EVALUATION OF DIFFERENT BARLEY GENOTYPES FOR THEIR PHENOLOGICAL TRAITS, YIELD AND YIELD ATTRIBUTES IN THE WESTERN MID-HILL OF NEPAL

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ABSTRACT

There is a need to increase the yield potential of barley by utilizing improved cultivars. So, the present study was done to assess the performance of barley genotypes for phenological and yield attributing traits. A field study was carried out at Lumle,Kaski in Nepal involving seven barley genotypes during two growing seasons in 2018/2019 and 2019/2020, employing RCB design replicated three times. The results, combined for the years, showed significant differences for all traits except effective tillers/m^2 and thousand grains weight. The grain yield was highest for B86122-1-0K-3 (2.756 t/ha and was at par with the genotypes Xveola-28 (2.411 t/ha) and B90K-024-1-1-2-0K (2.350 t/ha) and significantly higher than the Bonus (standard check) (1.852 t/ha). These superior genotypes should be further evaluated at on-station and on-farm conditions of western hills of Nepal so that low and stagnating barley yield in Nepal can be improved.[1]

Keywords: Barley, genotypes, phenological traits, grain yield

INTRODUCTION

Barley is an important and one of the first cultivated grains among cereals (Kant, 2016). It belongs to the grass family, Poaceae, the subfamily Festucoideae, tribe Hordeae and genus *Hordeum*. While the cultivated barley belongs to the subspecies *vulgare*, its wild forms belong to subspecies *spontaneous*. Barleys are self-pollinating and diploid annuals (2n=14). The barley spike has three florets contained in three each set of attached spikelets. The spike bears such spikelets in the alternate fashion to the side of the rachis. Depending on the numbers of kernels developed in the triplet, they are distinguished as six-rowed barley (all three florets developed into kernel) and two-rowed barley (only central floret developed into kernel and two lateral florets sterile)(MacGregor, 2003).

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In Nepal, there are hulled and hull less or naked barley (*Mudule jau, uwa*) in cultivation whose popularity differs according to location and their use. Owing to the range of nutritional benefits it possesses, barley is used as food for both humans and livestock and malting. Barleys are used for making *sattu* and *khole* in high hills and in mountainous regions (Paudel, 2016). The presence of high dietary fiber and β- glucan in barley makes it a better choice over other cereals (Naser *et al*., 2018). Barley has prospects for diverse end uses. Currently, barley's interest is increasing worldwide for its nutritional value, health benefits, and industrial importance (Al-Sayaydeh *et al*., 2019). Barley comes fourth in terms of production and productivity in the world (Erdenetsogt *et al.,* 2019). Globally, it was cultivated in 51 million hectares of land with production of 158 million metric tonnes for the year 2019 (FAOSTAT, 2021). It ranks fifth in Nepal's case in terms of area and production behind rice, maize, wheat, and finger millet (MoALD, 2020).The area, production and productivity of barley in Nepal for the year 2019 is 30550 ha, 24409 Metric tonnes and 1.25 ton/ha respectively. Nepal's barley yield increased from 1.058 tons/ha in 1961 to 1.238 tons/ha in 2018, growing at an average annual rate of 0.30 percent (FAOSTAT, 2020).With its ability to sustain biotic and abiotic stress, this annual cereal crop is cultivated from dry areas to humid subtropics (Sravani *et al*., 2018) and from the Terai to the high hills in Nepal (Baniya *et al*., 1997). Barley dominates the cropping system of the high hills of Nepal and grows under extreme weather conditions. Though barley is an underutilized crop in Nepal, it has a great potential for expansion (Agrawal *et al.,* 2018). The increased production and product diversification can contribute to food and nutritional security.

Poor Nepalese farming communities of the high hills cultivate barley for nutrition, socio-cultural preferences, traditional and religious uses. The stagnating yield of barley for decades indicates the inadequacy of research and development work in the crop. Besides, low productivity, deteriorating local food systems, changing food habits, and policy constraints for underutilized crops like barley are the challenges limiting their cultivation and consumption, leading to decreasing acreage and lower yield (Adhikari *et al.,* 2017). A range of agronomic factors like the genotype, seeding rates, climatic factors, soil fertility, weeds, etc., affect barley production (Tawaha *et al.,* 2003); however, the climatic conditions and the cultivar's response to them is the primary determinant. Thus, the evaluation of barley accessions for different agro-morphological traits and yield performance at different locations is crucial for crop improvement in Nepal (Kandel *et al*., 2019). There is a need to increase the yield potential of barley and reduce the gap between potential and realized yield by utilizing improved cultivars (Newton *et al.,* 2011). Therefore, the main objective of the study is to evaluate the phenological traits and the yield performance of barley accessions in the mid-hill climate of Lumle, Kaski.

