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ORIGINAL RESEARCH ARTICLE

Effect of transplanting dates on growth, yield and quality of broad leaf mustard (*Brassica juncea* L. var. rugosa) varieties at Rampur, Chitwan, Nepal

Kaushila Bista[1*], Arvind Srivastava[2], Hom Nath Giri[3], Sandhya Joshi[4], Kabita Bhusal[5] and Bhawana Bhatta[6]

[1]Department of Horticulture, Agriculture and Forestry University, Rampur, Chitwan, NEPAL
[2]Professor, Department of Horticulture, Agriculture and Forestry University, Rampur, Chitwan, NEPAL
[3]Associate Professor, Department of Horticulture, Agriculture and Forestry University, Rampur, Chitwan, NEPAL
[4]Department of Horticulture, Institute of Agriculture and Animal Science, Kirtipur, Kathmandu, NEPAL
[5]Department of Agri botany and Conservation Ecology, Agriculture and Forestry University, Rampur, Chitwan, NEPAL
[6]Department of Horticulture, Agriculture and Forestry University, Rampur, Chitwan, NEPAL
[*]Corresponding author's E-mail: bistakaushila02@gmail.com

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ABSTRACT

Broad Leaf Mustard, one of the most popular, highly commercialized, and widely grown green vegetables due to its richness in vitamin and minerals with peculiar taste. The precise knowledge of ideal planting time with right selection of variety provides suitable environmental conditions at all growth stages that increase the yield. The field experiment was carried at Horticulture Farm, Faculty of Agriculture, Agriculture and Forestry University, Rampur, Chitwan to evaluate the effect of transplanting dates on growth, yield and quality of Broad Leaf Mustard (*Brassica juncea* L. var. *rugosa*) varieties in Terai condition of Nepal during October 2021 to March 2022. The experiment was laid out in two factorial randomized complete block design (RCBD) with three replications. There were sixteen treatment combination comprising four varieties (Khumal Broad Leaf, Marpha Broad Leaf, Manakamana and Mike Giant) with four transplanting dates (October 25, November 9, November 24 and December 9). The results revealed that transplanting dates and varieties along with interaction significantly influenced the growth, yield and quality of Broad Leaf Mustard. Among the varieties, Khumal Broad Leaf was significantly superior on growth parameters like plant height, leaf length and breadth, plant canopy but on yield attributes the superior variety was Mike Giant based on number of leaves harvested per plot (226.08) and leaf yield (26.43 mt ha^{-1}). However, the organoleptic test result revealed that the Mike Giant had excellent taste (74%) along with highest recovery percentage of Gundruk (27.62 %). Among the date of transplanting, mid transplanting on November 9 was better in terms of growth and leaf yield of 28.92 mt ha^{-1}. While poorest performance was recorded on last transplanting on December 9 in all growth, yield and quality parameters with leaf yield of 17.36 mt ha^{-1}. The interaction effect of different varieties and transplanting dates resulted better growth and quality in Khumal Broad Leaf and Manakamana varieties when transplanted on November 9. So based on the results of the experiment, Mike Giant transplanted on November 9 produced better growth and yield than others for the optimum yield production in Chitwan, Nepal.

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INTRODUCTION

Broad Leaf Mustard (BLM), *Brassica juncea* L. var. *rugosa*, a member of the Cruciferae family native to the Indian subcontinent's sub-Himalayan plains, is one of Nepal's most popular, highly commercialized, and widely grown green vegetables

(Shrestha *et al.*, 2021). It is called as 'Rayo' in Nepali, grown as winter season leafy vegetable gaining popularity due to its richness in vitamin and minerals and peculiar taste. Due to its wide range of agro-climatic adaptation, it is a common vegetable crop in Nepal (Rauniyar & Bhattarai, 2017). It is grown in various seasons from plain places to mountainous regions. BLM is regarded as a winter crop from the terai/plain to the mid-hills but it is a summer crop for the high hills in Nepal. It is a high value crop due to its high consumers' preference and market demand, creates employment opportunities, promote income generation and rich in nutrient substances (Schreinemachers *et al.*, 2018). Area under BLM in Nepal is 11,658 ha and production 171,215 tons with a yield of 14.69 t ha^{-1} during the year 2021/22 (MoALD, 2023). In Chitwan, the covered area was 177 ha with a total production of 2,124 mt and yield of 12 mt ha^{-1} in the year 2020/21 (MoALD, 2023). Fresh green leaves eaten as vegetables, seed as oil and also consumed in fermented form locally name Gundruk mostly popular and favorite Nepalese dish (Bhattarai *et al.*, 2018). The leaves of BLM are dark green in colors with pungent flavor and taste. Only when consumed as raw, the greens are bitter and pungent; however, when cooked, they soften and become delicious (Gotame *et al.*, 2021). During cool weather, long stalks with young tender leaves taste best while summer heat leads to bitter taste and less tender with quick development of seeds (Gotame *et al.*, 2021).

Regarding the research and development activities conducted on BLM, study on genetic diversity and varietal performances in different varieties under different agro-ecological condition with its package of practices are very limited in Nepal. Although the consumption and subsequent cultivation (including commercial farming) has increased in an exponential scale, but the required research for it has been lacking. Farmers have started cultivating many exotic BLM varieties (especially Japanese and Chinese) but the scientific study of these varieties and cultivation practices under different agro-ecological condition are very limited. So, it is realized that the selection of suitable BLM varieties having better qualitative as well as quantitative characters with their improved cultivation practices are very essential. Additionally, weather patterns have a significant impact on mustard productivity through its life cycle because different sowing dates offer varying environmental circumstances for a crop's growth and development in the same location (Panda *et al.*, 2004; Prasad *et al.*, 2018; Niraula & Timilsina, 2020). Being a long-day plant, BLM thrives in cool (15-18°C) temperatures rather than short day lengths. It requires cool weather before flowering and warm and dry condition during flowering and seed maturation (Singh & Bhandari, 2015). As a result, the plant bolts and flowers during the long days, especially when they are combined with temperatures above 25°C, which is detrimental to the production of leaves (Kaur *et al.*, 2022). Due to climate change or very early or late planting for certain crops, the production potential may be hampered (Naxrul & Zannat, 2020). Sowing crops at the optimum time is an important agronomic factor and non-monetary input that plays a crucial role in obtaining the potential yield of a crop in any region by creating suitable environment for BLM (Kumar *et al.*, 2018). Whereas, the physical factors mainly climatic factors cannot be manipulated under field conditions but sowing time can be adjusted to meet the optimum thermal requirements of crop at various phenological stages to avoid any adverse effect on the yield of mustard (Gupta *et al.*, 2017). Thus, altering the timing of sowing is one of the few strategies known for adapting the crop to cope with temperature fluctuations (Kaur *et al.*, 2022).

