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Research article

Assessment of different genotypes of wheat under late sowing condition

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ABSTRACT

The research was conducted by sowing seven genotypes of wheat which were allotted in the Farmers Field Trial kit of National Wheat Research Program, Bhairahawa, Rupandehi. This study responds to the urgency to assess wheat (*Triticum aestivum* L.) performance in late sowing conditions. Sowing was done on the 17th of December and heat stress was induced due to the delay in sowing. For each genotype, yield attributing characters and physiological growth stages showed up differently, and the yield obtained was not similar. Among the parameters measured, genotypes with shorter vegetative periods and longer reproductive periods thrived well in existing environmental conditions. Days to anthesis and days to maturity were major parameters for selection criterion of yield effective genotype i.e., faster the anthesis, higher the yield; slower the maturity, higher the yield. Growth stages and quantitative yield attributing parameters justified the majority of variation in yield (80.2%) whereas the remaining is expected to be environmental and nutritional factors. Vijay variety (4.06 ton/ha) out-yielded the other six genotypes while NL1193 produced the least (1.97 tons/ha). Considering Vijay best, Vijay (4.06 ton/ha) and Gautam (3.52 ton/ha) are major genotypes recommended for the cultivation in a farmer's field with the least effect of heat stress in the Terai region of Nepal.

1. Introduction

As wheat (*Triticum aestivum* L.) accords 20% of the global protein and calorie diet, it is established as an impressive crop fostering hunger and enhancing food security in today's world (Shiferaw et al., 2013). Though it is the most cultivated cereal crop in the world, it is ranked third in terms of area of production as well as productivity in Nepal. With average productivity of 2.85 tons/ha, wheat is cultivated in a 703,992-hectare area of which 60% production is done in the Terai region only (MoALD, 2020b). Wheat has fascinating nutrient quality. Carbohydrates are the primary constituent and other crucial nutrients like vitamins, minerals, phytochemicals, and fibers are also found in it (Shewry and Hey, 2015). Wheat can be modified into diversified food products with or without processing i.e., bread, dhindo, biscuits, cookies, chapatti, noodles, and some baked foods and for the same reason, people in Nepal are devouring it, and the consumption rate is increasing rapidly (Maskey et al., 2007). Along with its increasing demands, problems associated with its production are also at a peak.

Nepalese farming system compasses small farm holders with land less than 1 ha with limited knowledge about mechanization and proper use of inputs (seeds, fertilizers, water supply, manures, etc.). Genotypes used for sowing and improper management practices seem to bring a yield gap. In research done by Chapagain and Good (2015), 18% genetic and 24% management gap was seen between the actual and attainable yield of wheat respectively. Choosing a suitable variety for particular climatic and sowing conditions is very important (Singh et al., 2006). Some of the wheat varieties were developed before Nepal Agricultural Research Council (NARC) establishment and these varieties are frequently used by farmers even with their high susceptibility to diseases (CIMMYT, 2020; Sanjiv et al., 2019).

Late sowing has been declared as one of the major problems in our agricultural system (Pecio and Wielgo, 1999). Wheat is a temperate crop that is susceptible to high temperature (Wang et al., 2016). Its different growth stages have different temperature requirements and when exposed to extreme temperature physiological behavior and yield are affected negatively (Oyewole, 2016). When the temperature rises above 24 °C and ranges towards 30 °C crop encounters heat stress (Barnabás et al., 2008; Prasad and Djanaguiraman, 2014). Heat stress experienced by the crop during anthesis and grain filling stage is known as terminal heat stress (Suryavanshi and Singh, 2016). This leads to various structural and physiological alterations in a plant like reduction in height of the plant, decreased spike length, number of grains, and total grain yield (Dwivedi et al., 2017; Ihsan et al., 2016).

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Sowing time plays a crucial role in wheat production. Generally, wheat is sown in the winter season from early November to late December in Nepal (Joshi et al., 2007). When sowing is delayed from November 21st to December 21st and ahead this is said to be a late sowing condition (Refay, 2011). Hereby in the late sowing condition grain filling stage is exposed to high temperature (Pandey et al., 2015). In research done by Thapa et al. (2020), a 62% yield reduction was seen in crop sown in January compared to one sown in November. In Terai and Siwalik hill plains, 84% of wheat is sown after rice harvesting and late sowing has been practiced mainly due to the conventional rice-wheat cropping system (Chauhan et al., 2012). This situation has aroused due to delays in the harvesting of previous crops; mainly rice, different technological and input shortages, intercultural handling issues, and post-harvest management problems (Dahal and BB Basnet, 2010).

