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Performance of Some Broccoli Genotypes with Respect to Morphological, Phenological, Head and Yield Traits at Three Localities of Nepal

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ABSTRACT

Broccoli (*Brassica oleraceae* var. *italica*) belongs to the family Cruciferae which is mainly used as vegetable at its tender stage. The study was conducted to evaluate the morphological, phenological, head and yield traits of broccoli genotypes at Karma Innovative Research and Development Stations of Kathmandu, Kavre and Kaski district of Nepal from September 2019 to March 2020. The experiment was laid out on Randomized Complete Block Design with four replications at each location. Genotypes, location and interaction between them showed significant variation on almost all parameters. BL-17001, BL-18012 and Centauro genotypes were observed with no lateral heads, which means low yield than other varieties. BL-16003 was observed with maximum yield (1.0 kg plant^{-1} at Kathmandu and Kavre and 0.9 kg plant^{-1} at Kaski) at all locations comparing to other genotypes. Among high-yielding genotypes (BL-16003 and BL-18009), BL-16003 found as early maturing and also had lateral heads so, it can also be used for multi-harvesting. In addition, the height of this genotype was in the lower range with highest number of leaves. Thus, BL-16003 is found as the promising genotype at all localities.

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Introduction

Broccoli belonging to the group Cole crop is an edible green plant of species *Brassica oleraceae*. It's large flowering head is eaten as a vegetable at its tender stage. It was used as vegetable on Italy in ancient roman time and about 1720 in England. It is in the same group of cabbage, cauliflower, knol-khol, kale and brussels sprouts. However, among Cole crops, it is more nutritious. The edible portion consists of immature, fully-differentiated flower buds and tender portion of upper stem. This is a rich source of vitamins and minerals such as vitamins A, C, carotenoids, fiber, calcium and folic acid. It is also a rich source of sulphoraphane and is associated with reducing the risk of cancer (Guo et al., 2001). There are two types of broccoli i.e. heading and sprouting and most common is heading type on which large central head is consumed as vegetable just like cauliflower but sprouting types form one central sprout and many small florets and these types of broccoli are suitable for multi-harvesting. Likewise, three classes of broccoli are found according to the color i.e. green, purple and white however the green type are most popular (Shoemaker and Teskey, 1962). Farmers can gain a lot of profit by growing this vegetable as this attracts very high prices in cosmopolitan markets, star hotels and tourist places. This can also be exported to foreign countries especially to India as Nepal has climatic advantages over for the production of broccoli.

Broccoli can be grown in wide range of soil like light sand to heavy loam and even at the clay supplied with high range of organic matter. These are also adapted to grow at higher temperature than cauliflower (Rashid, 1976). Broccoli can be grown in cool season. Especially, it is more sensitive when the plants are at small and tender stage. Both very cold and warm weather are disadvantageous for the growth of broccoli. At cold condition it is susceptible to cold injury and at warm weather bud cluster loose quickly.

With the change in food habits and consciousness of people toward health and nutrition, broccoli is gaining popularity in Nepal. Realizing the tremendous potential of this vegetable at domestic and foreign market, Nepalese farmers are gradually shifting to cultivate broccoli in the place of cabbage and cauliflower. In Nepal, the total area under broccoli was 1986 ha in 2016/17 with the production

of 20,048 mt and productivity is 10 mt ha^{-1} (MOALD, 2017). The genotypes play an important role in growth, yield and quality of broccoli plants. Relatively few varieties of broccoli are used in Nepal but increasing interest of farmers on broccoli cultivation makes genotypic evaluation of necessary. Considering this, to popularize this high value crop among the farmers, the study was conducted to describe morphological, phenological, head and yield traits of six broccoli genotype and select the best at the condition of Nepal.

Materials and Methods

Experimental Location

This research was conducted at the three localities of Nepal i.e. Kathmandu, Kavre and Kaski of Nepal from September 2019 to March 2020 (Figure 1). The latitude, longitude and elevation of sites are presented on the Table 1.

Soil and Climate

The climate of Kaski is warm and temperate, the summers are much rainier than the winters. The average annual temperature in Kaski is 19.7°C and the rainfall is 2693 mm per year. The climate in Kathmandu and Kavre are classified as warm and temperate. The average annual temperature of Kathmandu is 17.6°C and precipitation here is about 1662 mm per year. Likewise, average annual temperature and rainfall of Kavre district is 17.2°C and 1745 mm per year respectively.

Composite soil sample was taken from top (0-30 cm) layer of experimental plot before transplanting broccoli seedlings. Instrumental analysis of soil was carried out to determine soil pH, soil electrical conductivity (EC) and general visual and feeling method is used to determine physical properties of soil. The information of soil analysis conducted by the Karma Groups of Companies is presented in the Table 2.

