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Comparative Study of Wheat (*Triticum aestivum* L.) Genotypes in Irrigated and Rainfed Conditions.

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Abstract
Wheat is 3rd major cereal crop of Nepal in terms of production and productivity, however, in a significant area wheat is still grown under rainfed conditions. There are very less wheat varieties particularly released for rainfed environments, indicating a very poor varietal choice for the farmers. This study aims to compare the performance of selected wheat genotypes under irrigated and rainfed conditions of the western terai region of Nepal to identify suitable genotypes for low moisture stress conditions. The experiment was conducted comprising 24 wheat genotypes including check varieties (Gautam, RR21, and Bhrikuti) in Alpha Lattice design with two replications at the Directorate of Agricultural Research, Lumbini Province, Khajura, Banke in 2021/22. The set of genotypes was evaluated simultaneously under rainfed and irrigated environments in an open field condition. In a rainfed environment, NL 1446 produced the maximum grain yield of 3488 kg ha-1, followed by NL 1437 (3357 kg ha-1). The highest grain yield under irrigation was obtained from NL 1503, which produced 4273 kg ha-1, followed by NL 1437 (4242 kg ha-1). Regarding grain yield, NL 1437 was observed to be a better genotype under both circumstances. NL 1437 produced an average grain yield of 3799 kg ha-1 after integrated analysis. According to the study, NL 1503 is the best genotype to be used, provided timely irrigation is guaranteed; otherwise, NL 1446 and NL 1437 are the best alternatives. NL 1437 gave the highest mean grain yield in both rainfed and irrigated conditions, thus having greater potential for cultivation in water-stress environments. Likewise, the results from the study can be helpful in breeding programs and facilitate the development of drought-tolerant wheat varieties.

Keywords: Wheat, Genotypes, Rainfed, Irrigated, Yield

Introduction

Wheat *(Triticum aestivum* L.) is one of the major staple crops cultivated worldwide, and its productivity greatly influences global food security. It is the third-most significant cereal crop and a key crop for Nepal's food security (Upadhyay, 2017). However, its production is highly dependent on environmental conditions, particularly water availability. Irrigated and rainfed environments represent two distinct agricultural settings with different levels of water supply.

According to a study's findings, Nepal's western area is most affected by the increase in the number of dry months and the frequency of droughts that coincide with the winter wheat cropping season. (Hamal et al, 2020). One of the primary abiotic issues limiting the global yield of wheat is moisture stress (Richards et al, 2002). About 21% of the wheat growing area of terai region of Nepal is rain-fed and partially irrigated (CBS, 2015). In Nepal, wheat is grown throughout the winter months, which are the drier period of the year, as the summer monsoon season, from June to September, receives between 70 and 90 percent of the nation's yearly precipitation (Nayava et al, 2009).

In comparison to irrigated conditions, the drought can cause the wheat grain yield to drop by more than 40% (Bohara et. al, 2023). Therefore, evaluating wheat genotypes for their performance in these environments is crucial for the development of crop varieties with enhanced adaptation and productivity under varying water regimes. This study aims to compare the performance of selected wheat genotypes under irrigated and rainfed conditions in western terai region of Nepal.

Objectives

i. To compare the yield performance of different wheat genotypes under rainfed and irrigated conditions.
ii. To identify the wheat genotypes that are better suited to rainfed or irrigated conditions of western terai region based on their performance.

Materials and Methods

Experiment site:

This experiment was conducted in open field condition at Directorate of Agricultural Research (DoAR), Lumbini Province, Khajura, Banke in
2021..

Geographically, it lies between 81^{0} 37” East longitudes and 28^{0} 06” North lattitude at an altitude of 181 meters above mean sea level. It receives an average annual rainfall of 1000-1500 mm.

