 DAS	90 DAS
Factor A (Date of sowing)			
13 December 2023	24.38	55.03	88.71
23 December 2023	22.53	51.29	89.18
2 January 2024	20.89	52.98	83.99
SEM (±)	0.961	1.55	2.019
LSD(<0.05)	Ns	Ns	Ns
Factor B (Varieties)			
Banganga	22.55	60.66	83.39
Zinc Gahun 1	21.20	48.14	81.35
Gautam	25.66	57.41	86.57
BL 4341	24.53	59.12	90.47
Borlaug 2020	22.0	50.46	81.45
NL 1386	21.67	54.69	88.48
NL 1349	21.75	47.19	96.99
BL 4818	21.47	47.14	89.65
SEM (±)	0.713	2.741	1.823
LSD(<0.05)	2.098**	8.061**	5.363***
A*B	Ns	Ns	Ns
CV (%)	7.7	12.6	5.1

Note: NS= Non-significant; Significant at 5% level of significance ""; highly significant at 1% level of significance "**"; very highly significant at 0.1% level of significance "***"*

The effect of different sowing dates on Leaf area index of wheat varieties is presented in Table 3. Leaf area index (LAI), though statistically non-significant, showed a decreasing trend with delayed sowing. LAI dropped by approximately 25% in wheat sown on 2 January compared to early sowing, likely due to poor leaf expansion and canopy development under higher temperatures. Banganga exhibited the highest LAI (2.67), suggesting better photosynthetic potential. These results are consistent with (Gupta et al 2017), who found that early sowing enhances canopy development.

Table 3. Effect of different sowing dates on Leaf Area Index of different varieties on different days after sowing at CNRM Bardibas, Mahottari, 2023-2024.

Treatment (Leaf area index)	30 DAS	60 DAS
Factor A (Date of sowing)		
13 December 2023	0.89	2.476
23 December 2023	0.95	2.462
2 January 2024	1.07	1.853
SEM (±)	0.150	0.5235
LSD(<0.05)	Ns	Ns
Factor B (Varieties)		
Banganga	0.96	2.670
Zinc Gahun 1	0.86	2.375
Gautam	0.97	2.251
BL 4341	1.01	2.127
Borlaug 2020	0.77	2.144
NL 1386	1.04	2.454
NL 1349	0.90	2.021
BL 4818	1.25	2.067

Treatment (Leaf area index)	30 DAS	60 DAS
SEM (±)	0.134	0.1962
LSD(<0.05)	Ns	Ns
A*B	Ns	Ns
CV (%)	33.8	33.8

Note: NS= Non-significant; Significant at 5% level of significance ""; highly significant at 1% level of significance "**"; very highly significant at 0.1% level of significance "***"*