Experimental Design

The experiment was laid out on Randomized Complete Block Design (RCBD). The experiment consisted of five broccoli genotypes (collected from different sources) and one cultivar as shown in Table 3 and Figure 2 with four replications. The size of the individual plot was maintained at 4 m^2. Twenty-five plants were planted in each plot. The crop was planted at the spacing of 0.5 m x 0.5 m. One-meter distance was maintained between two adjacent replications. Similarly, distance between two adjacent plots was maintained at 0.5 m. Randomization of treatments was done by lottery method.

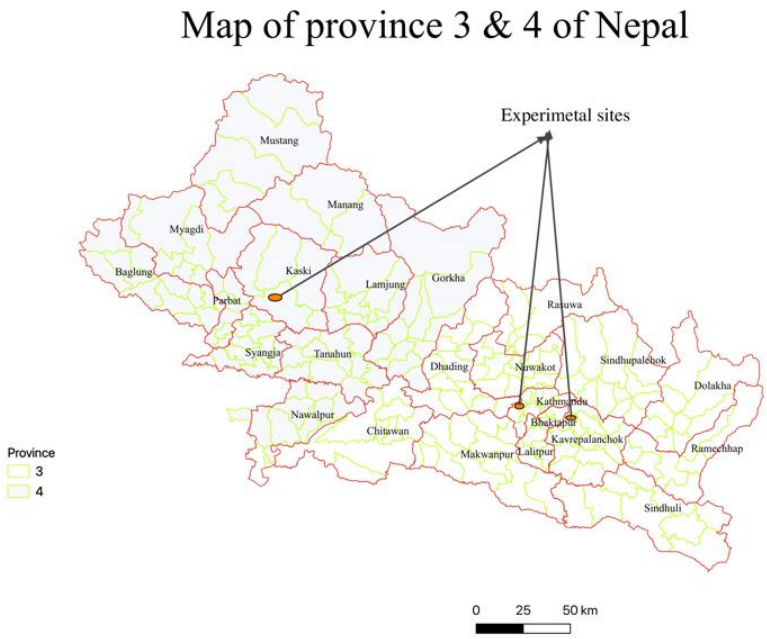

Figure 1. Administrative map showing different locations of the field experiments in Kathmandu, Kavre and Kaski districts of the Nepal

Table 1. Latitude, longitude and elevation of experimental sites

Location	Latitude	Longitude	Elevation
Kathmandu	27°42'59.99" N	85°26'59.99" E	1777 masl
Kavre	27° 36' 59.99" N	85° 32' 59.99" E	1500 masl.
Kaski	28° 19' 60.00" N	84° 00' 0.00" E	1058 masl

Table 2. Physical and chemical characteristics of soil of the three experimental sites, Nepal, 2019/2020

Location	pH	EC (mS/cm)	Texture
Kathmandu	6.0	0.21	Clayey
Kavre	6.1	0.49	Silty loam
Kaski	6.8	0.43	Sandy loam

mS/cm = miliSiemens/cm

Table 3. Description of broccoli genotypes used in the experiment as treatments

SN	Symbols	Broccoli varieties	Source
1	T1	BL-16003	Chia Tai Co., Ltd. (Thailand)
2	T2	BL-16076	Chia Tai Co., Ltd. (Thailand)
3	T3	BL-17001	Chia Tai Co., Ltd. (Thailand)
4	T4	BL-18009	Chia Tai Co., Ltd. (Thailand)
5	T5	BL-18012	Chia Tai Co., Ltd. (Thailand)
6	T6	Centauro	Takii Seeds Pvt. Ltd. (Japan)

