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Evaluation of Promising Lines and Biofortified Varieties of Wheat in Tikapur, Kailali, Nepal

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ABSTRACT

Variety is one of the major factors affecting the productivity of wheat in Nepal. To compare the performance of promising lines, zinc fortified wheat and popular varieties of wheat, the field experiment was laid out in randomized complete block design at Agronomy farm of Far Western University, Tikapur, Kailali during November 2022. Observations were made on the growth stages, plant height, yield attributing traits and yields. The results revealed significant variation among the varieties at 5% level of significance. Among the promising lines compared, NL 1451 was significantly superior ($p \leq 0.05$) in yielding the number of effective tillers (338), grains per spike (48), grain yield (3.79 t ha^{-1}) and straw yield (7.07 t ha^{-1}) but BL 4951 had significantly smallest plant height and spike length. Similarly, NL 1446 also performed better after NL 1451 yielding more than 3.5 t ha^{-1}. Among the recommended varieties compared, Zinc gahun-2 performed poorly than Zinc gahun-1 in all the parameters except for total tiller count, effective tiller count, grain filling period and peduncle length. BL 4951 outperformed all the Nepal lines and varieties in plant height and spike length but could not perform better in other parameters.

Keywords: Promising lines, Zinc fortified, Grain diameter, Phenology, Yield attributing traits

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INTRODUCTION

Wheat, the second most important cereal crop after rice in terai region of Nepal, occupies 716,978 ha land and produces 2,144,568 tons of wheat (MoALD 2023). Rich in carbohydrate (70-80% of total grain mass), proteins (9-18%), fiber, vitamins and many macro- and micro-nutrients including calcium, zinc, iron and Selenium (Igrejas and Branlard 2020, Šramková et al 2009), this crop plays important role in food and nutritional security of Nepalese population. In Nepal, where agriculture contributes 23.95% to the country's GDP, wheat crop alone contributes 5.67 % to the AGDP in the year 2023 (Agriculture and Livestock Diary 2080). Rice-wheat cropping sequence is commonly practiced in South Asia and Nepal has 0.5 M ha under this cropping system (Bhatt et al 2016), where majority of the growers are small holders having less than 1 ha land (Gc and Hall 2020). Several problems like formation of hard pans, degradation of soil due to excessive use of chemical fertilizers, sudden out breaks of diseases and pests, soil water depletion, (Dawadi et al 2023; Subedi et al 2019) and lack of technology adoption by farmers persists in this cropping system, which limits the production of wheat. Besides, access to quality seeds of improved varieties during sowing, fertilizers especially for top dressing and extension support services during growth stages and mechanization has been identified as major factors limiting the production of wheat in Nepal (Devkota et al 2020). Despite an increase in productivity of this crop, current production is not sufficient enough to meet the country's demand. The area under wheat has declined by 5.64% in the last 10 years (MoALD 2023) and there has been a rise in import of wheat by 34.15% over the past 10 years (FAOSTAT

2023).

To overcome such challenges and improve the yield of wheat crop, the government of Nepal has prioritized this crop along with others in its policies, plans and programs. Government of Nepal, under PMAMP has declared Kailali district of Far Western Province as wheat super zone for transformation in wheat production and technology. Kailali district alone occupies 23.8% of land area under wheat at Far Western Province. Despite such efforts, the productivity of Far Western Province is the lowest (2.56 t ha^{-1}) among all the provinces in Nepal. Lack of fertilizers during sowing, attack of insect pests, lack of mechanization, quality seeds and irrigation has been identified as the major challenges to wheat production in this region (Devkota et al 2020). Most of the varieties grown by the farmers are susceptible to new strains of wheat rust (Timsina et al 2018, Upadhyaya et al 2021) and hence, suitable high yielding varieties adapted to this region be promoted, replacing the low yielding traditional varieties with high yielding wheat varieties for improving wheat production and productivity (Prasai and Shrestha 2015). Altogether 42 improved varieties of wheat for different ecological regions including 5 biofortified varieties of wheat has been recommended and 13 varieties have been denotified due to genetic deteriorations, susceptible to disease and mostly non-preferred by farmers (SQCC 2023). So, with the aim to contribute to the production and productivity of wheat through appropriate varieties, this study tried to evaluate the performance of promising lines and biofortified wheat and compare them with commonly grown wheat varieties under Tikapur condition, this experiment was conducted.

MATERIALS AND METHODS

Experimental site

The study was conducted at Agronomy Farm of Far-western University, Faculty of Agriculture at Tikapur, Kailali during November, 2022 to April, 2023. Located at 28°31'30" North and 81°07'15" East at an elevation of 158 meter above sea level, the site had sandy soil with low organic matter content (1.45%) having pH 6.5. With low levels of nitrogen, phosphorous and potash content, as shown in Table 1. The site received a total of 60.02 mm precipitation during the experimental period, with the highest 15.5 mm maturity stage. The average maximum temperature during the study period was 25.1^{0}C with average minimum temperature 10.70^{0}C. The temperature reached up to 31.73^{0}C during the grain filling stage whereas the lowest was recorded during stem elongation phase (8.07^{0}C).