The genotypes and sowing time of the mustard have an impact on its productivity (Meena *et al.*, 2017). It is essential to have knowledge of the appropriate planting time and selection of important varieties in order to boost crop yields as it provides suitable environment conditions at all growth stages of the crop. The advantages of timely planting include favorable weather, increased growth duration, proper rainfall and optimal temperature for establishment and early vegetative growth. However, there are few research activities on the performance of different varieties of the BLM with dates of sowing. It is a common fact that the genotypes performing better under one locality may not be suitable for another locality or region. It is in fact that, all released cultivars do not perform well in all agro-ecological regions. For the crop to grow and develop properly, different cultivars need different weather conditions and sowing times. Therefore, a suitable dates of sowing is critical to increase the production of the crop. Hence it is very necessary to identify the variety which gives higher yield by adopting the appropriate management practices. Thus, the present investigation was carried out with the objective to find out the suitability of various BLM varieties with respect to different sowing time to evaluate the growth and yield parameters.

MATERIALS AND METHODS

Experimental site

The experiment was conducted in the Department of Horticulture, Faculty of Agriculture, Agriculture and Forestry University, Rampur, Chitwan during the period of October, 2021 to March, 2022. The meteorological data for the cropping season were taken from the meteorological station of the National Maize Research Program (NMRP), Rampur, Chitwan. Further, the composite soil sample taken from the experimental site was tested at the Lumbini Agro Environment Lab Pvt. Ltd., Sunwal - 12, Nawalparasi - west, following the specific principles and procedures.

Experimental details

The experimental was laid out in two factor factorial RCBD (Randomized Complete Block Design) with four varieties of BLM (Khumal Broad Leaf, Marpha Broad Leaf, Manakamana and Mike Giant) and four different transplanting dates (October 25, November 9, November 24 and December 9). Whole experiment was replicated three times with sixteen treatment combinations in each replication. The total area of the individual plot was 4.05 m^2(2.25 m × 1.8 m). There were 48 plots in total with 30 plants in each plot transplanted at the spacing of 45 cm × 30 cm. The total net area of the research plot was 317.625 m^2 (36.3 m × 8.75 m). The distance between two replications was 1m while the distance between two plots was 0.5 m.

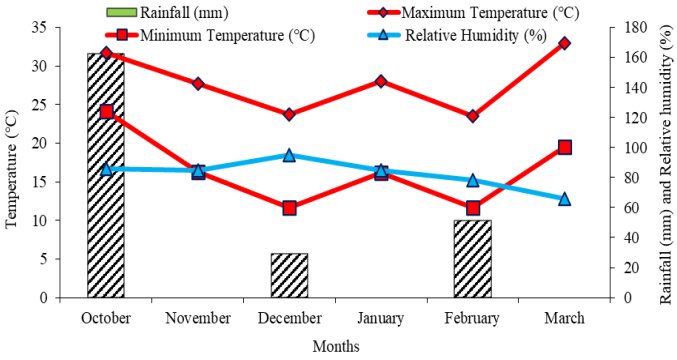

Figure 1. *Agro-meteorological data of the experimental site during cropping period from October 2021 to March 2022 in BLM at Rampur, Chitwan (Source: (National maize Research Program (NMRP), Rampur, Chitwan).*

RESULTS AND DISCUSSION

Growth parameters

Plant height: Plant height of different varieties of Broad Leaf Mustard was significantly differed at 20 DAT, 30 DAT and 40 DAT where there was non-significant difference at 10, 50 and 60 DAT. Significantly taller plant was recorded in Khumal Broad Leaf at 20 (19.87 cm), 30 (22.76 cm) and 40 DAT (30.31 cm) among the varieties while was statistically similar with Manakamana (28.81 cm) at 40 DAT. There was increase in plant height with the advancement of growth period and after certain time the plant height gradually decreased due to continuous multiple harvesting. The significant variation in plant height may be related to genetics or varietal traits of the varieties (Begum *et al.*, 2023). This result is in accordance with the findings of Adhikari *et al.* (2021). The plant height was decreased after 40 DAT as data of plant height was measured from ground level to normal highest leaf position and after certain period due to senescence resulted decrease in plant height. Plant height on different transplanting dates of BLM was differed at all growth stages except at 50 DAT. The maximum plant height was recorded at 40 DAT which was significantly taller on November 9 (30.88 cm) and was statistically similar with December 9 (18.47 cm). The main reason for highest plant height at late transplanting (December 9) is due to increase in temperature that result gradual increased in height instead of spreading during early days. After 40 DAT, the leaves of late transplanting was ready to harvest that's why the highest plant height was recorded in late transplanted dates. After that there was decreased in plant height and showed least plant height among all other date of transplanting. Meena *et al.* (2017) reported that when dates of sowing were earlier and delayed from normal, there was reduction in plant height which may be due to exposure to relatively high thermal regime that quickly complete the phenological stages giving very short time for the crop growth resulted in less biomass. Interaction effect of transplanting dates and different varieties of BLM on plant height was significantly differed at 40 DAT and 60 DAT.