METHODOLOGY

Plant Materials: In this study, seven barley genotypes were used that included a released barley cultivar (Bonus- Origin Sweden) as a standard check, a Lumle Jau as a local check, and rest 5 Nepalese barley breeding lines (Xveola-28, NB-1003-37/1214, B90K-024-1-1-2-0K and B86122-1-0K-3) were received from the Hill Crops Research Program of Nepal Agricultural Research Council at Kabre, Dolakha.

Field Experiments: The barley genotypes were grown for two growing seasons (2018-2019 and 2019- 2020) in agronomy fields of the Directorate of Agricultural Research (DOAR), Lumle, Gandaki Province ($28^0$17'49.75" N, $83^0$49'2.50" E; elevation: 1675 m). The soil type of the research plot was sandy loam (Table. 1). The climatic conditions for the area were recorded for both the experimental years (Table. 2). The crop was sown on 2^{nd} November 2018 for the first year and 5^{th} November 2019 for the second year at the rate of 120 kg seeds per hectare. Organic fertilizer was applied in the form of farm yard manure at the rate of 6 tons/ha, while the chemical fertilizer dose was 60:30:30 kg N_2:P_2O_5:K_2O/ha, provided through urea, diammonium phosphate, and muriate of potash. The experiment was conducted after the harvesting of the summer maize in the field.

The experiment was conducted in a randomized complete block design (RCBD) with three replications. Each plot area was 6 m^2 comprising eight rows having a length of three-meter. Seeds were sown continuously within the rows separated at a distance of 25 cm.

Traits Measurement: Days to 50% heading, days 80% physiological maturity (no green tissue remained in 80% of plants in each plot), plant height, spike length was measured. Effective tillers per meter square were counted.

Plants were harvested at maturity. Grains per spike were recorded from five randomly selected spikes from each plot. The four-meter square net plot were harvested. Grain yield was measured and adjusted to 12 percent moisture content. After proper drying, weight of thousand grains was taken.

Data analysis: The analysis of variance (ANOVA) and coefficient of variation (CV %) for traits under study were statistically analyzed using R- studio. Mean separation was analyzed using the least standard error of the difference between means and Least Significant Difference (LSD) test was done at 0.05 level of probability.

Table 1. Soil properties in the experimental field at DOAR, Lumle, Kaski, Nepal

Soil properties	Value	unit
P^H	4.8	
Soil texture	Sandy loam	
Soil Nitrogen content	0.26 – 0.45	Percentage
Soil available Phosphorus content	300	Kg/ha
Soil Available Potassium content	186	Kg/ha
Organic matter content	6.8	Percentage

RESULTS

Growing Seasons and Weather conditions: Analyzing weather data during the two growing seasons recorded at the meteorological station at DOAR, Lumle showed that mean, maximum and minimum temperatures for the first two months of growing seasons (November to December) were higher in 2019/2020 growing season except for minimum temperature in December 2020. The minimum, maximum and mean temperature in February, March, and April were higher in 2018/19 than in 2019/20 (Table. 2). The data for January looked similar for both the years.

Lumle is the region of highest rainfall in Nepal. The annual rainfall can exceed 5000 mm. In the first growing season (2018/19) there was less winter rainfall in before sowing period (October) and after sowing period (November and December) and higher rainfall during flowering phase (February) as compared to the second growing season (2019/20) (Table. 2).

Table 2. Temperature and Rainfall regimes during the experiment at DoAR, Lumle, Kaski, Nepal

Month	2018/19				2019/2020			
	Temperature (℃)			Total Rainfall (mm)	Temperature (℃)			Total Rainfall (mm)
	Max	Min	Average		Max	Min	Average	
October	20.4	11.3	15.9	50.8	20.8	12.5	16.6	245.6
November	17.7	8.5	13.1	8.0	19.3	10.4	14.8	10.0
December	14.1	4.8	9.4	0.0	14.3	4.7	9.5	55.6
January	13.9	3.8	8.9	76.9	12.7	3.9	8.3	99.0
February	15.1	5.8	10.4	141.8	14.3	5.5	9.8	55.7
March	19.1	8.2	13.7	68.1	18.6	8.1	13.3	83.7
April	20.9	12.6	16.7	232.5	20.6	10.9	15.8	305.2

Performance of barley under field conditions: Phenological traits like days to heading, days to maturity, etc. indicate the adaptability of the crop in the given environment.