Table 1. Physicochemical properties of soil at study site, 2022

Description	Content	Type/level
Soil type	sandy soil	-
pH	6.5	Slightly acidic
Organic matter	1.45 %	Low
Nitrogen	0.07 %	Low
Phosphorus	17.49 kg/hectare	Low
Potash	108.0 kg/hectare	Low

(Source: Soil and fertilizer testing laboratory, Sundarpur, Kanchanpur, Nepal)

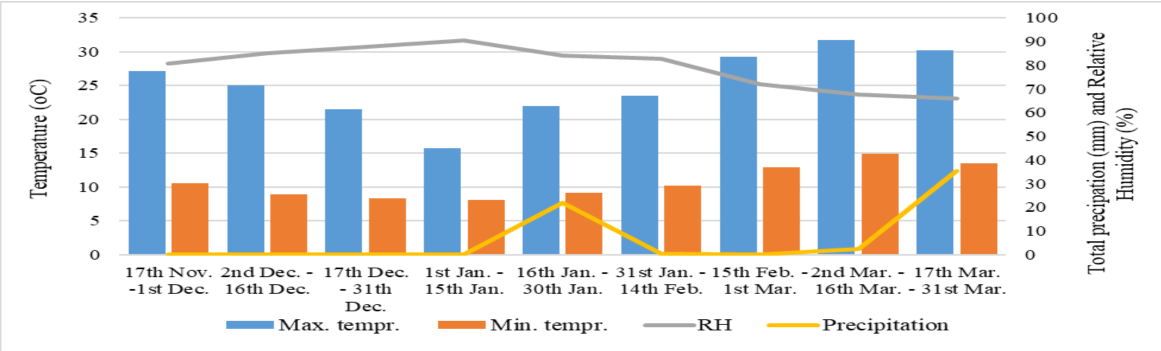

Figure 1. Weather and climatic conditions during experimental field at Tikapur, Kailali, Nepal.
(Source: Department of hydrology and meteorology, Babarmahal, Kathmandu, Nepal)

Experimental materials

For evaluation, six promising lines (Bhairahawa Line and 5 Nepal lines), two bio-fortified varieties and two popular varieties, obtained from Regional Agriculture Research Station, NARC, Khajura, sown on 17th

November, 2022 for this study.

Table 2. Name of wheat genotypes used in the study

Wheat Genotypes	Details
BL 4951	Promising Bhairahawa Line
NL 1345	Promising Nepal Line
NL 1423	Promising Nepal Line
NL 1446	Promising Nepal Line
NL 1456	Promising Nepal Line
NL 1451	Promising Nepal Line
Gautam	Recommended variety for terai, taar and lower valleys of Nepal
Zinc Gahun-1	Recommended biofortified variety for terai & inner terai of Nepal
Zinc Gahun-2	Recommended biofortified variety for terai & inner terai of Nepal
Banganga	Recommended variety for terai, taar and lower valleys of Nepal

Experimental design

The design used in the experiment was RCBD (Randomized Complete Block Design) with three replications. Six wheat promising lines and recommended varieties including biofortified wheats were randomly arranged in each block. The size of the plot receiving a genotype/variety was 8 m^2 and the distance between each plot was maintained at 0.5m.

Cultural practices

Seeds were continuously sown in lines made 25cm apart after incorporation of basal dose of chemical fertilizers. The recommended dose nutrients i.e. 120:50:50 NPK kg/ha through urea, diammonium phosphate and muriate of potash, were used in the experiment. $1/3^{rd}$ of N and total amount of phosphorus and potassium were applied as basal dose, whereas the remaining $2/3^{rd}$ of N was applied 21 days after sowing (DAS) and 60 DAS respectively in splits after weeding. Irrigation was given four times at 21, 60, 80 and 90 DAS.

Data collection

Observations were recorded for plant height, tiller count, days to heading (DH), days to anthesis (DA), days to senescence (DS), days to maturity (DM) from randomly selected 10 plants from each plot. Plant height was measured from the base of the plant to the tip of the spike. DH was recorded when peduncles were visible in 50% of the plant population, and DA were recorded when yellowish anthers were visible in 50% spikes. DS was measured when 50% of the plant population had lost greenness in flag leaf. Similarly, DM was recorded for sampled wheat spikes when the seed produced cracking sound when placed between the teeth. Yield attributing traits like effective tillers, spike length and grains per spike were taken just before the harvest from randomly selected 10 plants. The parameters like seed length, seed diameter, thousand grain weight, grain yield and straw yield were recorded from 1 m^2 area after harvesting for each promising lines.

Statistical analysis

Collected data were tabulated and graphs were prepared in Microsoft excel whereas analysis of variance (ANOVA) table was prepared and the means were estimated and compared to R studio version 4.3.0, “doebioresearch” package.

RESULTS AND DISCUSSION

The study revealed significant differences in growth, yield attributes and yield among the wheat promising lines and varieties compared in the study.