Broadly this research is carried out to observe and compare the overall physical and physiological growth and yield potential of wheat crops under late sowing and irrigated condition in the Terai region of Nepal. It aims to expose the most suitable variety of wheat for farmers i.e., with less probable loss and more yield. The Research was carried out as Farmers' Field Trial (FFT) which uplifts R&D activities by evaluating proposed genotypes performance in actual farmers' fields (Ashby, 1987).

2. Materials and methods

2.1. Experimental site

FFT was conducted at Siddharthanagar Municipality, Paklihawa, Rupandehi, Nepal. Paklihawa lies on the Terai plan of Nepal (Figure 1) with an altitude of 100 masl, latitude 27°28′51.58″N and longitude 83°26′48.67″E. Soil in the field was mildly acidic (pH = 6.0) and sandy loam. Being a tropical region, the temperature of Paklihawa reached up to 35 °C during the research period as shown in Figure 2.

2.2. Planting materials

Seven wheat genotypes that were allotted in the FFT kit of Terai by the National Wheat Research Program (NWRP), Bhairahawa were sown. Mainly Nepal line (NL series) and Bhairahawa Line (BL series) were

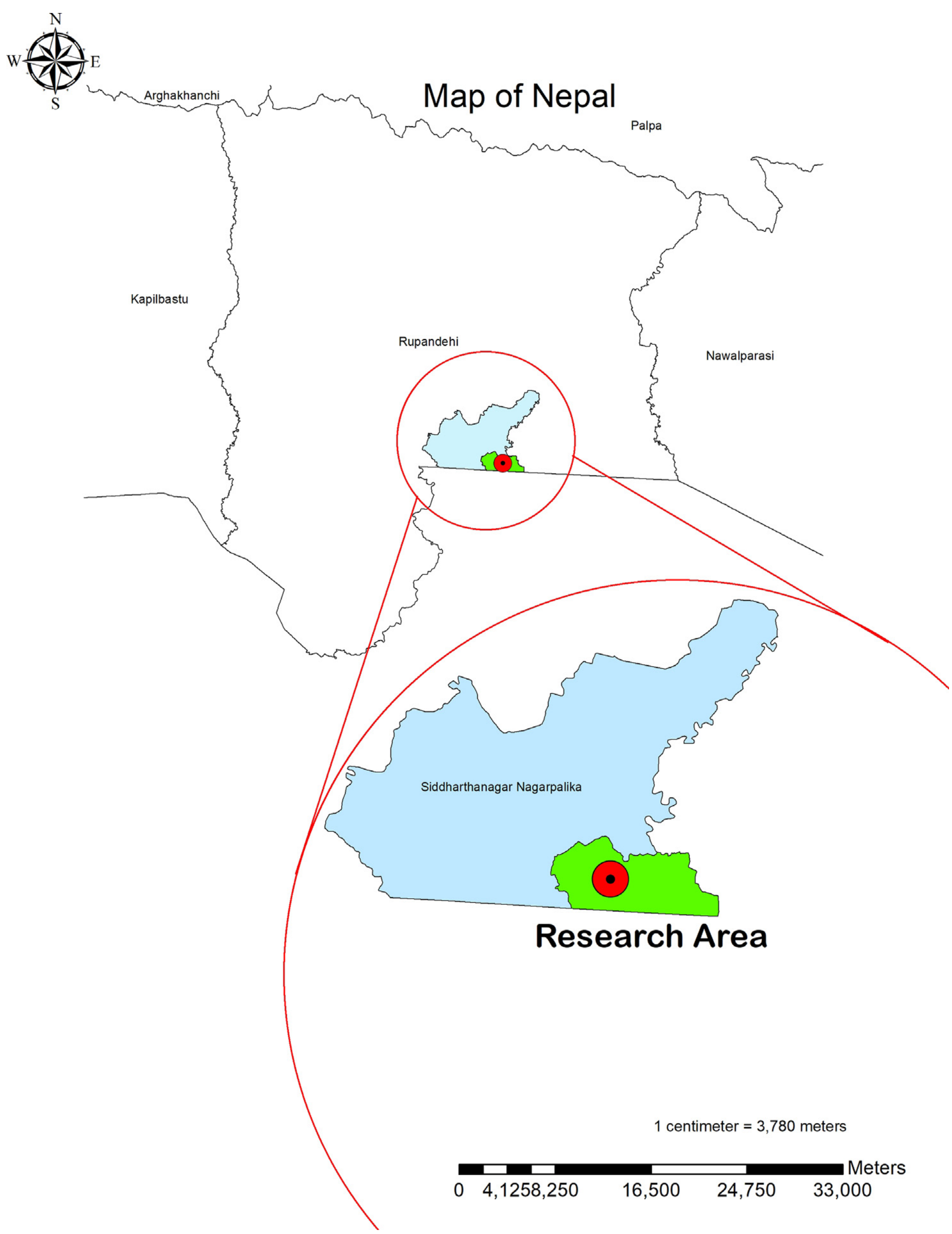

Figure 1. GIS map indicating study area.

included in the kit. Genotypes used with their source and origin are presented in Table 1.

2.3. Experimental design

Seven wheat genotypes were planted in RCBD (Randomized Complete Block Design) with three replications. Each block had seven plots with each plot of size 10 square meters. The Overall area of the field was 0.23-hectare (73 m*32 m). Spacing between two replications was 1 m and spacing between each treatment was 50 cm.

2.4. Cultural practices

Agronomic practices which include planting method, seed rate, depth of planting, weeding, irrigation, and harvesting method were the same for all treatments. The Field was irrigated the day before sowing which was done on the 17^{th} of December. Ideal seed rate in the context of Nepal i.e., 120 kg/ha was applied (NWRP, 2017). Sowing was done by line sowing method with Row-Row spacing of 20 cm and