Table 1. Plant height as influenced by the transplanting dates and varieties of Broad leaf Mustard at Rampur, Chitwan, 2021/022.

Treatments	Plant height (cm)					
	10 DAT	20 DAT	30 DAT	40 DAT	50 DAT	60 DAT
Varieties (Factor A)						
Khumal Broad Leaf	9.88	19.87^{a}	22.76^{a}	30.31^{a}	25.65	24.27
Marpha Broad Leaf	8.50	15.01^{c}	19.93^{b}	24.98^{b}	23.74	23.02
Manakamana	8.60	17.51^{b}	20.86^{b}	28.81^{a}	25.00	24.06
Mike Giant	8.63	15.49^{c}	19.53^{b}	22.83^{b}	22.04	22.30
F-test	ns	***	**	***	ns	ns
LSD $_{0.05}$	-	1.8	1.73	3.22	-	-
Date of transplanting (Factor B)						
October 25	8.14^{b}	17.72^{a}	20.11^{b}	23.11^{b}	22.71	24.97^{a}
November 9	10.26^{a}	19.35^{a}	19.68^{b}	30.88^{a}	25.24	22.00^{b}
November 24	7.68^{b}	18.02^{a}	24.82^{a}	23.30^{b}	23.53	25.15^{a}
December 9	9.54^{a}	12.80^{b}	18.47^{b}	29.66^{a}	24.95	21.52^{b}
SEm (±)	0.12	0.16	0.60	1.11	1.04	0.72
F-test	**	***	***	***	ns	***
LSD $_{0.05}$	1.36	1.8	1.73	3.22	-	2.07
CV, %	18.35	12.77	10.0	14.44	14.95	10.59
Grand mean	8.90	16.97	20.77	26.73	24.11	23.41
V*T				*		**

The common letter(s) within the column indicate non-significant difference based on Duncan Multiple Range Test (DMRT) at 0.05 level of significance. ns= non-significant, **significant at 1% (p<0.01) and ***significant at 0.1% (P< 0.001). SEm= Standard error of mean, LSD= Least Significant Difference, CV= Coefficient of Variation and DAT= Days after transplanting.

Table 2. Number of leaves per plant as influenced by the transplanting dates and varieties Broad Leaf Mustard at Rampur, Chitwan, 2021/022.

Treatments	Number of leaves per plant					
	10 DAT	20 DAT	30 DAT	40 DAT	50 DAT	60 DAT
Varieties (Factor A)						
Khumal Broad Leaf	3.20	5.87^{ab}	4.80^{b}	4.93^{b}	4.27^{b}	3.98^{b}
Marpha Broad Leaf	2.98	5.27^{c}	4.70^{b}	4.90^{b}	4.25^{b}	4.52^{b}
Manakamana	3.37	6.32^{a}	5.73^{a}	6.52^{a}	5.48^{a}	5.54^{a}
Mike Giant	3.08	5.43^{bc}	4.77^{b}	5.08^{b}	4.22^{b}	4.17^{b}
F-test	ns	**	*	**	***	***
$LSD_{0.05}$	-	0.55	0.69	1.05	0.64	0.63
Date of transplanting (Factor B)						
October 25	3.30^{a}	6.48^{a}	4.03^{c}	6.30^{a}	4.23^{b}	4.53^{ab}
November 9	3.33^{a}	6.08^{ab}	3.78^{c}	5.08^{b}	5.05^{a}	3.95^{b}
November 24	3.70^{a}	5.63^{b}	6.63^{a}	3.82^{c}	5.14^{a}	5.12^{a}
December 9	2.28^{b}	4.68^{c}	5.55^{b}	6.23^{a}	3.80^{b}	4.60^{ab}
SEm (±)	0.15	0.19	0.24	0.36	0.22	0.22
F-test	***	***	***	***	***	**
$LSD_{0.05}$	0.43	0.55	0.69	1.05	0.64	0.63
CV, %	16.34	11.54	16.64	23.53	16.99	16.73
Grand mean	3.15	5.72	5.00	5.36	4.55	4.55
V*T		*				

The common letter(s) within the column indicate non-significant difference based on Duncan Multiple Range Test (DMRT) at 0.05 level of significance. ns= non-significant, *significant at 5% (p<0.05), **significant at 1% (p<0.01) and ***Significant at 0.1% (P< 0.001). SEm= Standard error of mean, LSD= Least Significant Difference, CV= Coefficient of Variation and DAT= Days after transplanting.

Table 3. Leaf length as influenced by the transplanting dates and varieties of Broad Leaf Mustard at Rampur, Chitwan, 2021/022.

Treatments	Leaf length (cm)					
	10 DAT	20 DAT	30 DAT	40 DAT	50 DAT	60 DAT
Varieties (Factor A)						
Khumal Broad Leaf	15.12	25.28^{a}	32.75^{a}	41.05^{a}	35.69^{a}	31.71^{a}
Marpha Broad Leaf	14.27	22.44^{b}	28.92^{b}	33.42^{bc}	29.46^{bc}	26.83^{b}
Manakamana	14.43	21.64^{b}	28.43^{bc}	35.33^{b}	31.79^{b}	28.20^{b}
Mike Giant	14.18	21.23^{b}	26.67^{c}	31.86^{c}	28.22^{c}	27.35^{b}
F-test	ns	**	***	***	***	***
$LSD_{0.05}$	-	2.21	1.78	3.28	2.83	2.20
Date of transplanting (Factor B)						
October 25	18.86^{a}	25.90^{a}	27.40^{b}	31.43^{c}	28.08^{c}	29.91^{a}
November 9	13.37^{b}	25.28^{a}	31.89^{a}	39.71^{a}	35.98^{a}	29.52^{a}
November 24	13.04^{b}	23.64^{a}	32.53^{a}	34.21^{bc}	28.53^{c}	29.18^{a}
December 9	12.72^{b}	15.78^{b}	24.95^{c}	36.30^{b}	32.58^{b}	25.47^{b}
SEm (±)	0.43	0.77	0.62	1.14	0.98	0.76
F-test	***	***	***	***	***	***
$LSD_{0.05}$	1.24	2.21	1.78	3.28	2.83	2.20
CV, %	10.23	11.72	7.32	11.11	10.83	9.26
Grand mean	14.50	22.64	29.19	35.41	31.29	28.52
V*T			**			*

The common letter(s) within the column indicate non-significant difference based on Duncan Multiple Range Test (DMRT) at 0.05 level of significance. ns= on-significant, **significant at 1% (p<0.01) and ***Significant at 0.1% (P< 0.001). SEm= Standard error of mean, LSD= Least Significant Difference, CV= Coefficient of Variation and DAT= Days after transplanting.