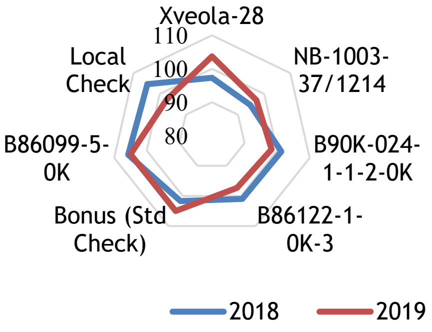

Figure 1. a. Radar diagram of days to 50% heading for genotypes in two different years

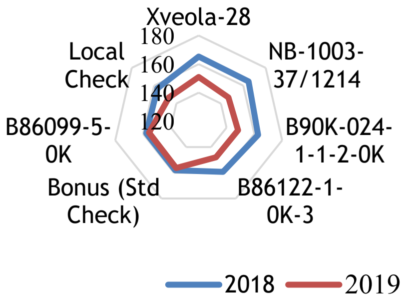

Figure 1. b. Radar diagram of days to 80% heading for genotypes in two different years

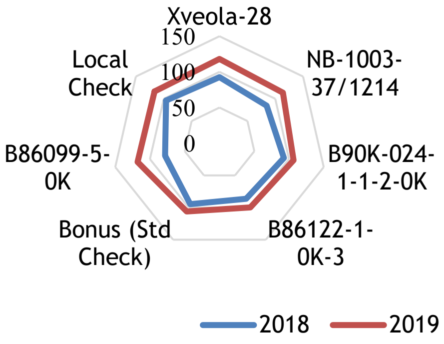

Figure 1. c. Radar diagram of plant height (cm) for genotypes in two different years

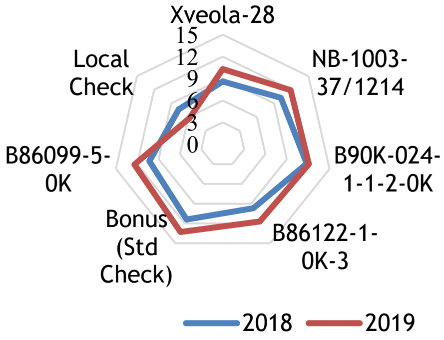

Figure 2. d. Radar diagram of spike length (cm) for genotypes in two different years

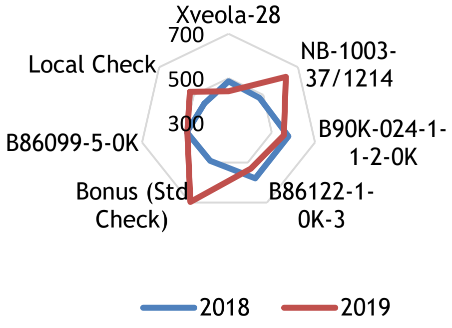

Figure 1. e. Radar diagram of effective tillers/m2 for genotypes in two different years

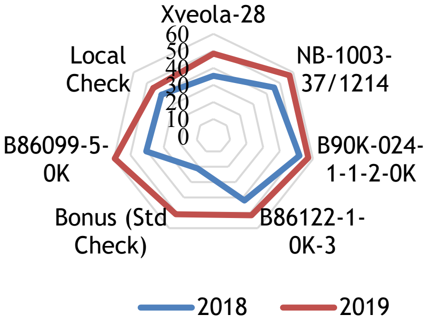

Figure 1. f. Radar diagram of grains per spike for genotypes in two different years

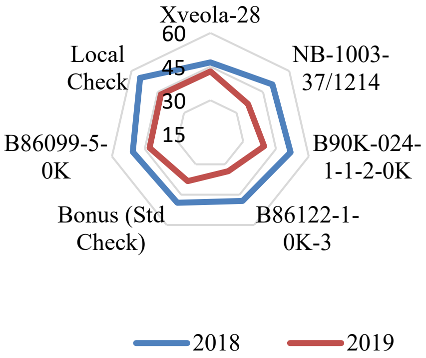

Figure 1. g. Radar diagram of effective tillers/m2 for genotypes in two different years