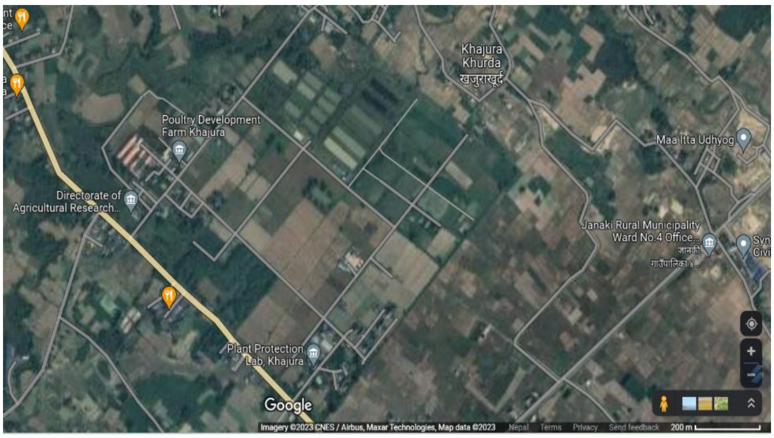

Figure 1: Map of the experimental site (DoAR, Khajura). *Source: Google map*

Agro-meteorological data:

The agro-meteorological information of the experimental site during the crop period was obtained from the meteorological station of DoAR, Lumbini Province, Khajura, Banke (Figure 2).

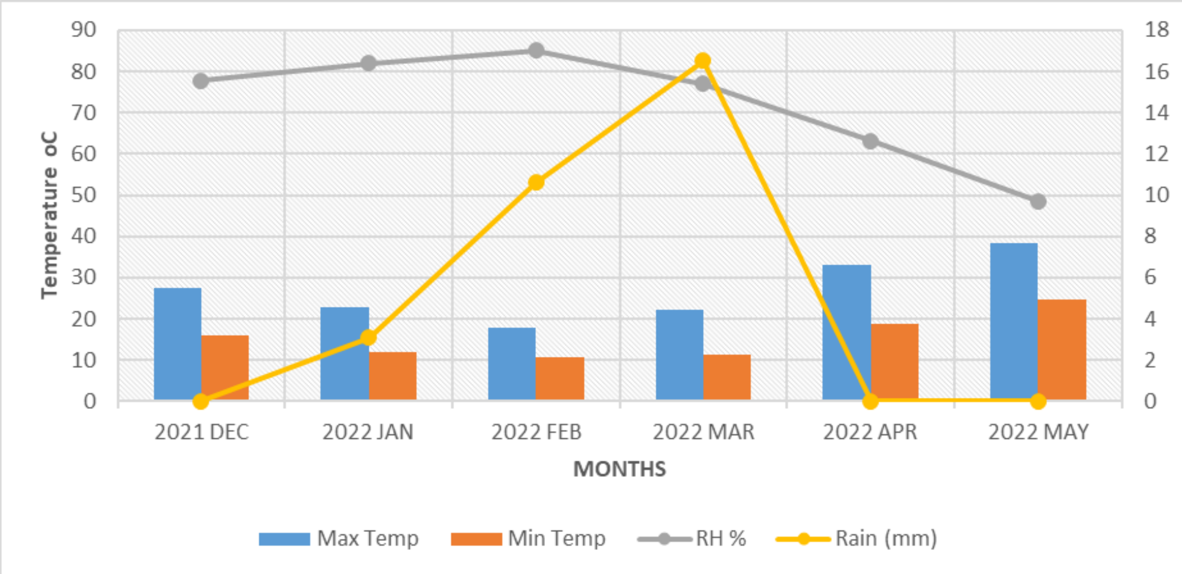

Figure 2: Agro-meteorological data of the crop growing period

Plant materials:

Two sets of twenty-four wheat genotypes including Gautam, RR21 and Bhrikuti as standard checks were obtained from National Wheat Research Programme (NWRP), Bhairahwa, Rupandehi, Nepal. Among twenty-four genotypes, four were Bhairahawa lines (BL), seventeen were Nepal lines (NL) and rest three were released varieties (Table 1). All the genotypes were treated with Vitavex @ 2gm/kg seed.

Table 1: Information of the wheat genotypes used in the experiment.

S.N	Genotypes name	Source	Origin	Parentage
1	BL 4984	NWRP, Bhairahawa	NWRP, Nepal	Not defined
2	NL 1437	NWRP, Bhairahawa	CIMMYT, Mexico	Not defined
3	NL 1445	NWRP, Bhairahawa	CIMMYT, Mexico	Not defined
4	NL 1446	NWRP, Bhairahawa	CIMMYT, Mexico	Not defined
5	NL 1447	NWRP, Bhairahawa	CIMMYT, Mexico	Not defined
6	NL 1450	NWRP, Bhairahawa	CIMMYT, Mexico	Not defined
7	NL 1451	NWRP, Bhairahawa	CIMMYT, Mexico	Not defined
8	NL 1452	NWRP, Bhairahawa	CIMMYT, Mexico	Not defined
9	BL 5099	NWRP,	NWRP, Nepal	Not defined