Plant stand

Significant difference in the plant stand was observed across the genotypes compared, which was significantly highest ($p \leq 0.05$) for Nepal line 1345 followed by NL 1451. This genotype NL 1451 was statistically at par with NL 1423, NL 1456 and Zinc gahu-2. Among the Nepal lines, NL 1446 was significantly poor in germination and stand but was superior over all the genotypes compared in the study. Plant population from Zinc gahu-1 was significantly lowest among all the genotypes, but was statistically at par with BL 4951 and Gautam. The results revealed that Nepal lines were statistically superior over the local check Gautam, zinc fortified wheat varieties as well as Bhairawa lines in terms of plant stand at Tikapur condition. This implies that Nepal lines need lesser quantity of seed as compared to other varieties, compared in the study.

Total number of tillers

Observations made at different days after sowing showed significant differences in total number of tillers per square meter (Table 3). When compared at 60 DAS and 80 DAS, total tiller count increased for the varieties Gautam, Zinc gahun-2 and Banganga but decreased or remained constant for others indicating these varieties to be late tillering ones. The result also revealed that Nepal lines were quick to generate tillers than recommended varieties of wheat. Nepal lines and BL 4951 showed a significantly greater number of tillers per square meter ($p \leq 0.05$) than the recommended varieties of wheat tested in the study. The varieties Gautam, Banganga and Zinc gahun-1 were statistically poor in yielding number of tillers per square meter as compared to the Zinc gahun-2 at Tikapur condition. Similarly, among the Nepal lines, NL 1451 showed a significantly highest number of tillers followed by NL 1345 and NL 1423, whereas the lowest number of tillers were observed in NL 1456, which was statistically at par with BL 4951. The lowest number of tillers per plant was observed in Zinc gahun-2 whereas the highest number of tillers per plant were observed in NL 1423 during our observation. Similarly, NL 1345, NL 1456 and Gautam yielded relatively fewer tillers per plant than other varieties of wheat compared in the study. Difference in responses of different varieties to specific weather might be the cause of differences in the tiller count per plant, which has also been reported by Siyal et al (2021). Similarly, Khan et al (2021) and Rajbanshi et al (2024) have also reported significant difference in total number of tillers among wheat genotypes.

Effective tiller number

The number of effective tillers per square meter for wheat were found to be statistically highest in NL1451 followed by NL 1345 and NL 1423 respectively proving Nepal lines to be proficient in generating tillers with spikes, as compared to BL 4951 and other recommended varieties. NL 1451 yielded 25.27 % more effective tillers accompanied by low sterility percentage than poor performing Nepal line 1456. Similarly, among the recommended varieties, Zinc Gahun-1 and Banganga yielded statistically the lowest number of effective tillers, showing the death of a greater number of tillers in later growth stages than Gautam and Zinc gahun-2. 40.82% higher number of effective tillers were obtained in Zinc gahun-2 over Zinc gahun-1. Similarly, Zinc gahun-2 yielded 19.71% and 16.23% greater number of effective tillers over Banganga and Gautam varieties respectively. However, the number of tillers per plant in Zinc gahun-2 was found to be the lowest among all the lines compared in the study. Differences in root architecture and corresponding hormonal imbalances might have impacted the effective tiller number differently (Hodgkinson 2017), which might be due to difference in light and temperature responses among varieties (Rahman et al 2009). However, an increase in the number of productive tillers leads to greater yield, as only the effective tillers contribute to spikelet production. The dissimilarity in the number of effective tillers among genotypes has been documented in several studies (Khan et al 2021, Poudel et al 2020).

Table 3. Plant stand and tiller count per square meter of wheat promising lines at Tikapur, Kailali

Genotypes	Plant stand	Tillers (60 DAS)	Tillers (80 DAS)	Effective tillers at harvest	Tiller sterility %
BL 4951	187.66^{c}	342.33^{ab}	320.33^{cd}	267.67^{cd}	16.53^{a-c}
NL 1345	280.00^{a}	371.66^{a}	371.66^{ab}	315.66^{ab}	14.97^{a-e}
NL 1423	248.66^{ab}	371.33^{a}	368.66^{ab}	300.00^{bc}	18.58^{a}
NL 1446	237.66^{b}	354.66^{ab}	336.66^{bc}	286.00^{b-d}	15.01^{a-e}
NL 1456	248.33^{ab}	311.33^{bc}	311.33^{cd}	270.33^{cd}	13.05^{c-e}
NL 1451	262.33^{ab}	388.00^{a}	380.66^{a}	338.66^{a}	11.10^{e}
Gautam	188.00^{c}	232.00^{d}	246.3^{f}	217.66^{ef}	11.65^{de}
Zinc gahun-1	151.66^{c}	226.66^{d}	219.3^{f}	179.66^{g}	18.04^{ab}
Zinc gahun-2	247.00^{ab}	286.00^{c}	292.00^{de}	253.00^{ef}	13.34^{b-e}
Banganga	175.00^{c}	233.33^{d}	252.33^{ef}	211.33^{fg}	16.29^{a-d}
SEm (±)	13.63	16.35	13.87	11.98	1.60
F-test	***	***	***	***	*
$LSD_{0.05}$	40.50	48.57	41.21	35.60	4.77
CV %	10.60	9.08	7.75	7.86	18.73
Mean value	222.63	311.73	309.93	264	14.85