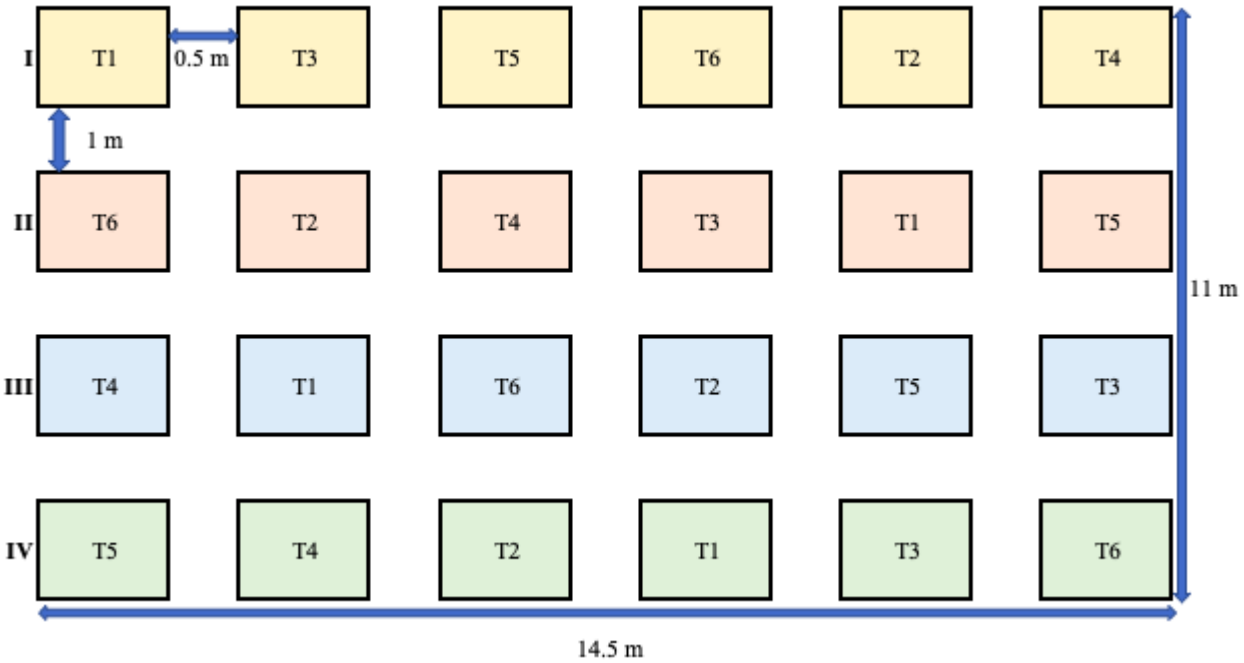

Figure 2. Layout and geometry of experimental field

Management

The experimental field was prepared by deep digging, a week before the date of transplanting. The layout was done prior to transplanting. Akanee @ 52.5 g m^{-2}, Karma Bio @ 15 g m^{-2}, Urea @ 20 g m^{-2}, DAP @ 42.5 MOP g m^{-2}, MOP @ 17.5 g m^{-2} and Herculus Utah one @ 12.5 g m^{-2} was applied as basal dose of fertilizer during the final land preparation. Urea @ 2 g $plant^{-1}$ was used for topdressing after 30 days of transplantation. Weekly spray schedule was followed as per package of practice of Karma Groups which included spray of NPK, micronutrients, fungicides and insecticides. Seeds were sown on tray with 128 holes on 20-Sept-2019. Seedlings at two true leaf stage were transplanted in on 24-Oct-2019. Transplanting was done at the PP×RR spacing of 40 cm×40 cm. A light irrigation was provided just after transplanting for better anchorage of broccoli seedlings. Dead plants were replaced within a week after transplanting. All the intercultural operations like weeding and hoeing were carried out when necessary. Irrigation was provided on weekly basis through water pipe.

Observation

Five randomly selected plants were observed for eleven characters i.e., plant height (cm), plant spread (cm), number of leaves, stalk height (cm), days to head initiation, days to harvest, central head diameter (cm), central head weight (kg), number of lateral heads, weight of lateral heads (kg), yield (kg $plant^{-1}$).

Statistical Analysis

All observed, measured and calculated data were encoded in Microsoft Excel (MAC version 16.16.15) for data curation and management. R-program (version 3.5.2) was used for data analysis. Statistical tools such as Two-way ANOVA was used to check significant differences between treatments and Least Significance Difference (LSD) at 0.05 significant level was used to compare differences between treatment means.

Results and Discussion

The analysis of variance test showed that almost all of the parameters were significantly different according to the genotypes and locations (Table 4). Many of these parameters also had strong interaction effect between genotype and location.

The studies are related to morphological (plant height, plant spread, number of leaves, stalk height), phenological (days to head initiation, days to harvest), floral (central head diameter, central head weight, number of lateral heads and weight of lateral heads) and yield kg $plant^{-1}$. These traits are described on the result below.

Morphological Traits

Plant Height (cm) and Plant Spread (cm)

Plant height and stalk height varied significantly ($P \leq 0.05$) due to the location and genotypes. Also, strong interaction ($P \leq 0.001$) between genotypes and location was observed on

the both traits. Maximum plant height is 55 cm on the cultivar BL-18012.Figure 3 depicts that the minimum plant height was observed on the genotype BL-16003 (40 cm at Kathmandu, 43 cm at Kavre and 48 cm at Kaski). However, the range of plant height was 36 cm to 55 cm.

Similarly, Minimum stalk height was observed on the genotype BL-16076 at the location Kathmandu (12 cm) and Kavre (13 cm) and maximum stalk height was observed on the genotype Centauro (20 cm at Kathmandu and 16 at Kavre) (Figure 3.(b)). The range of stalk height on all genotypes at all locations was 12 cm to 20 cm

Plant Spread (cm)

Plant spread of the broccoli genotypes varied significantly due to the location (P≤0.001) but genotypes and interaction between them showed non-significant result. Plant spread of all broccoli varieties was the highest on the location Kaski (66.7 cm) being significantly different remaining two locations (Table 5.). Location Kathmandu (56.6 cm) and Kavre (57.4 cm) were at par regarding the plant spread.

Number of Leaves

Genotype and location were also significantly different (P≤0.01) for number of leaves. And the strong interaction between genotype and location was also observed. Figure 4 shows that number of leaves were maximum on the genotype BL-16003 (23 at Kaski and 35 at Kathmandu and Kavre) followed by the genotypes BL-18012 (28 at Kathmandu, 27 at Kavre and 22 at Kaski). The minimum number of leaves were observed on the varieties BL-17001 (21 at Kaski and 22 at Kavre and Kaski).