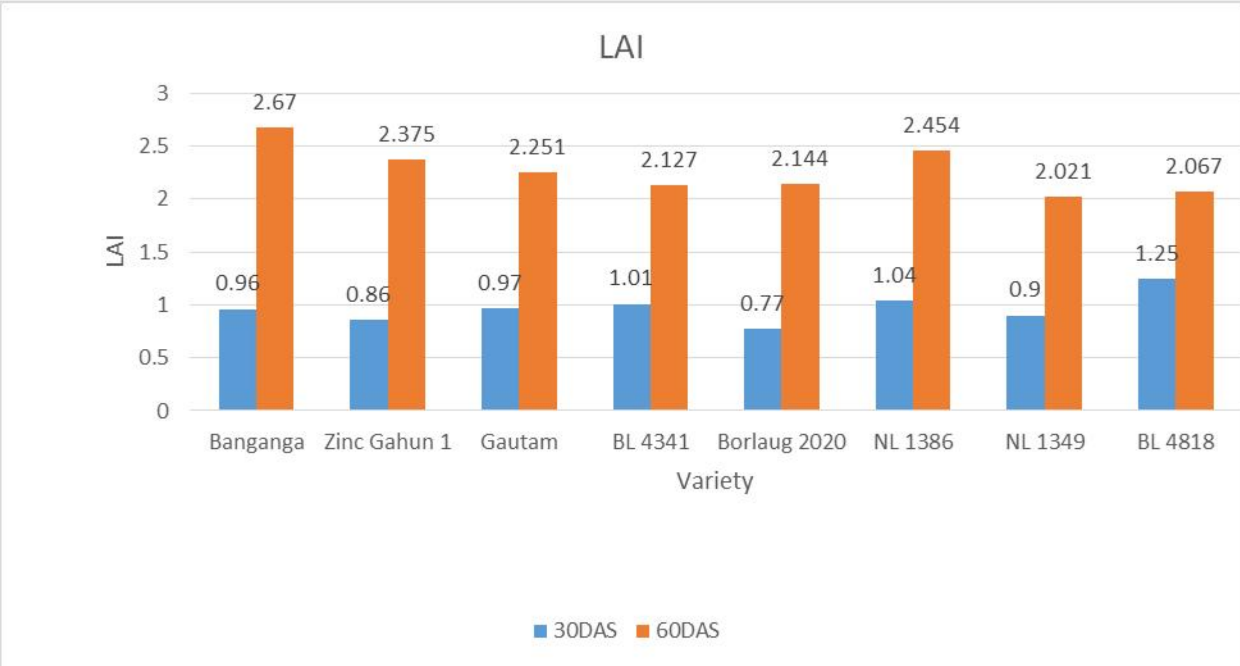

Figure 1. Chart showing wheat varieties' LAI after 30, 60, and 90 DAS.

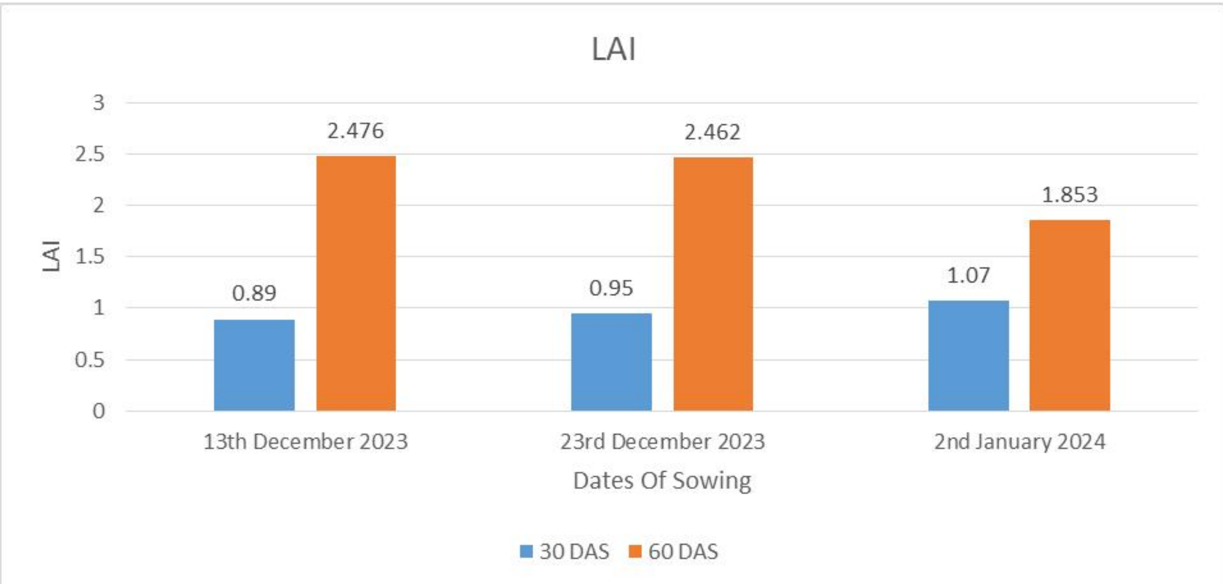

Figure 2. Chart showing the effect of different dates of sowing wheat on LAI after 30, 60, and 90 DAS.