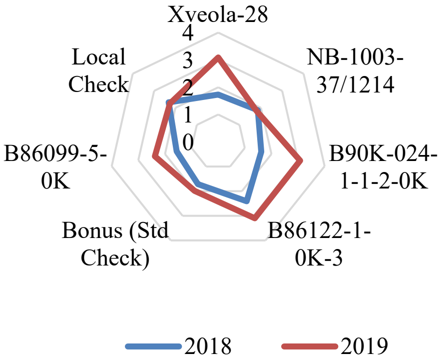

Figure 1. h. Radar diagram of grains per spike for genotypes in two different years

Some differences within the genotypes in their characteristics were observed in different years which were due to the differences in climatic conditions. The longest duration of 105 days for 50% anthesis was observed for the genotype B86122-1-0K in both the years while the genotype NB-1003037/1214 had the shortest duration of 95 days and 97 days in 2018 and 2019 respectively for 50% anthesis (figure 1. a). Some discrepancies among the genotypes were observed for the days to 80% maturity. Xveola-28 was late (165 days) to 80% maturity for the year 2018 while local check was earliest to mature. In the following year, Bonus (standard check) was late (156 days) in attaining 80% maturity (figure 1 b). Barleys grown in the year 2019 were relatively taller than the year 2018 (figure 1 c). The radar diagram for the spike length of genotypes in two different years shows that the longest spike (11.8 cm) was observed for the genotype B90K-024-1-1-2-0K in the year 2018 while the Bonus (standard check) had longest spike (13.3 cm) in the year 2019. In both the years Local check had the shortest spike length of 7.7 cm and 5.8 cm in the corresponding years (figure 1 d).

The number of effective tillers per meter square varied distinctly over the years of trial for genotypes namely NB-1003-37/1214 and Bonus (standard check) while it was similar for other genotypes. The highest number of effective tillers per meter square (578) was observed for the genotype B86099-5-0K in the year 2018 while bonus (standard check) had the highest (696) effective tillers per meter square in the year 2019 (figure 1. e). Higher grains per spike were observed in the year 2019 than 2018 for all genotypes. The highest number of grains per spike (59) was observed for the genotype B86099-5-0K in the year 2019 while it was highest (52) for the genotype B90K-024-1-1-2-0K in the year 2018 (figure 1. f). The highest thousand grain weight of 55.1 g and 43.2 g was observed for local check in the years 2018 and 2019 respectively (figure 1. g). Radar diagram for the grain yield shows that the year 2019 was better as compared to the previous year for the genotypes Xveola-28, B90K-024-1-1-2-0K, B86122-1-0K-3, B86099-5-0K while it was similar for others. The highest grain yield of 3.09 tons per hectare was observed for Xveola-28 in the year 2019.

The ANOVA for the years combined showed the significant differences among the genotypes for days to 50% heading and days to 80% maturity (Table. 3). The genotype NB-1003-37/1214 was earliest for 50 % heading, while the local check was earliest to mature, which was statistically similar to the genotype NB-1003-37/1214. In addition, the genotype B86099-5-0K showed delayed heading, whereas the genotype Xveola-28 was the latest to attain maturity. For plant height, clear significant differences were observed among the genotypes (Table. 3). The genotype local check was significantly tallest genotype, which was statistically similar to the Xveola-28, while the genotypes B86122-1-0K-3 and B90K-024-1-1-2-0K were significantly the shortest. For spike length, local check showed a significantly shortest spike, whereas Bonus (Standard check) showed the longest spike, which was not significantly different from all the genotypes except Xveola -28.