Table 4. Analysis of variance to evaluate the significance of main effects (genotype and location) and interaction between genotype and location of different observed and calculated parameters

Parameters	Location	Variety	Loc*Var
Plant height	2.54e-10 ***	5.69e-11 ***	7.73e-08 ***
Plant spread	4.92e-06 ***	0.333	0.104
Number of leaves	1.27e-05 ***	7.01e-15 ***	9.57e-08 ***
Stalk height (cm)	0.0197 *	5.01e-05 ***	3.46e-09 ***
Days to head initiation	< 2e-16 ***	< 2e-16 ***	6.57e-07 ***
Days to harvest	6.53e-16 ***	4.03e-07 ***	0.0492 *
Central head diameter (cm)	0.98302	2.32e-06 ***	0.00177 **
Central head weight (kg)	0.7046	6.78e-05 ***	6.78e-05 ***
Number of lateral heads	5.44e-09 ***	< 2e-16 ***	3.61e-10 ***
Weight of lateral heads (kg)	7.32e-09 ***	< 2e-16 ***	1.45e-09 ***
Yield (kg/plant)	2.46e-05 ***	1.09e-15 ***	0.00426 **

ns, *,**,***: non-significance and significance at 0.05, 0.01 and 0.001% level, respectively

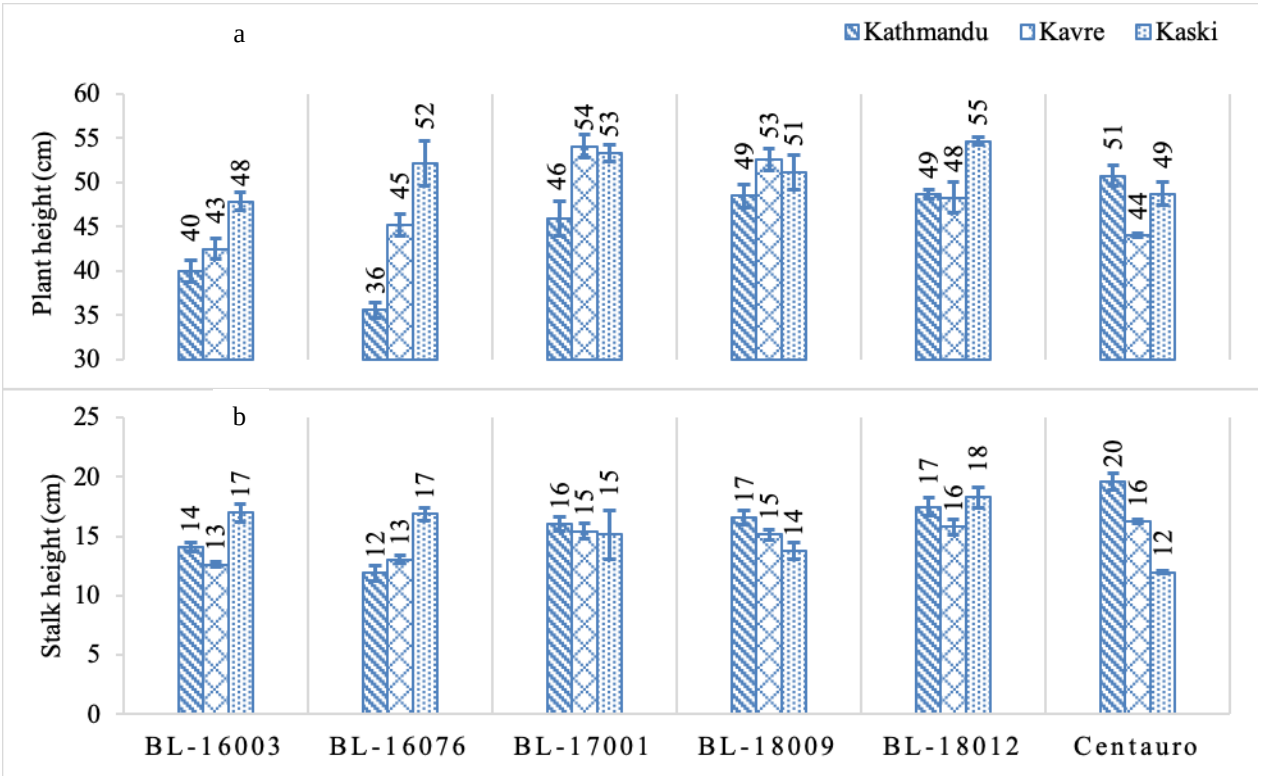

Figure 3. Interaction effect of genotypes and location on plant height and stalk height of broccoli varieties at Kathmandu, Kavre and Kaski of Nepal during 2019/2020 (a) plant height and (b) stalk height

Table 5. Effect of location on plant spread of broccoli varieties at Kathmandu, Kavre and Kaski of Nepal during 2019/2020