Plant-Plant spacing of 5 cm. Fertilizer was applied as recommended by Nepal Agriculture Research Council @120: 50: 50 NPK kg/ha (NARC, 2011). At the time of field preparation and final plowing $2/3^{rd}$ of Nitrogen and total dose of Phosphorous and Potassium was applied as basal dose along with FYM @ 7 ton/ha. Irrigation was done four times at critical growth stages i.e. I_1 tillering stage (27 DAS), I_2 booting stage (60 DAS), I_3 anthesis stage (79 DAS), and I_4 grain filling stage (90 DAS) (Maqbool et al., 2015). No external irrigation was done on other stages. The Remaining dose of Nitrogen was applied just after 1^{st} irrigation. Manual weeding was done at 20 and 40 days after sowing (DAS).

2.5. Data collection

Phenological data including crown root initiation (CRI), days to booting (DB), days to heading (DH), days to anthesis (DA), days to maturity (DM), effective tillering (TL), leaf number (LN), flag leaf length (FLL), plant height (PH) and grain yield (GY) were measured and collected carefully. Days to CRI were noted after 10 DAS until root was seen in all genotypes by uprooting destructive sample plants sown on the boundary of the main plot. DB was measured when 50% of the plant population had an observable swollen head on leaf sheath below flag leaf. DH and DA were recorded when 50% of the plant population had the emergence of ear head from a sheath of flag leaf and yellowish anthers were seen in spikes respectively. Similarly, DM was measured by counting days from the sowing time to the date when more than 50% of spikes turned yellowish. To measure GY, matured grains from a $2m^2$ sample area (avoiding border effects) were harvested, dried in bright sunlight, threshed, and weighed which was then converted into ton/ha. Thus, harvested grains were kept separately for different treatments. From each plot, ten random plants were selected and data for average PH, TL, FLL, LN were recorded. PH was measured at the time of harvesting from ground level to the level of the spikelet angled to the uppermost flag leaf.

Table 1. Complete list of wheat lines with their source and origin.