Number of leaves per plant: Number of leaves per plant on BLM varieties was significantly differed at all growth stages except at 10 DAT. Significantly maximum number of leaves per plant was recorded in Manakamana at all growth stages while it was statistically similar to Khumal Broad Leaf at 20 DAT. Significantly, maximum number of leaves was observed at 40 DAT in Manakamana (6.52) among other varieties. The reason behind was that Manakamana produced many smaller leaves after certain period. Number of leaves per plant on different transplanting dates was differed at all growth stages up to 60 DAT. At 10 DAT, the number of leaves per plant was significantly highest on November 24 (3.70) which was statistically similar with November 9 (3.33) followed by October 25 (3.30). At 20 DAT, significantly higher number of leaves per plant was recorded on October 25 (6.48) which was statistically at par with November 9 (6.08). AT 30 DAT, the number of leaves per plant was statistically maximum when transplanted on November 24 (6.63). At 40 DAT, statistically maximum number of leaves per plant was found on October 25 (6.30) which was statistically similar to December 9 (6.23). Up to 40 DAT in late transplanting i.e. December 9, harvesting was not ready so higher number of leaves was recorded which gradually decreased after that. Similarly, at 50 DAT, the number of leaves was statistically maximum on November 24 (5.14) which was statistically similar with November 24 (5.14). Likewise, at 60 DAT, significantly higher number of leaves per plant was recorded on November 24 (5.12) which was statistically at par with December 9 (4.60) followed by October 25 (4.53). The variation in number of leaves per plant as affected by

dates of sowing might be due to the variation of environmental condition during growing period. Interaction effect of transplanting dates and different varieties on number of leaves per plant was non-significant at all growth stages except at 20 DAT which significantly differed at 0.05 level of significance.

Leaf length: Leaf length on Broad Leaf Mustard varieties was significantly differed at all growth stages except at 10 DAT. Significantly longer leaf was recorded in Khumal Broad Leaf at all growth stages in which longest leaf was recorded at 40 DAT of 41.05 cm. Similar results were reported by Gotame *et al.* (2021) and Dahal (2021) in case of leaf length and Chalise *et al.* (2020) found that Khumal Broad Leaf has the widest leaf but it was statistically at par with HRD-BLM007. Adhikari *et al.* (2021) also reported similar findings when research conducted in the western mid hill region of Nepal. Leaf length on different transplanting dates was differed at all growth stages up to 60 DAT. The maximum leaf length was recorded at 40 (39.71 cm) and 50 DAT (35.98 cm), statistically longest leaf was found on November 9 than other transplanting dates. There is increased in leaf area with earlier planting with longer growing season due to maximal photosynthesis at longer growth period while in late sowing the growth decreased due to decrease in temperature at early stage causing cessation (Kaur *et al.*, 2022). This result is in accordance with finding of Naxrul and Zannat (2020) who reported that increase in leaf length (53.42 cm) and leaf width (23.99 cm) when sown on November 15. Interaction effect of transplanting dates and different varieties of BLM on leaf length was significantly differed at 30 DAT and 60 DAT.

Leaf breadth: Leaf breadth on BLM varieties was significantly differed at all growth stages except at 10 and 60 DAT. At 20 DAT, significantly wider leaf was recorded in Khumal Broad Leaf (14.49 cm) which was statistically at par with Marpha Broad Leaf (13.42 cm). At 30 (22.55 cm) and 50 DAT (20.73 cm), leaf breadth was significantly wider in Khumal Broad Leaf (19.41 cm). Similarly, at 40 DAT, significantly wider leaf was recorded in Khumal Broad Leaf (22.55 cm) which was statistically at par with Marpha Broad Leaf (21.08 cm). Leaf breadth on different transplanting dates was differed at all growth stages of Broad Leaf Mustard. At 40 DAT, statistically wider leaf was found on November 9 (23.23 cm) which was statistically similar to November 24 (21.89 cm).

Petiole length: Petiole length on BLM varieties was significantly differed at all growth stages except at 20 DAT. At 10 DAT, significantly longer petiole was recorded in Khumal Broad Leaf (1.69 cm) which was significantly similar with Mike Giant (1.66 cm). At 30 DAT, petiole length was significantly longer in Mike Giant (1.53 cm). The petiole length was significantly longer in Mike Giant which was statistically similar with Khumal Broad Leaf (2.24 cm) at 40 DAT while statistically similar with Marpha Broad Leaf (1.69 cm) at 50 DAT. Likewise, the petiole length was significantly higher in Mike Giant (1.66 cm) at 60 DAT. The one of the desired characters of green leafy vegetable; Broad Leaf Mustard cultivar is shorter petiole length (Shrestha *et al.*, 2021). Petiole length on different transplanting dates was differed at all growth stages except at 50 DAT and 60 DAT. At 10 DAT, petiole length was significantly longer on December 9 (2.79 cm). The longer petiole at early growth period when transplanted on December 9 is due to temperature fluctuations as weather is transitioning from cooler to warmer conditions and as seasons progressed, the day length may decrease and light intensity might decline that triggers stem elongation. At 20 DAT, significantly longer petiole was recorded on October 25 (1.80 cm). Similarly, at 30 DAT, petiole length was statistically maximum when transplanted on October 25 (1.37 cm) which was statistically similar with November 24 (1.36 cm) followed by November 9 (1.32 cm). Likewise, at 40 DAT, statistically maximum petiole length was found on November 24 (2.48 cm) which was statistically similar with November 9 (2.29 cm). Interaction effect of transplanting dates and different varieties of BLM on petiole length was significantly differed at 10 DAT.