The effect of different sowing dates on spike length of wheat varieties is presented in Table 4. Spike length was significantly affected by variety. Gautam produced the longest spikes

(11.53 cm), while Zinc Gahun 1 had the shortest (9.12 cm). Longer spikes are generally correlated with a higher number of grains per spike, although the latter trait was not statistically significant in this study. NL 1386 recorded the highest grains per spike (57.1), followed by Banganga and NL 1349. (Tahir et al 2009) previously emphasized that grain number is more influenced by genotype than environmental variables like sowing time.

Table 4. Effect of different sowing dates on Spike Length of different varieties at different growth stages at CNRM Bardibas, Mahottari, 2023-2024.

Treatments	**Length of Spike (cm)**
Factor A (Date of sowing)	
13 December 2023	9.89[b]
23 December 2023	10.71[a]
2 January 2024	10.39[a]
SEM (±)	0.1087
LSD(<0.05)	Ns
Factor B (Varieties)	
Banganga	10.78
Zinc Gahun 1	9.12
Gautam	11.53
BL 4341	9.42
Borlaug 2020	9.76
NL 1386	10.66
NL 1349	10.86
BL 4818	10.52
SEM (±)	0.2890
LSD(<0.05)	0.8499***
A*B	Ns
CV (%)	6.9

Note: NS= Non-significant; Significant at 5% level of significance ""; highly significant at 1% level of significance "**"; very highly significant at 0.1% level of significance "***"*

Effect of different dates of sowing on the yield and yield attributes

The effect of different sowing dates on yield and yield attributing characters of wheat varieties is presented in Table 5. Yield and yield components were profoundly influenced by both sowing dates and varietal traits. Interestingly, although later sowing increased effective tillers per square meter (4.8% rise over 20 days), this did not translate into higher grain yield. This is likely due to shorter grain filling periods and reduced thousand grain weight (TGW) under heat stress, corroborating the observations of (Alam et al 2020 ,Singh 2021). Banganga showed the highest TGW (48.91 g) and yield (3.94 t ha^{-1}), outperforming others, particularly under early sowing. The TGW declined significantly (~12.4%) under late sowing (2 Jan), reinforcing the sensitivity of grain development to sowing time (Acharya et al 2017).

Grains per spike were largely genotype-dependent and unaffected by sowing date. NL 1386 had the highest grains per spike (57.1), while BL 4341 had the lowest (45), consistent with (Tahir et al., 2009), who emphasized genetic control over this trait. Harvest index (HI) was highest for NL 1349 (42.79%), Banganga (42.17%), and NL 1386 (42.16%), suggesting efficient partitioning of biomass into grain.

Table 5. Effect of different sowing dates and different varieties on yield and yield attributing character at CNRM Bardibas, Mahottari, 2023-2024

Treatments	Effective tillers per m^2	Grains $Spike^{-1}$	TGW (gm)	Grain Yield (t ha^{-1})	Biological Yield (t ha^{-1})	Harvest index
Factor A (Date of sowing)						
13 December 2023	240.5	48.3	45.15^{a}	3.52^{a}	8.50	41.19
23 December 2023	257.33	49.8	44.52^{a}	3.37^{ab}	8.43	40.1
2 January 2024	252.67	51.5	39.53^{b}	2.79^{b}	6.96	39.9
SEM (±)	8.185	1.19	0.435	0.107	0.300	0.2820
LSD(<0.05)	Ns	Ns	2.645*	Ns	Ns	Ns
Factor B (Varieties)						
Banganga	249.78	52.4	48.91	3.94	9.29	42.17
Zinc Gahun 1	247.33	48.2	41.56	3.27	8.27	39.59
Gautam	228.44	48.6	46.37	2.97	7.19	41.14
BL 4341	408	45.0	37.57	3.17	8.97	35.17
Borlaug 2020	203.56	47.5	39.74	2.79	7.25	38.35
NL 1386	220.89	57.1	41.58	3.25	7.65	42.16
NL 1349	210	53.8	46.51	3.39	7.88	42.79
BL 4818	233.33	46.1	42.30	3.03	7.23	41.76
SEM (±)	21.817	3.40	1.584	0.198	0.384	1.0430
LSD(<0.05)	64.163***	Ns	4.659***	0.582*	1.129**	3.0676***
A*B	Ns	Ns	Ns	Ns	Ns	Ns
CV (%)	21.24	16.7	9	15	11.8	6.3