		Bhairahawa		
10	BL 5106	NWRP, Bhairahawa	NWRP, Nepal	Not defined
11	BL 5116	NWRP, Bhairahawa	NWRP, Nepal	Not defined
12	NL 1488	NWRP, Bhairahawa	CIMMYT, Mexico	Not defined
13	NL 1492	NWRP, Bhairahawa	CIMMYT, Mexico	Not defined
14	NL 1501	NWRP, Bhairahawa	CIMMYT, Mexico	Not defined
15	NL 1503	NWRP, Bhairahawa	CIMMYT, Mexico	Not defined
16	NL 1504	NWRP, Bhairahawa	CIMMYT, Mexico	Not defined
17	NL 1506	NWRP, Bhairahawa	CIMMYT, Mexico	Not defined
18	NL 1508	NWRP, Bhairahawa	CIMMYT, Mexico	Not defined
19	NL 1509	NWRP, Bhairahawa	CIMMYT, Mexico	Not defined
20	NL 1512	NWRP, Bhairahawa	CIMMYT, Mexico	Not defined
21	NL 1638	NWRP, Bhairahawa	CIMMYT, Mexico	Not defined
22	RR 21	NWRP, Bhairahawa	India	1154-388/AN/3/ YT54/NIOB/RL64
23	BHRIKUTI	NWRP, Bhairahawa	CIMMYT, Mexico	CMT/COC75/3/ PLO//FURY/ANA75
24	GAUTAM	NWRP, Bhairahawa	NWRP, Nepal	SIDDHARTH/ NING8319/NL297

Experimental design:

Two sets of the genotypes were tested simultaneously under rainfed and irrigated environment in an open field condition. The trial was set up in Alpha Lattice design with four blocks, six plots per block and two replications. Each genotype was continuously hand sown in a plot size of $10m^2$; ten rows of 4m length spaced at 25cm. A gap of 50cm was maintained between plots, blocks and a gap of 75 cm was maintained between the replications.

Fertilizer:

Urea, Di-ammonium phosphate (DAP), and Murate of Potash (MOP) was used as s source of nutrients. In rainfed experiment, the fertilizer was applied at the rate of 60:30:30 kg N: P2O5:K2O per hectare.

Full dose of N, P_2O_5, and K_2O was applied as a basal dose at the time of final land preparation, before sowing. In irrigated condition, the fertilizer was applied at the rate of 120:50:50 kg N: P_2O_5:K_2O per hectare. Half dose of nitrogen and full dose of P_2O_5, and K_2O was applied as basal dose during land preparation and remaining half dose of nitrogen was applied in two equal splits; one after first irrigation (28 DAS) and other at late booting stage.

Field preparation and sowing:
A pre-sowing irrigation was given prior tillage in both the trials to maintain optimum soil moisture at sowing. One disc harrowing and two crisscross plowing using rotavator (rotary tiller) was done to bring soil in good tilth.

Irrigation and weed management:
Only single pre-sowing irrigation was given to the rainfed experiment whereas for irrigated experiment, irrigations were given at CRI Stage (21 DAS) and booting stages (45 DAS) apart from pre-sowing irrigation were given during the crop period.
To control weed, pre-emergence herbicide, Pendimehtalin 30% EC was applied @2ml/l water in both trials within 72 hours of sowing when the soil was still moist.

Harvesting and threshing:
Net-plot harvesting of $8m^2$ (excluding border rows) was done manually with the help of serrated sickles when the spike and peduncle fully turned straw colored and became brittle. Threshing was done with the help of electrically powered plot thresher and the grain was stored in a cloth bags.

Data collection and analysis:
Agro-morphological data such as date of heading, plant height, spike length, date of maturity, grains per spike, 1000 kernel weight, grain yield, grain moisture etc. were recorded manually and processed using Microsoft Excel 2007. Analysis of variance was conducted using ADEL-R developed by CIMMYT, Mexico, and correlation analysis was performed by using IBM SPSS Statistics 20.