Note: SEm: Standard error of the mean, LSD: Least Significant Difference, CV: Coefficient of Variation, Ns: Non-significant, *: $p \geq 0.05$)statistically significant(, **: $p \geq 0.01$)statistically significant(, ***: $p \geq 0.001$)statistically significant), DAS: Days After Sowing

Plant height

Bhairawa line 4951 had statistically the longest plants i.e. 95.53 cm, as compared to others in the study. Significantly shorter plants were observed for the varieties Zinc gahun-2 which was 77.06 cm followed by

Banganga, which were statistically at par with each other. Similarly, NL 1423 was the tallest among the Nepal lines followed by NL 1451 whereas, NL 1446 was the shortest. The recommended varieties Zinc gahun-1 and Gautam performed equally in generating plant heights (near to 90 cm) and were statistically taller than other two recommended varieties. Different studies also reported the differences in plant height among the genotypes and varieties (Ali et al 2008; Prasai and Shrestha 2015). Research indicated apical dominance in some wheat varieties, which might have influenced the plant heights differently (Wang et al 2019). Despite the smallest height of Gautam during the early growth stage (40 DAS), the plant height was relatively the highest among Nepal lines and recommended varieties during the harvest. This revealed that some varieties perform poorly during the initial growth stage but attains good growth during the later stages. Hence in the areas where straw is burnt or where lodging due to wind or hailstorm is common in far western province, Zinc gahun-2 and Banganga could be recommended due to their shorter heights.

Table 4. Plant heights of wheat promising lines at Tikapur, Kailali

Genotypes	Plant height (cm)			
	40 DAS	**60 DAS**	**80 DAS**	**At harvest**
BL 4951	30.06^{a}	54.00^{a}	84.20^{a}	95.53^{a}
NL 1345	25.73^{bc}	45.23^{bc}	74.06^{bc}	87.46^{b-d}
NL 1423	24.06^{c}	39.16^{de}	72.80^{bc}	92.46^{ab}
NL 1446	28.03^{ab}	44.43^{bc}	70.76^{c}	82.23^{de}
NL 1456	23.36^{c}	42.10^{cd}	74.93^{bc}	86.56^{cd}
NL 1451	24.96^{bc}	40.93^{cd}	73.66^{bc}	88.13^{bc}
Gautam	19.23^{d}	36.00^{e}	64.93^{d}	90.16^{a-c}
Zinc gahun-1	23.43^{c}	44.93^{bc}	76.33^{b}	89.63^{bc}
Zinc gahun-2	23.43^{c}	43.83^{b-d}	72.40^{bc}	77.06^{e}
Banganga	24.33^{c}	47.63^{b}	74.03^{bc}	78.13^{e}
SEm (±)	1.15	1.63	1.85	1.81
F-test	***	***	***	***
$LSD_{0.05}$	3.42	4.86	5.5	5.38
CV %	8.08	6.47	4.34	3.62
Mean value	24.65	43.82	73.81	86.74

Note: SEm: Standard error of the mean, LSD: Least Significant Difference, CV: Coefficient of Variation, Ns: Non-significant, *: p ≥ 0.05)statistically significant(, **: p ≥ 0.01)statistically significant(, ***: p ≥ 0.001)statistically significant), DAS: Days After Sowing

Days to heading

The time taken for heading in wheat varied greatly with 78.6 to 85.6 days from the time of sowing, showing almost 10 days differences in reaching maturity. Among the tested varieties and promising lines, Banganga was early to reach heading stage followed by Zinc gahun-2 and NL 1345 whereas NL 1451 showed delayed heading. Again, Gautam and BL 4951 were statistically at par in days to heading (83.6 DAS), which was nearly one day earlier than Zinc gahun-1 variety. In line with our results, Zinc gahun showed heading in 83 days in a research report (NWRP 2021).

Days to anthesis

As observed in Table 5, NL 1423 and Zinc gahun-1 took more than 88 days to reach anthesis, which were significantly higher than others. Banganga reached anthesis stage quite earlier requiring only 82.33 days which was significantly lower than Gautam and Zinc gahun-2. Also, Bhairahawa line required longer duration for flowering and pollination, as compared to all the Nepal lines except NL 1423. Of the biofortified wheat varieties, Zinc gahun-1 was late to reach anthesis by 2 days than Zinc gahun-2.

Days to maturity

Nepal lines and Bhairahawa line required significantly longer periods to reach the senescence stage and maturity than the recommended varieties of wheat, except Gautam. Among the Nepal lines, NL 1451 required a significantly higher number of days to cut off the supply of food to the grains, as observed from the flag leaf color which reached maturity in 132.6 days, and was statistically at par with BL 4951. However, Banganga was quick to reach maturity requiring only 122 days as compared to biofortified wheat varieties, requiring more than 127.6 days. Temperature, relative humidity, moisture condition and the nutrient supplying capacity of soi influence the days to maturity and senescence, which also differs for varieties (Hill and Li 2022). The findings of Prasai and Shrestha (2015) and Bohara et al (2022) and also reported the difference in days to maturity among the tested wheat genotypes.