Note: NS= Non-significant; Significant at 5% level of significance ""; highly significant at 1% level of significance "**"; very highly significant at 0.1% level of significance "***"*

DISCUSSION

The findings of this study emphasize the crucial role of sowing time and varietal choice in optimizing wheat yield in the Madhesh region. Early sowing (13 Dec) allowed wheat to exploit optimal environmental conditions for tillering and grain filling, which enhanced TGW and final yield. This is consistent with the conclusions of (Singh 2021), who attributed higher yields under early sowing to better synchronization of phenological events with favorable weather.While LAI and plant height showed limited sensitivity to sowing time, varietal differences were significant. Taller varieties like NL 1349 also had higher biomass, but not necessarily higher grain yield, reaffirming that plant height alone is not a yield determinant. Spike length and grain number were found to be mostly varietal traits, as seen in previous studies by (Mukherjee 2012, Chauhan et al 2020).Despite higher effective tillers under late sowing, reduced TGW and shortened reproductive phase due to rising temperatures led to lower yields. This aligns with earlier research from Jharkhand and Central Terai showing similar thermal sensitivity (Alam et al 2020, Sah et al 2022).Among the varieties, the reduction in TGW under delayed sowing was a major yield-limiting factor. Reduced grain weight under terminal heat stress is a well-documented issue in wheat cultivation across South Asia (Bastakoti and Poudel 2022, Tyagi et al 2003). Banganga consistently outperformed others in terms of TGW, yield, and early maturity. Its superior performance, particularly under early sowing, indicates high adaptability and yield potential under optimal planting windows. Conversely, Borlaug 2020 showed the poorest yield, especially under late sowing, suggesting low tolerance to terminal heat.

Overall, the study confirms that both genotypic selection and timely sowing are critical agronomic strategies for wheat production in subtropical environments like Madhesh Province. This insight is particularly relevant under climate change scenarios where adaptive agronomic management becomes vital. The harvest index trends also support that early sowing leads to better partitioning of biomass to grains. The higher HI in Banganga and NL 1349 reinforces their suitability for high-efficiency farming. Overall, Banganga emerged as the most promising variety, particularly under early sowing (13 December), with robust performance in terms of TGW, grain yield, and harvest index. This supports its recommendation for cultivation in Madhesh Province. Future studies should validate these results under farmer-managed fields and explore genotype × environment interactions further.

CONCLUSION

As the third most important crop in Nepal, wheat has the potential to contribute significantly to socio-economic development if effectively cultivated and utilized. Its yield is influenced by various agronomical and genetic factors including the appropriate date of sowing and suitable variety. Yield contributing characters like TGW, Days to Maturity, and Grain yield are influenced significantly due to varied dates of sowing. TGW of the early sown cultivars is high (45.15 cm) and reduces by 1.3% when sown 10 days late and on late sowing 10 days further, the loss can reach up to 12.44% while comparing it to the 13 December sown crop. Banganga (4.59 t ha^{-1}) performed best under the 13 December sown condition and surpassed other varieties under the late sown conditions. On sowing on 13 December condition NL 1386 yielded the lowest and the least yielding variety was Borlaug 2020. While, Variety Gautam, NL 1386 yields higher when sown on 23 December. The difference in days to maturity is seen as significant and is decreased if late sown. Banganga variety is the earliest maturing variety (100 days) followed by BL 4341 while Borlaug 2020 takes the longest time (108.67 days) to mature. This experiment concludes that sowing Banganga on December 13 results in the highest yield (4.59 t ha^{-1}) with a short maturity period (101.5 days) and is suitable for recommendation in Madhesh Province, Nepal.

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Authors' Contributions

Nishchal Pokhrel being the corresponding author for managing all the events. All authors listed have made a substantial, direct and intellectual contribution to the research and approved it for publication.

Conflicts of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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