S. N.	Name of genotypes	Source	Origin
1	NL1164	NWRP, Bhairahawa	CIMMYT, Mexico
2	BL4463	NWRP, Bhairahawa	Nepal
3	BL4407	NWRP, Bhairahawa	Nepal
4	Vijay	NWRP, Bhairahawa	Nepal
5	BL4406	NWRP, Bhairahawa	Nepal
6	NL1193	NWRP, Bhairahawa	CIMMYT, Mexico
7	Gautam	NWRP, Bhairahawa	Nepal

2.6. Statistical analysis

Data entry and processing were done using Microsoft Office Excel 2019. Inferential data analysis like Analysis of Variation (ANOVA), least significant difference (LSD) of mean, coefficient of variation (CV), and probability value ($p \leq 0.05$) were calculated using software - R studio 4.0.3 using Readxl and Agricolae packages. Linear correlation analysis and simple linear regression were calculated using IBM SPSS Statistics 22.

3. Results and discussion

The Effect shown by late sowing conditions on a particular crop may vary with cultivar and species, their vigor, and vulnerability but each phenological stage was fairly been affected by its impact as stated by Wahid et al. (2007). Different genotypes showed distinct responses to the late sowing condition. Parameters were analyzed in two distinct categories; growth stage parameters and yield attributing characters. Interaction of different factors and their level of significance for various parameters were presented in Table 2 and Table 3.

3.1. Growth stage parameters

3.1.1. Crown root initiation

Days to CRI ranged from 14 days to 20 DAS with mean days of 16. Crown Root was first observed in Vijay variety (14 days) followed by NL1193 (14 days), BL4407 (15 days), BL4406 (15 days), NL1164 (16

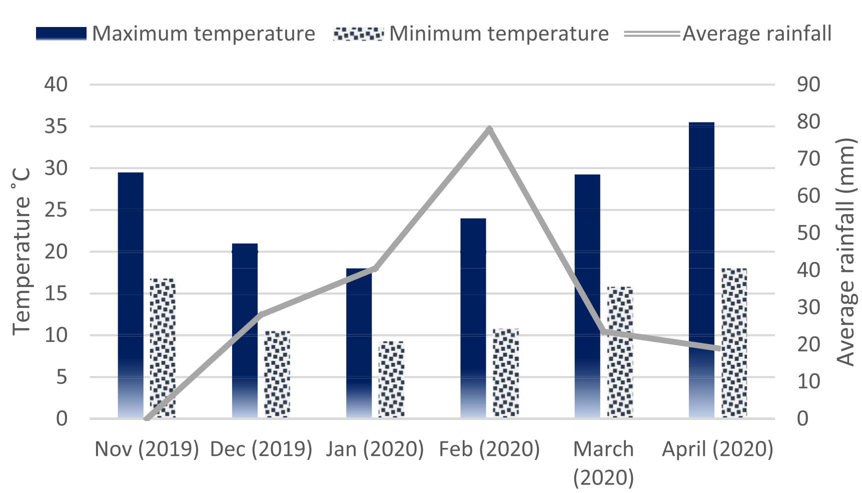

Figure 2. Distribution of temperature and rainfall in Paklihawa during the research period (DHM, 2020).

days), Gautam (16 days), and BL4463 (16 days) (Table 2). The difference in days to CRI was found to be highly significant among the genotypes. Varieties with earlier root growth have robust soil anchorage and a well-developed root system. The Nutrient is supplied earlier leading to healthier growth. One of the heat stress coping mechanisms of a plant is through evapotranspiration which depends upon water and nutrient supply from the root system (Lopes and Reynolds, 2010). Vijay being the one with earlier crown root initiation might have better growth even in late sowing conditions.

3.1.2. Days to booting

The booting stage is considered one of the temperature-sensitive reproductive phases of crop growth (Hossain et al., 2012). In the present study, genotypes booted in between 53 days to 67 DAS. Booting occurred earlier in Vijay (53 days) while NL1193, BL4407, NL1164, BL4406, Gautam, and BL4463 needed 54, 59, 60, 60, 62, and 67 days on average respectively. Genotypes had a significant statistical difference for DB with mean days of 59 (Table 2). Temperature above 30 °C for three days in a row at the booting stage leads to grain yield reduction (Alghabari et al., 2016). An increase in temperature during this stage intensifies the tiller mortality rate due to restricted nutrient availability (Kajla et al., 2015). The booting stage is attained earlier by resilient genotypes which then have to counteract less with high temperature leading to less heat stress impact. In another sense, genotypes taking a long time to attain the booting stage are prone to heat stress.