Grain filling period

Statistically significant variation in grain filling period of wheat was observed across the recommended varieties as well as promising lines at 5% level of significance. Among them, NL 1446 showed significantly longer grain filling period whereas, Zinc gahun-1 had the shortest duration i.e. only 29 days, which can be a great contributor to grain yield. Significantly higher numbers of days were required for NL 1451 and Gautam variety to cut off the supply of food to the grains, as compared to all other promising lines. Zinc gahun-2 took a statistically similar period for grain filling as required by Banganga and NL 1423. Despite the longer duration for anthesis, statistically lesser number of days were required by biofortified wheat varieties to reach senescence stage, indicating shorter grain filling period. This could be the reason for the lowest grain weight or yield from these Zinc gahun varieties. In line with these findings, grain filling period was found to be significantly correlated with grain yield at 1% level of significance (Tiwari 2007). Monpara (2011) also suggested that higher grain weight and longer grain filling are keys to yield improvement in wheat.

Table 5. Phenology of wheat promising lines at Tikapur, Kailali

Genotypes	Days to heading	Days to anthesis	Days to senescence	Days to maturity	Grain filling period
BL 4951	83.66^{b-d}	87.66^{ab}	119.66^{bc}	132.66^{ab}	32.00^{bc}
NL 1345	82.66^{d}	86.33^{b-d}	118.33^{cd}	130.33^{b}	32.00^{bc}
NL 1423	85.66^{a}	88.00^{a}	118.66^{cd}	131.33^{ab}	30.66^{cd}
NL 1446	83.00^{cb}	85.66^{d}	121.00^{ab}	131.66^{ab}	35.33^{a}
NL 1456	83.00^{cd}	85.66^{d}	118.00^{c-e}	130.66^{ab}	32.33^{bc}
NL 1451	85.33^{ab}	87.33^{a-c}	122.00^{a}	132.66^{a}	34.66^{ab}
Gautam	83.66^{b-d}	87.33^{a-c}	121.33^{ab}	130.66^{ab}	34.00^{ab}
Zinc gahun-1	84.66^{a-c}	88.33^{a}	117.33^{de}	127.66^{c}	29.00^{d}
Zinc gahun-2	82.00^{d}	86.00^{cd}	116.00^{e}	127.66^{c}	30.00^{cd}
Banganga	78.66^{e}	82.33^{e}	112.00^{f}	122.66^{d}	29.66^{cd}
SEm (±)	0.66	0.55	0.72	0.76	0.95
F-test	***	***	***	***	***
$LSD_{0.05}$	1.97	1.66	2.15	2.27	2.84
CV %	1.38	1.11	1.06	1.02	5.18
Mean value	83.23	86.46	118.43	129.66	31.96

Note: SEm: Standard error of the mean, LSD: Least Significant Difference, CV: Coefficient of Variation, Ns: Non-significant, *: $p \geq 0.05$)statistically significant(, **: $p \geq 0.01$)statistically significant(, ***: $p \geq 0.001$)statistically significant(

Spike length

Among the promising lines and recommended varieties compared in the study, Zinc gahun-1 and Banganga showed significantly longer spikes whereas Zinc gahun-2 had the shortest spike length at $p \leq 0.05$. Similarly, BL 4951 was superior to all Nepal lines followed by Gautam variety in this parameter. All the Nepal lines were statistically at par in spike length. However, at Tikapur condition, the length of spike was 20.23% greater in Zinc gahun-1 as compared to Zinc gahun-2. Ali et al 2008, Pandey et al 2017 also reported that the length of spike l was significantly different between genotypes.

Peduncle length

Significant variation in peduncle lengths were observed among promising lines, with BL 4951 having longest followed by NL 1423, which were statistically at par. Again, the peduncle length of wheat varied from 13.5 cm to 17.06 cm among the Nepal lines with the shortest in NL 1451, showing quick supply of food to the spike from its flag leaf. Significant role of peduncle has been identified in mobilization and storage of photosynthetic reserve, thus playing important role in grain yield (Paul and Duhan 2021). Similarly, Zinc gahun-1 and Banganga had statistically smaller peduncle length, as compared to Zinc gahun-2 and Gautam, which were vice versa for spike length. Significant relations were observed between grain weight per spike and peduncle length (Farooq et al 2018). Shorter peduncle length has the potential to improve grain yield by enhancing crop radiation use efficiency (Rebetzke et al 2011). Similar results were also reported by Rajbanshi et al 2024.

Grains per spike

Statistically greater variations were found among the Nepal lines where, significantly highest number of grains per spike was found in NL 1451 followed by NL 1456 and NL 1446 respectively, as observed in Table 5. But

NL 1456 was statistically superior to Zinc gahun-1 and Gautam, which were statistically at par with each other in yielding grains per spike. The results showed superiority of these two recommended varieties over Banganga. Zinc gahun-2 performed weakly with the lowest value of 36.61 grains per spike, which was 20.79 % and 19.32 % lower than Zinc gahun-1 and Gautam respectively. Variation in grains per spike was reported as genetic characteristics by different researches (Hsu and Walton 1971, Pandey et al 2017, Pant et al 2023).