Table 4. Leaf breadth as influenced by the transplanting dates and varieties of Broad Leaf Mustard at Rampur, Chitwan, 2021/022.

Treatments	Leaf breadth (cm)					
	10 DAT	20 DAT	30 DAT	40 DAT	50 DAT	60 DAT
Varieties (Factor A)						
Khumal Broad Leaf	7.08	14.49^{a}	19.41^{a}	22.55^{a}	20.73^{a}	18.27
Marpha Broad Leaf	7.62	13.42^{ab}	17.69^{b}	21.08^{ab}	18.97^{b}	17.69
Manakamana	7.08	12.47^{b}	17.53^{b}	20.02^{b}	19.00^{b}	16.91
Mike Giant	6.90	12.46^{b}	16.41^{c}	19.42^{b}	17.57^{b}	17.60
F-test	ns	**	***	**	**	ns
$LSD_{0.05}$	-	1.53	1.08	1.74	1.52	-
Date of transplanting (Factor B)						
October 25	10.43^{a}	14.95^{a}	17.44^{b}	18.41^{b}	18.31^{b}	18.40^{a}
November 9	7.29^{b}	15.41^{a}	19.12^{a}	23.23^{a}	21.27^{a}	18.59^{a}
November 24	5.567^{c}	14.96^{a}	19.08^{a}	21.89^{a}	16.22^{c}	17.86^{a}
December 9	5.30^{c}	7.52^{b}	15.41^{c}	19.55^{b}	20.47^{a}	15.63^{b}
SEm (±)	0.39	0.53	0.37	0.60	0.53	0.51
F-test	***	***	***	***	***	***
$LSD_{0.05}$	1.13	1.53	1.08	1.74	1.52	1.46
CV, %	18.95	13.87	7.30	10.07	9.57	9.95
Grand mean	7.17	13.21	17.76	20.77	19.07	17.62

The common letter(s) within the column indicate non-significant difference based on Duncan Multiple Range Test (DMRT) at 0.05 level of significance. ns= significant, **significant at 1% (p<0.01) and ***Significant at 0.1% (P< 0.001). SEm= Standard error of mean, LSD= Least Significant Difference, CV= Coefficient of Variation and DAT= Days after transplanting.

Table 5. Petiole length as influenced by the transplanting dates and varieties of Broad Leaf Mustard at Rampur, Chitwan, 2021/022.

Treatments	Petiole length (cm)					
	10 DAT	20 DAT	30 DAT	40 DAT	50 DAT	60 DAT
Varieties (Factor A)						
Khumal Broad Leaf	1.69^{a}	1.41	1.00^{b}	2.24^{a}	1.34^{b}	1.08^{c}
Marpha Broad Leaf	1.51^{ab}	1.32	1.19^{b}	1.71^{b}	1.77^{a}	1.41^{b}
Manakamana	1.38^{b}	1.28	1.10^{b}	1.87^{b}	1.37^{b}	1.25^{bc}
Mike Giant	1.66^{a}	1.47	1.53^{a}	2.39^{a}	1.69^{a}	1.66^{a}
F-test	*	ns	***	***	**	***
$LSD_{0.05}$	0.23	-	0.20	0.33	0.29	0.20
Date of transplanting (Factor B)						
October 25	1.24^{b}	1.80^{a}	1.37^{a}	1.80^{b}	1.59	1.46
November 9	0.94^{c}	1.25^{b}	1.32^{a}	2.29^{a}	1.33	1.31
November 24	1.27^{b}	0.97^{c}	1.36^{a}	2.48^{a}	1.55	1.37
December 9	2.79^{a}	1.47^{b}	0.78^{b}	1.64^{b}	1.71	1.29
SEm (±)	0.08	0.08	0.07	0.12	0.10	0.07
F-test	***	***	***	***	ns	ns
$LSD_{0.05}$	0.23	0.24	0.20	0.33	-	-
CV, %	17.51	21.23	20.30	19.43	22.57	17.67
Grand mean	1.56	1.37	1.21	2.05	1.54	1.35
V*T	***					

The common letter(s) within the column indicate non-significant difference based on Duncan Multiple Range Test (DMRT) at 0.05 level of significance. ns= non-significant, *significant at 5% (p<0.05), **significant at 1% (p<0.01) and ***Significant at 0.1% (P< 0.001). SEm= Standard error of mean, LSD= Least Significant Difference, CV= Coefficient of Variation and DAT= Days after transplanting.

Table 6. Plant canopy as influenced by the transplanting dates and varieties of Broad Leaf Mustard at Rampur, Chitwan, 2021/022.