Location	Plant spread (cm)
Kathmandu	56.6[b]
Kavre	57.4[b]
Kaski	66.7[a]
Mean	60.3
Pr(>F)	4.92e-06 ***
LSD	4.1
CV (%)	11.6

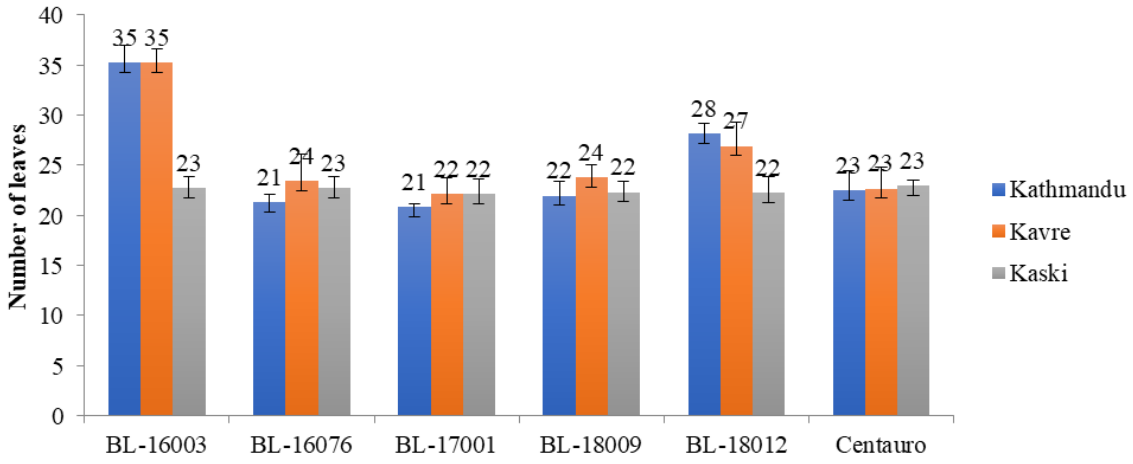

Figure 4. Interaction effect of genotypes and location on number of leaves of broccoli varieties at Kathmandu, Kavre and Kaski of Nepal during 2019/2020

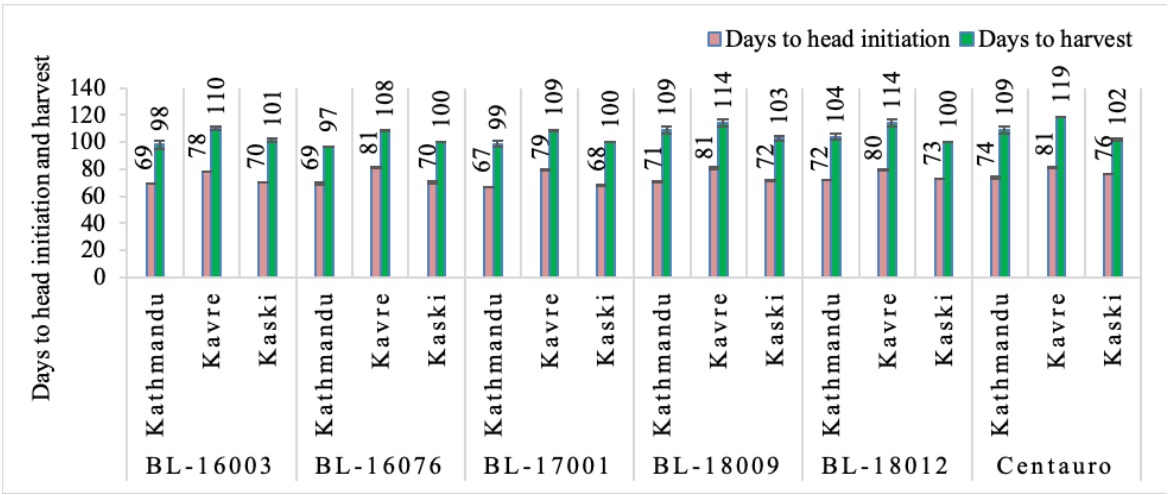

Figure 5. Interaction effect of genotypes and location on days to head initiation and days to harvest of broccoli varieties at Kathmandu, Kavre and Kaski of Nepal during 2019/2020

Morphological traits determine the plant structure and architecture of plant. Plant height, spread and number of leaves assist to determine the space required for plantation. Plant spread was the highest in the location Kaski and the variation might be due to environmental factor. Different environmental factor like precipitation, temperature, atmospheric humidity, solar radiation, wind velocity and atmospheric gases affect the plant growth. The results showed variation on the vegetative parameters and such variations on vegetative traits were also found by Farooq et al. (2018), Reza et al. (2015), Singh and Prasad, (2017), Abou El-Magd et al. (2015), Sanchez et al. (2016), Abou El-Magd and Zaki, (2017), Tejaswini et al. (2018), Dhakal et al. (2016), Abou El-Magd, (2013), Panta et al. (2018), Giri et al. (2013) and Thapa and Rai, (2012).