3.1.3. Days to heading

In given research, DH ranging from 63 to 73 days, the heading was observed first in Vijay (63 days). NL1193 (63 days), BL4407 (67 days), BL4406 (67 days), Gautam (68 days), NL1164 (68 days) were succeeding Vijay, and heading occurred at last in BL4463 (73 days) as shown in Table 2. The difference in DH was found to be highly significant among seven genotypes. DH was decreased for nine days when compared between wheat sown on the 10th of November and 25th of December (NWRP, 2017). Genotypes heading earlier are found to cope with heat stress-induced in late sowing conditions which helps to reduce yield loss (Tewolde et al., 2006) and are supposed to have better yield. When there occurs early heading, the grain filling period will be comparatively longer. This allows the crop to accumulate more photosynthate (Kajla et al., 2015) and increase energy accumulation which will compensate a part of yield loss due to heat stress. This indicates Vijay as a potential genotype.

Table 2. Comparison between seven wheat genotypes planted in Sidharthanagar, Rupandehi in terms of different phenological growth stages.

SN.	Treatment	CRI (days)	DB (days)	DH (days)	DA (days)	DM (days)
1	NL1164	15.67^{bc}	59.67^{bc}	68.00^{b}	82.67^{a}	101.00^{bc}
2	BL4463	19.67^{a}	67.33^{a}	73.00^{a}	83.00^{a}	106.67^{a}
3	BL4407	14.67^{cde}	58.67^{c}	66.67^{b}	76.67^{bc}	97.67^{c}
4	Vijay	13.67^{e}	53.00^{d}	61.33^{c}	74.00^{c}	105.67^{ab}
5	BL4406	15.33^{bcd}	60.33^{bc}	67.33^{b}	78.67^{ab}	100.00^{c}
6	NL1193	14.00^{de}	54.33^{d}	63.00^{c}	78.00^{bc}	97.00^{c}
7	Gautam	16.33^{b}	61.67^{b}	67.67^{b}	79.00^{ab}	106.00^{ab}
	LSD $_{(0.05)}$	0.91	2.99	3.67	4.37	5.18
	SE$_m$ (+-)	0.17	1.27	1.56	1.86	2.20
	F-test	***	***	***	**	**
	CV%	5%	2.83%	3.1%	3.11%	2.85%
	Grand mean	15.62	59.29	66.71	78.86	102

Note: the common letter(s) within the column indicates a non-significant difference based on the Duncan multiple range test (DMRT) at a 0.05 level of significance. LSD $_{(0.05)}$ indicates the Least significant Difference test at 0.05 level of significance. CV% indicates the Coefficient of Variation.
NS = non-significant.
*** = Highly significant.
** = moderately significant.

3.1.4. Days to anthesis

In this research BL4463 (83 days) and NL1164 (83 days) took longer time to attain the anthesis stage weighing with other genotypes i.e., BL4407 (77 days), NL1193 (78 days), BL4406 (79 days), Gautam (79 days) and Vijay (74 days) as seen in Table 2. The difference in days to anthesis was moderately significant statistically (Table 2). Air temperature of 12 °C - 22 °C is suitable for anthesis and grain filling period (Farooq et al., 2011). The period between anthesis to maturity is highly heat-sensitive (Hossain et al., 2012). Phenology of genotypes attaining anthesis stage latter will have longer vegetative phase than reproductive phase resulting limited time for grain filling. Higher temperature alters the process of photosynthate translocation, starch synthesis, and deposition in maturing grains (Kajla et al., 2015). In this case, genotypes attaining anthesis earlier should be preferred in late sowing conditions.