Table 6. Yield attributing traits of wheat promising lines at Tikapur, Kailali

Genotypes	Spike length (cm)	Peduncle length (cm)	Grains per spike (No.)	Seed length (cm)	Seed diameter (cm)	Thousand grain weight (g)
BL 4951	9.83^{ab}	20.60^{a}	40.50^{de}	7.05^{b}	3.45^{de}	46.00^{bc}
NL 1345	9.30^{bc}	16.03^{c}	41.00^{d}	6.28^{e}	3.51^{c-e}	47.33^{b}
NL 1423	9.06^{bc}	20.56^{a}	40.27^{de}	6.65^{cd}	3.55^{c-e}	47.00^{bc}
NL 1446	9.30^{bc}	14.13^{de}	42.83^{b-d}	6.72^{cd}	3.73^{ab}	53.66^{a}
NL 1456	9.30^{bc}	17.06^{bc}	46.33^{ab}	6.64^{cd}	3.66^{bc}	47.33^{b}
NL 1451	9.16^{bc}	13.56^{e}	48.22^{a}	6.12^{e}	3.86^{a}	48.33^{b}
Gautam	9.53^{bc}	18.63^{b}	45.38^{a-c}	7.04^{b}	3.41^{e}	46.33^{bc}
Zinc gahun-1	10.46^{a}	15.46^{cd}	46.22^{a-c}	6.52^{d}	3.61^{b-d}	48.00^{b}
Zinc gahun-2	8.70^{c}	17.93^{b}	36.61^{e}	6.86^{bc}	3.64^{bc}	44.66^{c}
Banganga	10.60^{a}	16.80^{bc}	42.16^{cd}	7.46^{a}	3.60^{b-d}	51.66^{a}
SEm (±)	0.28	0.62	1.38	0.07	0.05	0.79
F-test	**	***	***	***	***	***
$LSD_{0.05}$	0.83	1.86	4.12	0.22	0.16	2.36
CV %	5.13	6.36	5.59	1,98	2.61	2.86
Mean value	9.52	17.08	42.95	6.73	3.60	48.03

Note: SEm: Standard error of the mean, LSD: Least Significant Difference, CV: Coefficient of Variation, Ns: Non-significant, *: $p \geq 0.05$)statistically significant(, **: $p \geq 0.01$)statistically significant(, ***: $p \geq 0.001$)statistically significant(

Seed dimension

Among the recommended varieties, Zinc gahun-1 had statistically smallest grain whereas Banganga had the longest grain followed by Gautam and Zinc gahun-2. Gautam variety, which had quite the longer seed with comparatively smaller diameter, was statistically at par with BL 4951 in seed length but inferior in seed diameter. It indicated that BL 4951 was rounder than Gautam. But among the promising lines, BL 4951 was quite longer than all Nepal lines with the seed length almost the double of diameter. Similarly, the seed of NL 1451 was statistically the smallest and plumpest as revealed by the smallest length and the highest diameter. Between the biofortified wheat varieties, the seed of Zinc gahun-1 was smaller in diameter and length than Zinc gahun-2.

Thousand grain weight

At 12% moisture, the weight of thousand grains ranged from 53.6g to 44.6g. The highest value for thousand grain weight (TGW) was obtained from NL 1446, which was statistically at par with Banganga. NL 1423, was quite inferior in generating bolder and plumper grains, when compared to all the Nepal lines, but was statistically at par with BL 4951. Similarly, Banganga being the plumpier, showed the highest value for thousand grain weight whereas Zinc gahun-2 had the lowest among the recommended varieties compared in the study. The result revealed that Zinc gahun-1 had the heavier seed which was 3.6% and 7.48% more than Gautam and Zinc gahun-2 respectively. In line with our findings, Sisay et al (2012) found that test weight was significantly influenced by the genotypes. Apart from genotypic differences, high temperature during the grain filling period might be the cause of lesser grain weight in some of the genotypes. High temperature build up leading to forced maturity has also been reported (Poudel et al 2020).

Grain yield

All the promising Nepal lines were superior in yielding total grains per unit area as compared to recommended varieties of wheat. BL 4951 could not perform well for yielding grains, which was statistically the lowest among all ($p \leq 0.05$). However, NL 1451 provided the highest number of grains (3.79 t ha^{-1}) which was 24.67% greater than Gautam and 32.51% greater than Zinc gahun-1. NL 1446 also performed better yielding more than 3.5 t ha^{-1}. Similarly, Gautam and Banganga were statistically at par in grain yield but were superior to biofortified wheat varieties. 5.92% lower grain yield was obtained from Zinc gahun-1 when compared with Gautam. The productivity of Zinc gahun-1, 2 obtained from this experiment (2.8 t ha^{-1}) is far lower than the yield potential, which might be due to planting times at Tikapur condition. The development of grain production per plant was also directly influenced by plant height and days to 50% heading (Bhardwaj et al 2023). This NL-1451 also has highest grain per spike, seed diameter, effective tiller which lead to increase in yield among all. This result corroborates with the findings by Joshi et al (2016), Upadhyaya and Bhandari (2022) and Regmi et al 2021, who also reported genotypic differences as the cause for variation in grain yield.