Treatments	Plant canopy (cm)					
	10 DAT	20 DAT	30 DAT	40 DAT	50 DAT	60 DAT
Varieties (Factor A)						
Khumal Broad Leaf	13.97	31.37	35.51^{ab}	43.86^{a}	37.72^{a}	32.94
Marpha Broad Leaf	12.86	28.13	33.01^{bc}	37.15^{b}	29.75^{b}	31.89
Manakamana	13.97	30.16	36.98^{a}	43.67^{a}	36.97^{a}	35.42
Mike Giant	13.04	28.12	32.14^{c}	38.99^{b}	31.73^{b}	33.42
F-test	ns	ns	**	***	***	ns
$LSD_{0.05}$	-	-	2.98	3.34	3.64	-
Date of transplanting (Factor B)						
October 25	13.51^{a}	32.42^{a}	30.40^{c}	41.24^{b}	32.08^{b}	36.10^{a}
November 9	14.88^{a}	34.30^{a}	30.29^{c}	43.84^{ab}	38.05^{a}	35.26^{a}
November 24	14.33^{a}	31.09^{a}	42.05^{a}	33.01^{c}	33.80^{b}	34.28^{a}
December 9	11.13^{b}	19.98^{b}	34.89^{b}	45.59^{a}	32.24^{b}	28.02^{b}
SEm (±)	0.51	1.11	1.03	1.16	1.26	1.07
F-test	***	***	***	***	**	***
$LSD_{0.05}$	1.48	3.20	2.98	3.34	3.64	3.10
CV, %	13.19	13.03	10.39	9.79	12.81	11.13
Grand mean	13.46	29.45	34.41	40.92	34.04	33.42
V*T			**	*		

The common letter(s) within the column indicate non-significant difference based on Duncan Multiple Range Test (DMRT) at 0.05 level of significance. ns= non-significant, *significant at 5% (p<0.05), **significant at 1% (p<0.01) and ***Significant at 0.1% (P< 0.001). SEm= Standard error of mean, LSD= Least Significant Difference, CV= Coefficient of Variation and DAT= Days after transplanting.

Plant canopy: Plant canopy on BLM varieties was significantly differed at 20, 30 and 40 DAT where there was non-significant difference on 10, 20 and 60 DAT. At 30 DAT, significantly higher plant canopy was recorded in Manakamana (36.98 cm) which was significantly at par with Khumal Broad Leaf (35.51 cm). At 40 DAT, significantly higher plant canopy was recorded in Khumal Broad Leaf (43.86 cm) which was statistically similar with Manakamana (43.67 cm). Similarly, at 50 DAT, significantly higher plant canopy was recorded in Khumal Broad Leaf (37.72 cm) which was significantly similar with Manakamana (36.97 cm). This result is in agreement with the result of Acharya (2014) who stated that the highest plant canopy was found in Manakamana variety. Plant canopy on different transplanting dates was differed at all growth stages of BLM. At 40 DAT, statistically maximum plant canopy was recorded on December 9 (45.59 cm) which was statistically at par with November 9 (43.48 cm). At December 9, only after 40 DAT the first harvest was done which resulted highest plant canopy at 40 DAT which then gradually decreased. Interaction effect of transplanting dates and different varieties of BLM on plant canopy was significantly differed at 30 and 40 DAT.

Table 7. Days to harvest, crop duration and harvest duration as influenced by the transplanting dates and varieties of Broad Leaf Mustard at Rampur, Chitwan, 2021/022.

Treatments	Days to first harvest	Days to last harvest	Crop duration	Harvest duration
Varieties (Factor A)				
Khumal Broad Leaf	28.92	80.50^{a}	104.75^{a}	52.00^{a}
Marpha Broad Leaf	28.92	80.50^{a}	104.75^{a}	52.00^{a}
Manakamana	28.58	72.50^{b}	96.75^{b}	44.00^{b}
Mike Giant	28.83	79.42^{a}	103.67^{a}	50.92^{a}
F-test	ns	***	***	***
$LSD_{0.05}$	-	2.89	2.89	2.89
Date of transplanting (Factor B)				
October 25	20.67^{d}	86.08^{a}	111.08^{a}	65.08^{a}
November 9	24.08^{c}	79.33^{b}	100.33^{b}	55.33^{b}
November 24	30.00^{b}	70.00^{c}	96.00^{c}	40.00^{c}
December 9	40.50^{a}	77.50^{c}	102.50^{b}	38.50^{c}
SEm (±)	0.10	1.00	1.00	1.00
F-test	***	***	***	***
$LSD_{0.05}$	0.28	2.89	2.89	2.89
CV, %	1.15	4.43	3.39	6.98
Grand mean	28.81	78.23	102.48	49.73
V*T	*	**	**	**

The common letter(s) within the column indicate non-significant difference based on Duncan Multiple Range Test (DMRT) at 0.05 level of significance, ns= non-significant. ***Significant at 0.1% (P< 0.001). SEm= Standard error of mean, LSD= Least Significant Difference, CV= Coefficient of Variation and DAT= Days after transplanting.

Table 8. Number of leaves per plot, harvesting frequency and yield as influenced by the transplanting dates and varieties of Broad Leaf Mustard at Rampur, Chitwan, 2021/022.

Treatments	Number of leaves/plot	Harvesting frequency	Yield (mt ha^{-1})
Varieties (Factor A)			
Khumal Broad Leaf	201.00^{bc}	5.75^{a}	23.77^{ab}
Marpha Broad Leaf	189.83^{c}	5.75^{a}	21.84^{b}
Manakamana	221.83^{ab}	5.00^{b}	21.51^{b}
Mike Giant	226.08^{a}	5.67^{a}	26.43^{a}
F-test	**	***	*
$LSD_{0.05}$	22.10	0.30	3.39
Date of transplanting (Factor B)			
October 25	250.08^{a}	6.50^{a}	25.16^{b}
November 9	217.50^{b}	5.92^{b}	28.92^{a}
November 24	208.00^{b}	5.00^{c}	22.11^{b}
December 9	163.17^{c}	4.75^{c}	17.36^{c}
SEm (±)	7.65	0.10	1.18
F-test	***	***	***
$LSD_{0.05}$	22.10	0.30	3.42
CV, %	12.64	6.34	17.53
Grand mean	209.69	5.54	23.39
V*T		**	

The common letter(s) within the column indicate non-significant difference based on Duncan Multiple Range Test (DMRT) at 0.05 level of significance. *significant at 5% (p<0.05), **significant at 1% (p<0.01) and ***Significant at 0.1% (P< 0.001). SEm= Standard error of mean, LSD= Least Significant Difference, CV= Coefficient of Variation and DAT= Days after transplanting.