Results and Discussion

Days to heading and maturity:
There was highly significant difference ($P<0.001$) in days to heading and days to maturity for all the tested genotypes under rainfed as well as irrigated environment (Table 2). On an average, genotypes completed heading three days earlier in rainfed environment than in irrigated environment which is in agreement with the findings of Pokharel *et al.* (2013) and Olivares-Villegas *et al.* (2007), which stated that the moisture stress causes wheat to reduce their days to heading and anthesis. Likewise, genotypes showed earlier maturity in rainfed environment as compared to irrigated environment. This suggested that the wheat genotypes show earlier flowering and maturity under moisture stress condition. Similar result was obtained by Poudel et. *al* in 2020 while comparing wheat genotypes under irrigated and drought stress conditions. Among the tested genotypes, RR21 showed the earliest heading in both rainfed (72 days) and irrigated (78 days) conditions. Similarly, in rainfed conditions, RR21 and NL 1447 showed earliest maturity of 114 days while in irrigated conditions, RR21 showed earliest maturity followed by NL 1501 (116 days).

Plant height:

There was significant difference (P<0.05) in plant height for all the genotypes under both rainfed and irrigated conditions (Table 2). On an average, plant height of the wheat genotypes was reduced by more than 10cm in rainfed condition (83.3 cm) than in irrigated condition (93.8cm). Thus, it can be inferred that the plant stature reduces under low moisture stress condition.

Table 2: Mean of days to heading (DTH), days to maturity (DTM) and plant height (PH) in irrigated and rainfed conditions.

S.N	Genotypes	Days to heading (DTH)		Days to Maturity (DTM)		Plant height (cm)	
		Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated
1	BL 4984	75	82	116	123	85	98
2	NL 1437	84	87	120	126	81	94
3	NL 1445	88	90	120	128	85	102
4	NL 1446	78	81	115	119	79	84
5	NL 1447	81	83	114	120	86	94
6	NL 1450	78	84	115	123	83	91
7	NL 1451	81	85	118	120	81	93
8	NL 1452	85	87	119	126	74	95
9	BL 5099	86	88	116	128	91	106
10	BL 5106	86	87	120	125	83	95
11	BL 5116	88	88	119	125	88	97
12	NL 1488	79	82	116	119	89	97
13	NL 1492	85	87	118	126	87	98
14	NL 1501	76	81	115	116	79	94
15	NL 1503	86	87	120	126	81	91
16	NL 1504	87	89	118	125	87	103
17	NL 1506	86	85	117	123	85	92
18	NL 1508	87	88	120	128	78	89
19	NL 1509	75	81	116	120	82	86
20	NL 1512	82	84	119	124	82	91
21	NL 1638	88	90	119	124	82	89
22	RR 21	72	78	114	113	93	94
23	BHRIKUTI	79	82	115	123	78	83
24	GAUTAM	79	84	118	124	86	94
	Mean	**81.854**	**84.792**	**117.375**	**123.083**	**83.346**	**93.792**
	CV	**1.676**	**1.876**	**1.051**	**1.896**	**3.436**	**3.877**
	StdMSE	**1.372**	**1.591**	**1.234**	**2.333**	**2.864**	**3.636**
	LSD (5%)	**2.894**	**3.356**	**2.603**	**4.923**	**6.042**	**7.672**
	P-value	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**0.0014**	**0.0053**

Spike length, grains per spike, grain yield and TKW:

Significant difference (P<0.05) was observed among the genotypes in terms of spike length; however, no significant difference was observed for grains per spike, grain yield and thousand kernel weight (TKW). The average number of grains per spike, average grain yield and average TKW was found to be higher in irrigated condition than in rainfed conditions (Table 3). This result is in agreement with the findings of Bohara et. *al*, 2023. Highest grain yield of 3488 kg ha^{-1}, in rainfed condition was given by NL 1446 followed by NL 1437 (3357 kg ha^{-1}). In irrigated condition, highest grain yield (4273 kg ha^{-1}) was obtained from NL 1503, followed by NL 1437 (4242 kg ha^{-1}).

Table 3: Means of yield and yield attributing traits of wheat tested in rainfed and irrigated condition.