Phenological Traits

Phenological traits (days to head initiation and days to harvest) were found significantly different (P≤0.01) in terms of genotype and location. Likewise, these parameters were also affected by interaction between genotype and location. According to the Figure 5, all genotypes had longest duration for the initiation of head at the location Kavre, while at Kathmandu and Kaski genotypes had almost same duration for the initiation of head. Centauro (74 days at Kathmandu, 81 days at Kavre and 76 days at Kaski) showed the maximum days for the initiation of head and shortest duration was recorded in the genotype BL-17001 (67 days at Kathmandu, 79 days at Kavre and 68 days at Kaski) for the initiation of curd. Just like days to curd initiation, the longest duration for days to harvest was

reported in the genotype Centauro (109 days at Kathmandu, 119 days at Kavre and 102 days at Kaski), followed by the genotype BL-18009 (109 days at Kathmandu, 114 days at Kavre and 103 days at Kaski). Minimum duration was recorded in the genotype BL-16076 (97 days at Kathmandu, 108 days at Kavre and 100 days at Kaski) and BL-17001 (99 days at Kathmandu, 109 days at Kavre and 100 days at Kaski) for the curd harvest. The longest duration for the harvest was reported at location Kavre by all genotypes.

Phenological traits help to find out the precocity of the genotypes. Farmers can select the best genotypes according to their land availability and situation based on these characters. All of the genotypes had the longest duration for harvesting at the location Kavre and this is due to the low average annual temperature combined with high rainfall. Variations were found on broccoli genotypes regarding the days to curd initiation and days to harvest. Genotypes of a crop performs differently in different environment and this variation agrees with the finding of Latif et al. (2019), Kindo and Singh (2017), Abdel-Rehim, (2003) and Tejaswini et al. (2018).

Floral Traits

Central Curd Traits

Central head characters varied significantly due to the genotypes (P≤0.001). Similarly, interaction was also found between genotype and location, but location showed non-significant impact on these parameters. BL-16076 gave minimum curd weight (0.5 kg at Kathmandu, 0.4 kg at Kavre and 0.5 kg at Kaski) and maximum was observed on the genotype BL-17001 (0.7 kg) (Figure 6 (a)). In the same manner, minimum curd diameter was observed on the genotype BL-16076 (12.8 cm at Kathmandu, 10.4 cm at Kavre and 14.1 cm at Kaski) and the maximum as observed on BL-18012 (17.0 cm at Kathmandu, 17.8 cm at Kavre and 14.7 cm at Kaski) followed by BL-18009 (15.2 cm at Kathmandu, 16.4 cm at Kavre and 14.8 cm at Kaski). The range of curd diameter was 10.4 cm to 17.8 cm (Figure 6 (b)).

Lateral Curd Characters

Lateral curd traits such as number of lateral curds and weight of lateral curds were significantly different (P≤0.001) according to the genotype and locations. Likewise, a strong interaction of location and genotype was also observed on these traits. Three of the genotypes; BL-17001, BL-18012 and Centauro were observed as the non-sprout producing genotypes. Among remaining three, the highest number of lateral curds were observed on the genotype BL-16003 (6.5 at Kathmandu, 6.9 at Kavre and 7.2 at Kaski) followed by the genotype BL-16076 and BL-18009 (Figure 7 (a)). The highest weight of lateral curds was observed on the genotype BL-16003 (0.4 kg at Kathmandu and Kavre and 0.2 at Kaski), followed by the genotypes BL-16076 and BL-18009 (Figure 7 (b)).

Central head diameter, central head weight, number of lateral heads and weight of lateral heads are related to yield and quality. Some genotypes produced lateral heads while some did not in this study. This result is supported by the finding of Richardson, (2016), Islam et al. (2015), Singh and Prasad, (2017), Abou El-Magd et al. (2015), Reza et al. (2015), Sanchez et al. (2016), Nooprom and Santipracha, (2013) Latif et al. (2019), Abou El-Magd et al. (2017), Sahamishirazi et al. (2018), Tejaswini et al. (2018), Ordiales et al. (2017), Abou El-Magd, (2013), Giri et al. (2013) and Thapa and Rai, (2012).