Phenological characters

Days to harvest, crop duration and harvest duration: The days to last harvest, crop duration and harvest duration was significantly differed at p<0.001 but was found non-significant to days to first harvest among the different varieties of BLM. The days to last harvest took statistically longer time in Khumal Broad Leaf (80.5 days) and Marpha Broad Leaf (80.50 days) which was statistically similar to Mike Giant (79.42 days). The crop duration was statistically maximum in Khumal Broad Leaf (104.75 days) and Marpha Broad Leaf (104.75 days) which was statistically similar to Mike Giant (103.67 days). Similarly, the crop duration was statistically maximum in Khumal Broad Leaf (52 days) and Marpha Broad Leaf (52 days) which was statistically similar to Mike Giant (50.92 days). The result behind this was due to 100% bolting in Manakamana that resulted shorter leaf harvesting period. Chalise *et al.* (2020) reported that the harvesting of leaves in all varieties began 30 days after transplanting and continued for 75 days. Khatiwada (2008) reported that Marpha Broad Leaf was ready for harvesting after about a month of transplanting. The earlier harvesting was found in this result due to higher temperature in the inner terai condition during growing season than other researches (Acharya, 2014). The days to first harvest, days to last harvest, crop duration and harvest duration was significantly differed at p<0.001 among the different transplanting dates. The days to first harvest was

Table 9. Physiological loss in weight as influenced by the transplanting dates and varieties of Broad Leaf Mustard at Rampur, Chitwan, 2021/022.

Treatments	Physiological loss in weight (%)		
	1st DAS	2nd DAS	3rd DAS
Varieties (Factor A)			
Khumal Broad Leaf	11.28	21.33	28.61
Marpha Broad Leaf	10.55	20.35	29.39
Manakamana	10.05	19.68	26.57
Mike Giant	11.03	20.77	28.74
F-test	ns	ns	ns
$LSD_{0.05}$	-	-	-
Date of transplanting (Factor B)			
October 25	12.06[a]	18.76[c]	25.88[b]
November 9	6.05[b]	14.25[d]	23.23[b]
November 24	11.84[a]	23.44[b]	31.75[a]
December 9	12.97[a]	25.68[a]	32.45[a]
SEm (±)	0.49	0.70	1.12
F-test	***	***	***
$LSD_{0.05}$	1.40	2.03	3.24
CV, %	15.68	11.88	13.72
Grand mean	10.73	20.53	28.33
V*T	**	**	**

The common letter(s) within the column indicate non-significant difference based on Duncan Multiple Range Test (DMRT) at 0.05 level of significance. ***Significant at 0.1% (P< 0.001). SEm= Standard error of mean, LSD= Least Significant Difference, CV= Coefficient of Variation and DAS= Days after storage.

statistically shorter when transplanted on October 25 (20.67 days) and took longer time to first harvest when late transplanted on December 9 (40.5 days). The days to last harvest statistically took longer time when transplanted on October 25 (86.08 days). The crop duration was statistically maximum on October 25 (111.08 days) than other dates. Similarly, the crop duration was statistically maximum on October 25 (65.08 days). This might be as cool temperature favor vegetative growth with longer growth period (Bisbis *et al.*, 2018). The first harvest differed in case of different date of transplanting as at early sowing leaf can be harvested earlier and as the time of transplanting become late more days is required for first harvest. This may be because the plant experienced poor growth due to low temperatures, which made it take longer time for the first harvest i.e., more than a month. Interaction effect of transplanting dates and different varieties of BLM on days to first harvest significantly differed at p<0.05 while days to last harvest was significantly differed at p<0.01. Similarly, Interaction effect of transplanting dates and different varieties of BLM on crop duration and harvest duration was significantly differed at p<0.01.

Bolting behavior: The 100% bolting behavior was observed in only one variety i.e., in Manakamana while in other three varieties no bolting was observed. Late bolting is the most preferred trait in BLM by the farmers as a greater number of leaves can be harvested (Regmi *et al.*, 2005). Shrestha *et al.* (2021) reported that there was no bolting in Marpha Broad Leaf. There were 100% bolting in Manakamana variety while no bolting was recorded in other three varieties. This result is in accordance with the finding of Regmi *et al.* (2005) that as temperatures rises, Manakamana begins to bolt. Being high chilling varieties, Marpha Broad Leaf and Khumal Broad Leaf require a longer period of exposure to cold temperatures to bolting, thus due to lower chilling temperature in terai region resulted no bolting in these varieties. While Manakamana cannot tolerate temperature above 25°C resulting bolting at high temperature. Akhter *et al.* (2016) reported that early sown crop took a greater number of days for flowering and maturity than normal and late sowing while late sown crop took more days to complete early stages viz., emergence and rosette stage and after that took a smaller number of days to flowering due to higher temperature which fulfil the requirement of growing degree days and thermal units.

Yield and yield parameters

Number of leaves harvested per plot: The number of leaves harvested per plot differed significantly at p<0.01 among the different varieties. Significantly highest number of leaves harvested per plot was recorded in Mike giant (2226.08) which was statistically at par with Manakamana (221.83). Shrestha *et al.* (2021) reported that the yield is closely correlated with the number of leaves per plant; the more leaves, the higher the yield. Similarly, the number of leaves harvested per plot differed significantly at p<0.001 among different transplanting dates. Significantly, highest number of leaves harvested per plot was recorded on first transplanting (October 25) of 250.08.

Leaf yield: Leaf yield differed significantly at p<0.05 among the different varieties. Significantly highest leaf yield was recorded in Mike giant (26.43 t ha^{-1}) which was statistically at par with Khumal Broad Leaf (23.77 t ha^{-1}). Productivity of the mustard is influenced by genotypes (Shrestha *et al.*, 2021). The reason behind reduced leaf yield was that Manakamana variety recorded 100% bolting due to increase in temperature that resulted reduced leaf harvest. The highest biological yield was recorded in Manakamana variety as there occur bolting after the temperature rises (Shrestha *et al.*, 2021). Similarly, the leaf yield differed significantly at p<0.001 among different transplanting dates.