3.1.5. Days to maturity

The major indicator of physiological maturity was spikes and flag leaf turning yellow. Physiological maturity was first observed in NL1193 after 97 days of sowing which was followed by BL4407 (98 days), BL4406 (100 days), NL1164 (101 days), Vijay (106 days), Gautam (106 days), and BL4463 was the one to mature at last in 107 days (Table 2). DM for Vijay variety ranges 111–123 DAS and for Gautam, it is 117 DAS on normal sowing conditions (MoALD, 2020a). Due to unfavorable fluctuation in temperature, late sowing results in decreased phenological duration compared to normal sowing conditions (Yamamoto et al., 2008). The optimum temperature for the ripening period ranges from 21 °C -25 °C (Farooq et al., 2011; Flato et al., 2014). Wheat being more responsive to night temperature, it increasing from 20 °C to 23 °C decreases grain filling period up to a week (Prasad et al., 2008). In heat stress conditions, tolerant varieties generally have more grain filling periods compared to susceptible varieties (Sikder et al., 1999). Considering this, genotypes with more maturing days even in late sowing conditions can have surplus time for grain filling.

Table 3. Comparison between seven wheat genotypes planted in Sidharthanagar, Rupandehi in terms of morphological and yield parameters.

SN.	Treatment	PH (cm)	LN (/plant)	FLL (cm)	TL (/plant)	GY (ton/ha)
1	NL1164	68.03 ^{abc}	5.72^{ab}	19.17^{b}	3.50^{a}	2.43^{de}
2	BL4463	60.14^{bc}	5.83^{a}	21.58 ^{ab}	2.11^{b}	2.93^{cd}
3	BL4407	59.36^{c}	5.00^{c}	25.31^{a}	3.62^{a}	3.01 ^{bc}
4	Vijay	77.61^{a}	5.05^{bc}	19.98 ^{ab}	3.00^{ab}	4.06^{a}
5	BL4406	76.00^{a}	5.17 ^{abc}	20.28 ^{ab}	2.33 ^{ab}	2.84^{cd}
6	NL1193	71.19^{a}	4.50^{c}	16.86^{b}	2.83^{ab}	1.97^{e}
7	Gautam	70.11 ^{ab}	5.81^{a}	18.80^{b}	3.08^{ab}	3.52^{ab}
	LSD (0.05)	10.62	0.71	5.74	1.39	0.57
	SE$_m$ (+-)	4.51	0.30	2.44	0.59	0.24
	F-probability (genotype)	*	**	NS	NS	***
	CV%	8.66%	7.49%	15.91%	26.64%	10.81%
	Grand mean	68.92	5.30	20.28	2.92	2.97

Note: the common letter(s) within the column indicates non-significant difference based on Duncan multiple range test (DMRT) at 0.05 level of significance. LSD $_{(0.05)}$ indicates Least significant Difference test at 0.05 level of significance. CV% indicates Coefficient of Variation.
NS = non-significant.
*** = Highly significant.
** = moderately significant.
* = significant.

3.2. Yield and yield attributing characters

3.2.1. Plant height

Final height was maximum for Vijay (77.61 cm) followed by BL4406 (76 cm), NL1193 (71.19 cm), Gautam (70.11 cm), NL1164 (68.03 cm), BL4463 (60.14 cm), and least for BL4407 (59.36 cm) as seen in Table 3. The final heights were significantly different from each other. Along with heading and maturity, late planting decreases plant height compared to normal planting (NWRP, 2017; Singh et al., 2011). Too tall plants have lodging problems while too short plants have less yield. Hamam (2013) found 25.8% of average plant height reduction by heat stress as such Vijay variety being taller than other is seems to be less affected by higher temperature.

3.2.2. Leaf number & flag leaf length

Leaves were more in number in genotypes BL4463 (6), Gautam (6), NL1164 (6) while BL4406, BL4407, Vijay, and NL1193 had five leaves on average respectively (Table 3). Leaf numbers showed a moderate significant difference from each other. Leaves are the major site of photosynthesis in the plant. Since cell division and elongation process is altered by heat stress (Singh et al., 2014), the functioning of leaves is also expected to decrease in this situation. FLL was longest for BL4407 (25.31 cm) followed by BL4463 (21.58 cm), BL4406 (20.28 cm), Vijay (19.98 cm), NL1164 (19.17 cm), Gautam (18.8 cm) and NL1193 (16.86 cm). Though there was no significant difference between genotypes (Table 3), FLL has significant effects on various agronomic characters of each genotype (Liu et al., 2018). Various research declared that FLL has a determining role in the GY potential of the crop as it contributes to 50% proximate of overall photosynthetic activity and 41–43% of energy formation for grain filling (Sakamoto et al., 2006; Wang et al., 2011). Genotypes with optimal FLL will have more photosynthetic activity and more reserved food which can be used as a biological marker to predict GY (Tian et al., 2011; Wang et al., 2016).