Table 7. Grain yield, straw yield and harvest index of wheat promising lines at Tikapur, Kailali

Genotypes	Grain yield (t/ha)	Straw yield (t ha^{-1})	Harvest index
BL 4951	2.49^{e}	6.57^{ab}	0.27^{c}
NL 1345	3.17^{c}	5.59^{b-d}	0.36^{ab}
NL 1423	3.30^{bc}	6.54^{ab}	0.33^{b}
NL 1446	3.57^{ab}	6.39^{a-c}	0.35^{ab}
NL 1456	3.09^{cd}	5.21^{d}	0.37^{a}
NL 1451	3.79^{a}	7.07^{a}	0.34^{ab}
Gautam	3.04^{cd}	5.39^{cd}	0.36^{ab}
Zinc gahun-1	2.86^{d}	5.76^{b-d}	0.33^{b}
Zinc gahun-2	2.82^{d}	4.97^{d}	0.36^{ab}
Banganga	3.02^{cd}	4.87^{d}	0.38^{a}
SEm (±)	0.10	0.37	0.01
F-test	***	**	***
$LSD_{0.05}$	0.310	1.11	0.03
CV %	5.80	11.09	5.97
Mean value	3.11	5.83	0.34

Note: SEm: Standard error of the mean, LSD: Least Significant Difference, CV: Coefficient of Variation, Ns: Non-significant, *: p ≥ 0.05)statistically significant(, **: p ≥ 0.01)statistically significant(, ***: p ≥ 0.001)statistically significant(

Correlation and regression

The relationship between growth parameters, yield attributing traits and grain yield were studied through simple correlation and linear regression analysis. The results showed positive correlation between grain yield and effective tillers (r =0.53**), grain filling period (r = 0.59***), days to maturity (r = 0.42*) and thousand grain weight (r = 0.49**). But significant negative correlation was observed between peduncle length and grain yield of wheat (r = -0.47**).

Table 8. Correlation analysis of different traits of wheat promising lines at Tikapur, Kailali

	ET	TS %	PH	SL	PL	DA	DM	GpS	TGW	GFP	GY
ET	1										
TS %	-0.27	1									
PH	0.16	0.08	1								
SL	-0.54**	0.30	0.18	1							
PL	-0.09	0.10	0.40*	-0.06	1						
DA	0.07	0.10	0.66***	-0.09	0.13	1					
DM	0.59***	-0.32	0.61***	-0.40*	0.08	0.57**	1				
GpS	-0.02	-0.07	0.17	0.21	-0.48**	0.19	0.12	1			
TGW	0.01	-0.01	-0.19	0.37*	-0.41*	-0.44*	-0.04	0.09	1		
GFP	0.47**	-0.48**	0.21	-0.24	-0.1	-0.11	0.63***	0.04	0.38*	1	
GY	0.53**	-0.28	-0.03	-0.26	-0.47**	-0.11	0.42*	0.29	0.49**	0.59***	1

Note: PH: Plant height; ET: Effective tillers; TS: Tiller sterility; SL: Spike length; PL: Peduncle length; DA: Days to anthesis; DM: Days to maturity; GpS: Grain per spike; TGW: Thousand grain weight; GFP: Grain filling period; GY: Grain yield