S. N	Genotypes	Spike length (cm)		Grains per spike		Grain yield(kg/ha)		1000 kernel wt. (gm)	
		Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated
1	BL 4984	10	10	37	47	2648	3686	37.4	39.1
2	NL 1437	11	11	49	46	3357	4242	38.8	39.1
3	NL 1445	10	11	36	49	2277	3888	39.6	38.8
4	NL 1446	10	10	42	51	3488	3449	29.2	39.4
5	NL 1447	10	11	46	51	2771	4145	39.9	41.5
6	NL 1450	10	11	43	53	2966	3848	27.0	40.2
7	NL 1451	10	10	50	51	3251	3723	38.2	37.5
8	NL 1452	10	11	38	54	2868	4114	35.3	43.3
9	BL 5099	9	10	32	44	2747	3934	32.5	35.9
10	BL 5106	11	10	36	49	2830	3777	39.3	36.5
11	BL 5116	12	10	41	42	2859	3560	39.2	34.0
12	NL 1488	11	10	39	43	2981	3163	39.5	39.2
13	NL 1492	10	10	44	47	2979	3731	37.3	41.3
14	NL 1501	10	11	49	42	2804	3245	31.0	36.6
15	NL 1503	10	11	59	55	2699	4273	38.2	36.8
16	NL 1504	11	11	34	47	2672	3026	39.9	39.7
17	NL 1506	10	12	43	50	2695	3609	26.9	36.9
18	NL 1508	10	10	37	46	2953	4031	39.2	39.5
19	NL 1509	10	9	34	44	3140	4021	31.8	37.4
20	NL 1512	10	10	40	44	3022	4171	38.1	45.2
21	NL 1638	11	11	56	49	2538	3442	34.1	33.5
22	RR 21	11	11	38	52	2628	2777	34.8	43.7
23	BHRIKUTI	10	11	44	53	2788	3124	34.5	40.5
24	GAUTAM	12	10	39	49	2892	4124	35.0	35.4
	Mean	**10.250**	**10.408**	**41.646**	**47.938**	**2868.56**	**3712.67**	**35.667**	**38.758**

					3	**5**		
CV	**5.439**	**4.959**	**8.553**	**9.066**	**4.764**	**3.452**	**3.979**	**6.271**
StdMSE	**0.557**	**0.516**	**3.562**	**4.346**	**136.648**	**128.174**	**1.419**	**2.430**
LSD (5%)	**1.176**	**1.089**	**7.515**	**9.169**	**288.303**	**270.424**	**2.994**	**5.128**
P-value	**0.0205**	**0.0099**	**<0.001**	**0.2426**	**<0.001**	**<0.001**	**<0.001**	**0.0155**

Combined analysis of variance:

On observing overall performance of genotypes on rainfed and irrigated environment, it was found that days to heading, days to maturity, and grains per spike had significant difference (P<0.05) while highly significant difference (P<0.001) was found for grain yield and thousand kernel weight (Table 4).

Table 4: Combined analysis of variance by environment and genotypes.

S. N	Genotypes	Days to heading	Days to Maturity	Plant height (cm)	Spike length (cm)	Grains per spike	Grain yield(kg/ha)	1000 kernel wt. (gm)
1	BL 4984	78	120	92	10	42	3167	38.2
2	NL 1437	85	123	88	11	47	3799	39.0
3	NL 1445	89	124	94	10	42	3082	39.2
4	NL 1446	79	117	81	10	46	3468	34.3
5	NL 1447	82	117	90	11	48	3458	40.7
6	NL 1450	81	119	87	11	48	3407	33.6
7	NL 1451	83	119	87	10	50	3487	37.9
8	NL 1452	86	123	85	10	46	3491	39.3
9	BL 5099	87	122	98	10	38	3340	34.2
10	BL 5106	86	123	89	11	42	3303	37.9
11	BL 5116	88	122	92	11	41	3209	36.6
12	NL 1488	80	118	93	10	41	3072	39.3
13	NL 1492	86	122	93	10	45	3355	39.3
14	NL 1501	78	116	86	11	46	3024	33.8
15	NL 1503	86	123	86	10	57	3486	37.5
16	NL 1504	88	122	95	11	41	2849	39.8
17	NL 1506	85	120	88	11	46	3152	31.9
18	NL 1508	87	124	83	10	42	3492	39.3
19	NL 1509	78	118	84	10	39	3580	34.6
20	NL 1512	83	122	87	10	42	3596	41.6
21	NL 1638	89	122	85	11	52	2990	33.8
22	RR 21	75	114	93	11	45	2702	39.2
23	BHRIKUT I	80	119	81	10	48	2956	37.5
24	GAUTAM	82	121	90	11	44	3508	35.2
	Mean	**83.323**	**120.229**	**88.569**	**10.329**	**44.792**	**3290.619**	**37.213**
	CV	**2.908**	**3.305**	**8.275**	**7.293**	**13.740**	**17.046**	**9.859**