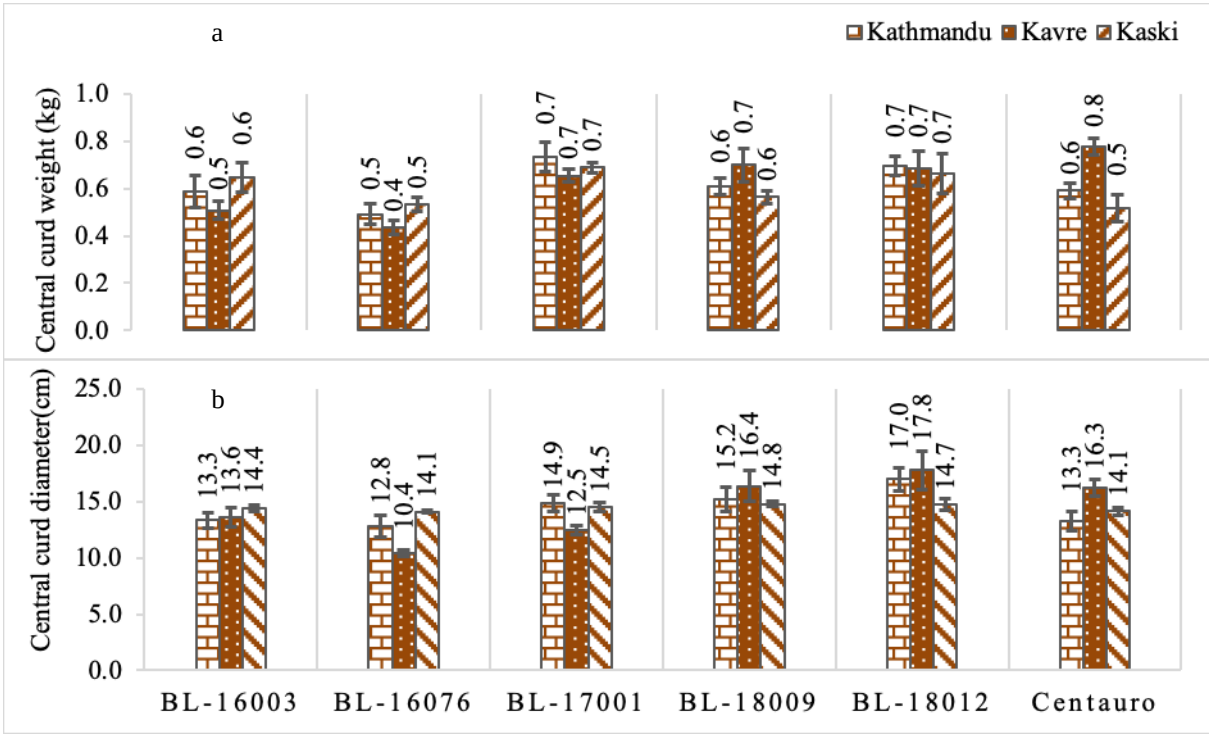

Figure 6. Interaction effect of genotypes and location on central curd weight and central curd diameter of broccoli varieties at Kathmandu, Kavre and Kaski of Nepal during 2019/2020 (a) central curd weight and (b) central curd diameter