3.2.3. Effective tillering

In this study, maximum tillering was about 4 tillers/plant seen in NL1164 and BL4407 genotypes. They showed an insignificant difference between genotypes with a grand mean of 2.92 tillers/plant. However, an increase in the number of productive tillers results in higher yield (Bassu et al., 2010; Sattar et al., 2010). Since all tillers are not productive, effective tillers are the ones to produce spikelets. Delayed sown condition might have reduced the number of effective tillers due to maximum air temperature during February (Bhattarai et al., 2015).

3.2.4. Grain yield

GY was obtained maximum from Vijay variety (4.06 ton/ha), followed by Gautam (3.52 ton/ha), BL4407 (3.01 ton/ha), BL4463 (2.93 ton/ha), BL4406 (2.84 ton/ha), NL1164 (2.43 ton/ha) and minimal yield was obtained from NL1193 (1.97 ton/ha). There were significant differences in yield among the genotypes of wheat which fits with the findings of (Ahmad et al., 2006; Khamssi and Najaphy, 2012). The average yield was calculated to be 2.97 ton/ha (Table 3). Under normal sowing conditions, the average yield of the Vijay variety is 4.45 tons/ha and Gautam is 3.4 tons/ha (MoALD, 2020a). Vijay variety had a minimal yield gap between normal and late sowing conditions while the yield of Gautam had no negative effect of late sowing at all. In late sowing conditions, crops face lower temperatures up to the booting stage and after that, they are exposed to an increasing temperature which has detrimental effects on grain development (Singh et al., 2011). Hereby phenotypical adaptation turns out to be different for each peculiar genotype which results in yield variation same as such stated by Jalal et al. (2008). A genotype is said to be flexible when it can perform well in any stochastic environmental condition (Ober et al., 2021).

3.3. Correlation and regression analysis

Correlation and regression analysis of GY of wheat and its related components has a vital role in the determination of appropriate genotype selection criteria and yield upliftment. The data concerning simple correlation coefficient (r) were presented in Table 4 while data regarding regression coefficient (b) and coefficient of determination (r^2) were tabulated in Table 5.

Table 4 shows the existence of the significant positive relationship between GY and DM which coincides with the findings of Nahar et al. (2010) that genotypes with more maturity duration are expected to have greater yield. A significant negative relation between GY and DA was seen (Table 4). When there is a large time gap between the sowing and anthesis period there is an ultimate decrease in yield but that doesn't mean anthesis is solely responsible for yield reduction as environmental and nutritional factors too are responsible (Midmore et al., 1984). Days to CRI, DB, and DH are found to have an insignificant negative correlation with GY (Table 4) referring they have less effect on grain yield. Research done by Munjal (2004) also shows a negative correlation between GY and DH. As discussed above, early development of the ear head has a positive role in yield increment and the more the time crop takes to initiate heading, the lesser it will have reproductive period. On the other hand, TL, FLL, LN, and PH were correlated with GY positively but

Table 4. Simple correlation coefficient (r) of grain yield and associated components among seven wheat genotypes.

Variables	GY	CRI	DB	DM	DA	DH	TL	LL	LN	PH
GY	1.00									
CRI	-0.092	1.00								
DB	-0.097	0.882***	1.00							
DM	0.544*	0.492*	0.361*	1.00						
DA	-0.39*	0.656**	0.613**	0.357*	1.00					
DH	-0.150	0.814***	0.91***	0.353*	0.776***	1.00				
TL	0.101	-0.264	-0.279	0.128	0.243	-0.023	1.00			
LL	0.203	0.119	0.114	0.028	0.037	0.115	0.177	1.00		
LN	0.273	0.574**	0.578**	0.486*	0.439*	0.490*	0.025	0.238	1.00	
PH	0.276	-0.356	-0.335	0.149	-0.149	-0.241	0.133	-0.53**	-0.292	1.00

* = Significant at 5% probability level YLD = yield, CRI = days to Crown Root Initiation, DB = days to booting, DM = days to maturity, DA = days to anthesis, DH = days to heading, TL = effective tillering, LL = leaf length, LN = leaf number, PH = Plant height.