StdMSE	**5.872**	**15.792**	**53.721**	**0.567**	**37.875**	**846.784**	**13.461**
LSD(5%)	**3.416**	**5.602**	**10.332**	**1.062**	**8.675**	**790.649**	**5.172**
P-value (G)	**<0.001**	**<0.001**	**<0.001**	**0.107**	**<0.001**	**<0.001**	**<0.001**
P-value (E)	**<0.001**	**<0.001**	**<0.001**	**0.292**	**<0.001**	**<0.001**	**<0.001**
G X E	**0.016**	**0.012**	**0.117**	**0.277**	**0.002**	**<0.001**	**<0.001**

Correlation analysis:

Correlation assesses the strength and direction of the relationship between two or more variables. A positive value of correlation shows that the changes of two variables are in the same direction, indicating, high values of one variable are associated with high values of other and vice versa (Sharma *et. al*, 2017). Correlation analysis was conducted among yield and yield attributes of rainfed and irrigated conditions and it was found that days to heading and days to maturity had strong, positive and highly significant correlation in rainfed conditions. Likewise, days to maturity and thousand kernel weight also had positive and significant correlations in rainfed conditions. Similarly, in irrigated conditions, days to maturity with days to heading, grain yield with days to maturity had strong, positive and highly significant correlation while days to heading with plant height, and grains per spike with spike length had positive and significant correlations.

Table 5: Correlation analysis of yield and yield attributing traits under rainfed and irrigated conditions

5.1. Correlation in rainfed environment

	DTH	**DTM**	**PH**	**SL**	**GPS**	**GY**	**TKW**
DTH	1						
DTM	.759**	1					
PH	-.076	-.266	1				
SL	.062	.253	.276	1			
GPS	.103	.124	-.324	.025	1		
GY	-.263	-.072	-.333	-.014	.083	1	
TKW	.353	.507*	.136	.315	-.039	-.147	1

5.2. Correlation in irrigated environment

	DTH	**PH**	**DTM**	**SL**	**GPS**	**GY**	**TKW**
DTH	1						
PH	.426*	1					
DTM	.855**	.318	1				
SL	.142	.036	-.017	1			
GPS	-.045	-.327	-.016	.480*	1		
GY	.350	-.012	.568**	-.194	.069	1	
TKW	-.351	-.078	-.184	.103	.251	-.015	1

***. Correlation is significant at the 0.05 level (2-tailed).**

****. Correlation is significant at the 0.01 level (2-tailed).**

Note: DTH =Days to heading, DTM= Days to maturity, PH= Plant height (cm), SL= Spike length (cm), GPS=Number of grains per spike, GY= Grain yield (kg/ha), TKW= Thousand Kernel weight (gm).

Conclusion

In a comparative study of twenty-four wheat genotypes simultaneously in the irrigated and rainfed environment, it was found that NL 1446 gave the highest grain yield of 3488 kg ha^{-1}, in rainfed conditions followed by NL 1437 (3357 kg ha^{-1}). In irrigated conditions, NL 1503 gave the highest grain yield of 4273 kg ha^{-1} followed by NL 1437 (4242 kg ha^{-1}). NL 1437 was found to be superior genotypes in terms of grain yield under both conditions. On combined analysis, NL 1437 gave an average grain yield of 3799 kg ha^{-1}. From the study, it can be concluded that if there is a certainty of a timely irrigation facility, NL 1503 is the best-suited variety else NL 1446 and NL 1437 are the best alternatives. The likelihood of these new, promising genotypes spreading to rainfed regions of the western Terai region is discussed in this study report. Such studies must be prioritized in the near future in order to identify domain specific wheat genotypes, particularly suited to Nepal's western Terai, which is prone to drought and a significant portion of agricultural land is rainfed. This research has limited scope to depict overall genotypic performance because it is concentrated on grain yield and some phenological traits only. To investigate the genotypes from many dimensions, further assessment for important diseases, yield-attributing traits, agronomic qualities, and quality attributes is required.

Conflict of Interest

The authors affirm that they have no known financial or interpersonal conflicts that would have seemed to have an impact on the research presented in this study.

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