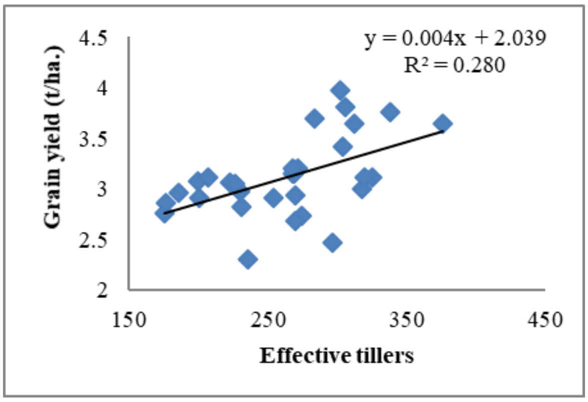

Figure 2. Correlation between grain yield and effective tiller

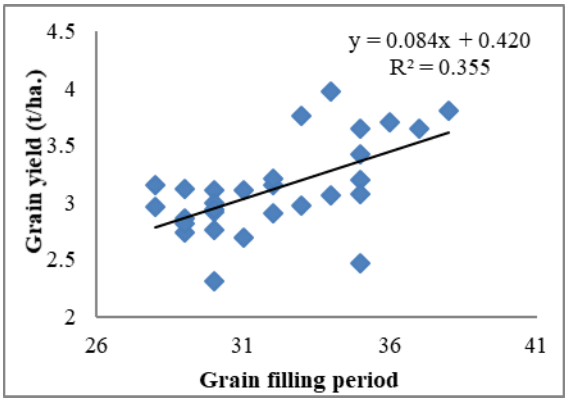

Figure 3. Correlation between grain yield and grain filling period

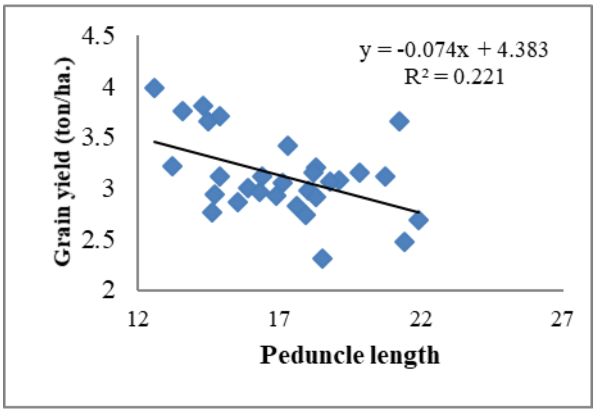

Figure 4. Correlation between grain yield and peduncle length

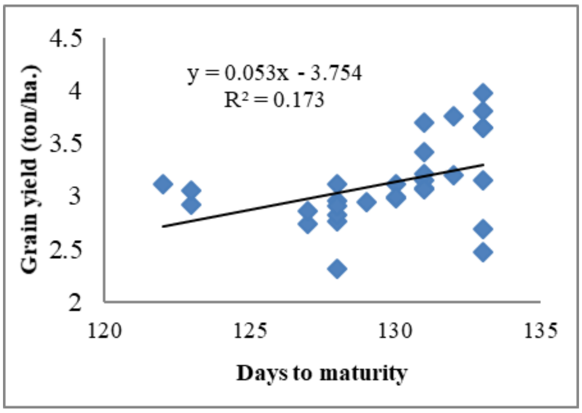

Figure 5. Correlation between economic yield and days to maturity

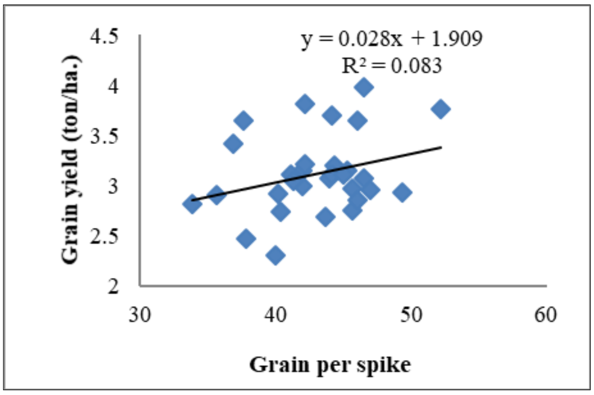

Figure 6. Correlation between economic yield and grain per spike

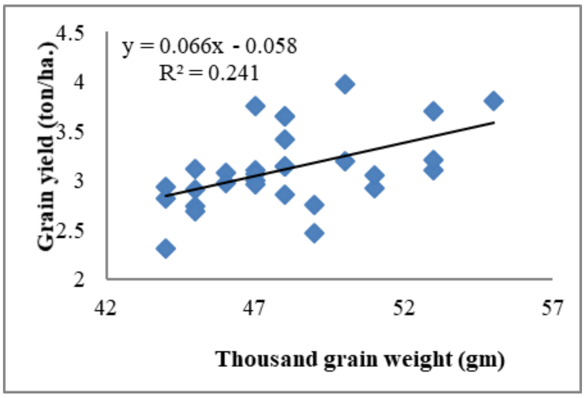

Figure 7. Correlation between economic yield and Thousand grain weight

CONCLUSION

The promising lines, NL1451 and NL 1446 performed better in grain yields due to significantly heavier grain size, longer grain filling period and days to reach maturity. The fortified wheat varieties could not yield higher than Gautam and Banganga varieties, however Zinc gahun-1 outperformed Zinc gahun-2 in most of the parameters revealing the potential to promote it, at far western province. Despite having higher number of grains per spikes, longer spikes, heavier grain size, the grain yield of Zinc gahun -1 was relatively low due to the lowest number of effective tillers and shorter grain filling period. Hence, it could be suggested to carry experiments on different dates of sowing at various locations, under different fertilizer condition and cropping system for Zinc gahun-2. Similarly, further studies to verify the potentiality of NL 1451 and NL 1446 could be suggested for validating the findings of this research.

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AUTHORS' CONTRIBUTION
Raksha Sharma conceived and designed the experiment, analyzed and interpreted the data, wrote the paper, finalized the manuscript; Devraj Rajbanshi performed the experiment, analyzed and interpreted the data, finalized the paper; Binod Bohara performed the experiment, reviewed the paper, interpreted the data, finalized the paper; Sangita Gaha Magar carried out the experiment, collected the data, interpreted the results; Ganesh Sharma carried out the experiment, collected the data, reviewed the paper.

CONFLICT OF INTEREST
The authors have no any conflict of interest to disclose.

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