*** = Highly significant.

** = moderately significant.

* = significant.

Table 5. Linear regression for the yield of wheat under the effect of different independent parameters.

Variables	Regression Coefficient (b)	Std Error	P-value	Coefficient of Determination (r^2)
CRI	-0.023	0.097	0.693	0.008
DB	-0.066	0.061	0.676	0.009
DM	0.094	0.023	0.011	0.296
DA	-0.189	0.038	0.046	0.152
DH	0.127	0.067	0.516	0.023
TL	0.043	0.121	0.66	0.010
FLL	0.049	0.026	0.37	0.041
LN	0.475	0.181	0.23	0.075
PH	0.020	0.011	0.22	0.076
				0.802 (Adjusted)

YLD = Grain yield, CRI = days to Crown Root Initiation, DB = days to booting, DM = days to maturity, DA = days to anthesis, DH = days to heading, TL = effective tillering, LL = leaf length, LN = leaf number, PH = Plant height.

insignificantly (Table 4) emphasizing that increments in these parameters tend to increase grain yield potential but in negligible amounts.

There is a significant positive relation between days to CRI and DB, DM, DA, DH, LN (Table 4) referring that genotype having earlier initiation of crown root will also have an earlier heading, booting, anthesis and maturity. Also, it has a positive role in the increment of leaf number. An insignificant positive relation between CRI and FLL and insignificant negative relation of CRI with TL and PH was seen suggesting a negligible impact of CRI in effective tillering, flag leaf length, and plant height of the wheat plant.

Similarly, there was seen significant positive relation between DB and DM, DA, DH, LN. If DB increases then related parameters will also increase simultaneously and vice versa. An insignificant positive relation between DB and FLL & insignificant negative relation between DB and TL, PH was found referring no relation between DB with FLL, TL, and PH. Here, DB is seen to be correlated with most of the other parameters significantly and this finding is similar to that of (Kaur et al., 2015). Other significant positive relations are in between DM and DA, DH and DA, DH and LN, also between LN and DA emphasizing that days to anthesis and leaf number would increase with an increase in days to heading. Days to maturity would increase with increasing days to anthesis. An increase in days to anthesis will result in a greater number of leaves as there will be a more vegetative phase ahead. A negative significant relation was seen between FLL and PH and also within LN and PH. This can be understood such that taller genotypes will have shorter flag leaf lengths and lesser numbers of leaves.

Table 5 shows the analysis of the magnitude of the relationship between yield (dependent variable) and nine independent variables. To analyze regression values precisely, the coefficient of determination (r^2) was calculated. The adjusted value of r^2 was 0.802 which indicated that 80.2% of yield variation is justified by mentioned nine variables. DM and DA justified 29.6%, 15.2% variation in yield respectively. Thus, they can be considered as strong parameters to predict GY potential. DA (−0.189) had the most negative influence on grain yield referring that a decrease in grain yield is expected when DA increases more than optimum days. Our result agrees with the findings of Woodruff and Tonks (1983) which state linear declination in yield of the wheat crop when DA exceeds beyond midwinter.

4. Conclusion

Time of sowing triggered the behavior of genotypes as late sowing induced heat stress. Varieties with a shorter vegetative phase and longer reproductive phase are the ones to yield more. Early emergence of the crown root, earlier heading, and booting, longer grain filling period had a positive role in yield increment. Besides, the genotype with a greater number of leaves, more productive tillers, longer FLL responded better with comparatively more GY. Having shorter DA and longer DM resulted in increased yield. Vijay (4.06 ton/ha) and Gautam (3.52 ton/ha) were top yielders in given environmental conditions. Vijay variety which outyielded all other genotypes had a minimum yield gap between normal and late sowing conditions. Also, its phenological duration and morphology were less fluctuated by induced heat stress. Hence, the Vijay variety is considered the best genotype for late sowing conditions in the Terai region of Nepal.

Declarations

Author contribution statement

Navaraj Upadhyaya: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Kalyani Bhandari: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data availability statement

Data will be made available on request.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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