Table 3. Combined results on effect of genotypes on phenological and growth attributes of barley

Genotypes	Days to 50% heading	Days to 80% maturity	Plant height (cm)	Spike length (cm)
Xveola-28	101	158	105	9.5
NB-1003-37/1214	96	152	99	11.1
B90K-024-1-1-2-0K	100	156	93	11.9
B86122-1-0K-3	99	154	93	10.7
Bonus (Std Check)	103	157	100	12.4
B86099-5-0K	105	157	98	11.4
Local Check	101	152	106	6.8
Mean	100.7	155.5	100.26	10.5
CV (%)	1.46	0.43	2.78	9.67
$LSD_{0.05}$	2.62	1.19	4.97	1.81
P value	< 0.001***	< 0.001***	0.001**	< 0.001***

***refers to significant at 0.01 and *** refers to significant at 0.001 level of significance*

There was no significant difference between the genotypes for effective tillers per meter square (Table. 4). The mean effective tillers per meter square were 529.50. For grains per spike, the genotype B90K-024-1-1-2-0K showed significantly the highest grains per spike, which was statistically similar to the genotypes NB-1003-37/1214 and B86099-5-0K. There was no significant difference among the genotypes for a thousand grains weight. The mean thousand grains' weight was 44.9 grams. Combined over the years, data showed significant differences for grain yield (P= 0.005) (Table. 4). B86122-1-0K-3 was the highest yielding genotype, which was statistically similar to the genotypes B90K-024-1-1-2-0K and Xveola-28.

Table 4. Combined results on effect of genotypes on yield and yield attributing traits of barley

Genotypes	Effective tillers/m^2	Grains/spike	Thousand grains weight (g)	Grain yield (t/ha)
Xveola-28	463.7	41.9	44.9	2.411
NB-1003-37/1214	554.7	51.5	43.5	1.834
B90K-024-1-1-2-0K	566.5	54.5	45.7	2.350
B86122-1-0K-3	554.7	46.8	40.7	2.756
Bonus (Std Check)	594.0	36.0	43.7	1.852
B86099-5-0K	492.0	50.0	46.7	1.969
Local Check	480.7	42.1	49.2	2.288

Mean	529.5	46.1	44.9	2.209
CV (%)	15.97	8.32	9.00	11.02
$LSD_{0.05}$	150.57	6.83	7.19	0.43
P value	0.446	< 0.001***	0.320	0.005**

***refers to significant at 0.01 and *** refers to significant at 0.001 level of significance*

DISCUSSION

Theevaluation of agro-morphological, phenological and yield attributing traits of the genotypes has a direct relevance to farmers and the breeders (Gupta, Upadhyay, & Shah, 2014). There is necessity of testing these genotypes at different locations and different year for stability and adaptability studies because such studies are useful in recommending and releasing a genotype for cultivation in wide as well as specific environment. The variations in the traits like days to heading, days to maturity, plant height, spike length, effective tillers per meter square, and grain yield; within the genotype over the years could be due to the change in environmental factors (Figure 1). A good soil moisture content during sowing time and vegetative growth stage of the crop in second growing season (2019/20) might have led to better crop emergence, better nutrition use efficiency and better growth leading to higher plant height (Figure 1. c) as compared to first season (2018/2019) (Table. 2). The flowering phase was accompanied by higher rainfall in the first season (Table. 2) which might have affected pollination leading to lesser grains per spike in the first growing season (Figure 1. f.). The plant height was positively correlated to yield attributing characters in barley (Amgai, Pantha, Chettri, & Budhathoki, 2013). The higher plant height in second growing season (Figure 1. c.) might have contributed to the greater yield (Figure 1. h.)

The significant variation among genotypes in phenological and yield attributing traits like days to heading, days to maturity, plant height, spike length and grains per spike led to significant variation in grain yield. These results are in accordance to findings of Dhami *et al.,* (2017). The similar findings were reported for the genotypes under study in Coordinated Varietal Trial in RARS, Lumle in 2015/16 (Annual Report 205/16). These genotypes can perform differentially at different locations due to differences in microclimate and genotypes and environmental interaction. The genotypes Xveola-28, B86122-1-0K-3, and B90K-024-1-1-2-0K were better yielding genotypes as compared to the Bonus (standard check) and local check. They should be tested further in same location and other research areas from yield perspective.

CONCLUSION

The present study analyzed the performance of the barley genotypes in the climatic condition of Lumle, Kaski. The variability shown by the same genotypes in phenological and yield attributing traits in different year is the expression of temporal variability of climate. The result indicates possibility of these genotypes for cultivation in the western mid-hills of Nepal with similar altitude and climatic conditions. The higher yielding genotypes viz. Xveola-28, B86122-1-0K-3, and B90K-024-1-1-2-0K should be utilized for on farm and on station trial so that they can be released or registered for enhancing the barely production in Nepal.

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