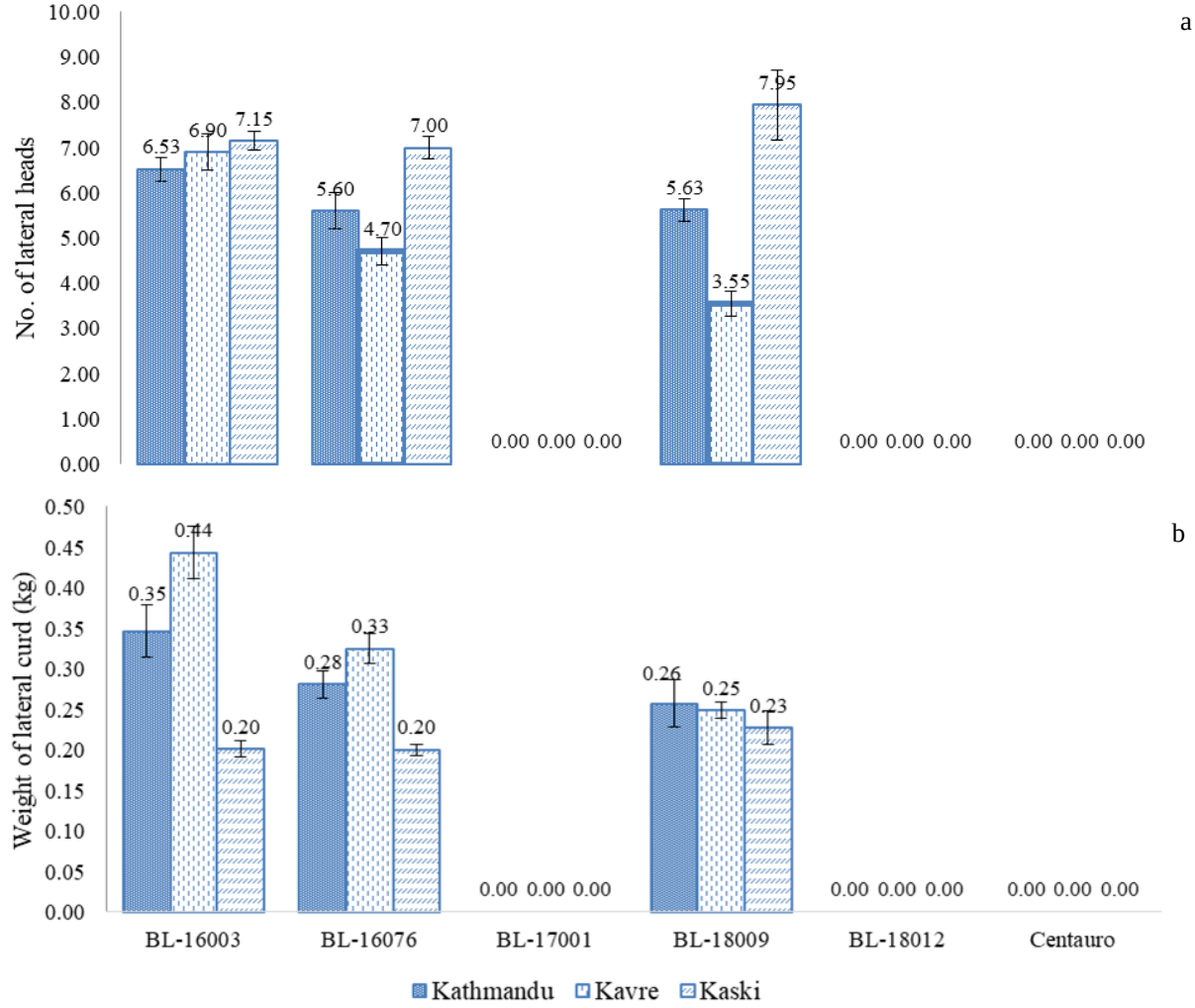

Figure 7. Interaction effect of genotypes and location on number of lateral heads and weight of lateral heads of broccoli varieties at Kathmandu, Kavre and Kaski of Nepal during 2019/2020 (a) number of lateral heads and (b) weight of lateral heads

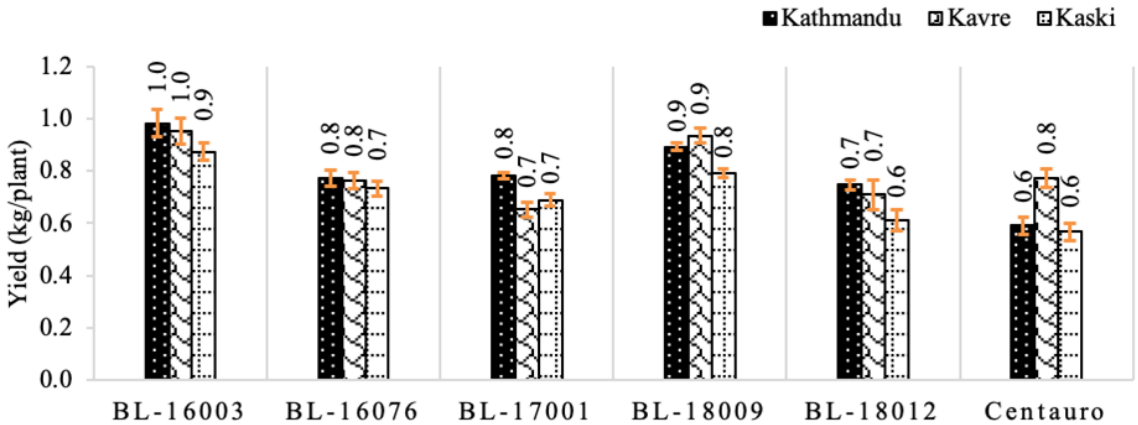

Figure 8. Interaction effect of genotypes and location on yield/plant of broccoli varieties at Kathmandu, Kavre and Kaski of Nepal during 2019/2020

Yield (kg/plant)

Yield of broccoli varieties differed significantly due to the genotypes ($P \leq 0.001$), location ($P \leq 0.001$) and interaction between them ($P \leq 0.01$). The highest yield was found on the genotype BL-16003 (1.0 kg at Kathmandu and kavre and 0.9 kg at Kaski) followed by BL-18009 (0.9 kg at Kathmandu and Kavre and 0.8 kg at Kaski) (Figure 8). The lowest yield was observed on the Centauro (0.6 kg at Kathmandu and Kaski and 0.8 kg at Kavre). However, the range of broccoli yield was 0.6 kg to 1.0 kg per plant.

Yield (kg/plant) is directly related to profit of farmers. More yield means more return to farmer. Different broccoli genotypes had different yield. This finding is in line with the finding of Silatar et al. (2018), Islam et al. (2015), Singh and Prasad, (2017), Latif et al. (2019) and Abou El-Magd et al. (2017).

Conclusion

Based on the experiment, Bl-17001, BL-18012 and Centauro were not observed lateral heads, which means low yield than other sprout producing varieties. So, these varieties are not found as suitable for gaining more profit by farmers. Genotype BL-16003 is the one which produced the highest yield at all locations comparing to other genotypes. Among high-yielding genotypes (BL-16003 and BL-18009), BL-16003 was found as early maturing genotype. This genotype also had lateral heads. Therefore, it can also be used for multi-harvesting. In addition, the height of this genotype was in the lower range with the highest number of leaves. This represents the strong plant architecture and can be resistant to lodging. Thus, genotype BL-16003 is found as the most suitable genotype at all locations.

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