Significantly, highest leaf was recorded on second transplanting (November 9) of 28.92 t ha^{-1}. These results are due to the better germination and maximum photosynthesis surface (number of leaves per plant) in earlier sowing resulting to accumulation of maximum fresh weight as compared to late sowing (Kaur *et al.*, 2022). Porter (2005) reported that late sown Indian mustard when exposed to high temperature and high atmospheric evaporative demands throughout the reproductive phase resulted in forced maturity, increased senescence and reduced output. Late sown crop encountered high temperature stress which causes a great reduction in yield (Godara *et al.*, 2018). Furthermore, it has been reported that delaying sowing until October results in lower leaf yields since plants are subjected to long days and high temperatures exceeding 25°C, which cause bolting and lower productivity (Changoo *et al.*, 2001; Hata *et al.*, 2006). Within the same location, different sowing dates provide variable environmental conditions for the growth and development of crop and yield stability as it depends on the onset of rainfall, temperature and humidity of the region (Alam *et al.*, 2015). The late sowing of mustard resulted in decreased yield through synchronization with high temperature, decrease in assimilates production, shortest growth period and acceleration of plant maturity (Alam *et al.*, 2015).

Harvesting frequency: Harvesting frequency differed significantly at $p<0.001$ among the different varieties. Significantly maximum harvesting frequency was recorded in Khumal Broad Leaf (5.75) and Marpha Broad Leaf (5.75) which was statistically similar with Mike Giant (5.67). Similarly, the harvesting frequency differed significantly at $p<0.001$ among different transplanting dates. Significantly, maximum harvesting frequency was recorded on first transplanting (October 25) of 6.50. Interaction effect of transplanting dates and different varieties of BLM on harvesting frequency was significantly differed at $p<0.01$.

Postharvest quality parameters

Physiological loss in weight: PLW differed significantly at $p<0.001$ among the different transplanting dates where, there was non-significant difference among the varieties of BLM. Significantly higher weight loss of 12.97% was recorded on December 9 which was statistically similar with October 25 (12.06%) followed by November 24 (11.84%) at first day after storage. In the second day of storage, significantly maximum weight loss was recorded on December 9 of 25.68% than other dates. Similarly, on the third day significantly maximum weight loss of 32.4 % was recorded on December 9 which was statistically similar to November 24 (31.75%). Weight loss is one of the visible changes in leafy vegetables, often limits the marketing life. Significantly higher weight loss was recorded in last transplanting (9^{th} December). The variation in physiological loss in weight was due to environmental condition. Interaction effect of transplanting dates and different varieties of BLM on physiological loss in weight was significantly differed at $p<0.01$.

Recovery percentage: There was high recovery percentage of fermented product i.e., Gundruk in case of Mike Giant (27.62 %) as compared to other varieties. This was due to higher petiole length resulted higher dry matter content in Mike Giant. Mike Giant was followed by Manakamana (22.62 %) and Khumal Broad Leaf (21.74 %). While, there was low recovery percentage in case of Marpha Broad Leaf (17.29 %) which was accompanied by the lower dry matter content. In case of date of transplanting, the higher recovery percentage of fermented product was found on October 25 (25.65 %) followed by November 24 (23.85 %). While, low recovery percentage was recorded at late transplanting on December 9 (18.43 %).

Morphological and organoleptic parameters

Leaf color: Among the respondents, majority of them (90 %) ranked Marpha Broad Leaf as the most attractive leaf color. 70 % of respondents ranked Khumal Broad Leaf and Manakamana as the most attractive leaf color while, 50 % respondents attractive to Mike Giant.

Leaf size: Majority of respondents (80 %) observed that Khumal Broad Leaf have large leaf size followed by Marpha Broad Leaf and Manakamana by 60 % respondents whereas, Mike Giant was rated medium size by 80 % respondents.

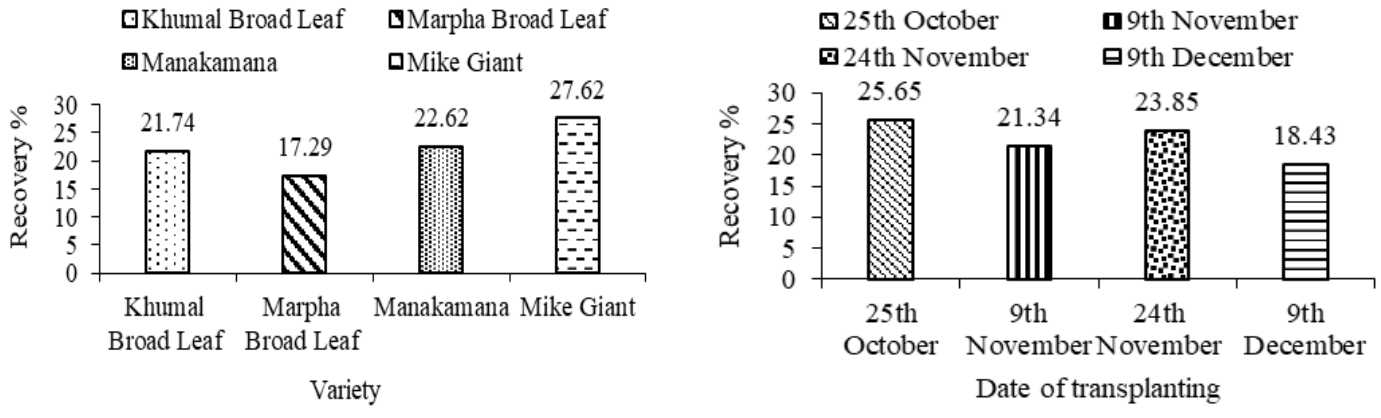

Figure 2. *Recovery percentage of fermented products (Gundruk) of different varieties and different transplanting dates in Broad Leaf Mustard at Rampur, Chitwan, 2021/022.*

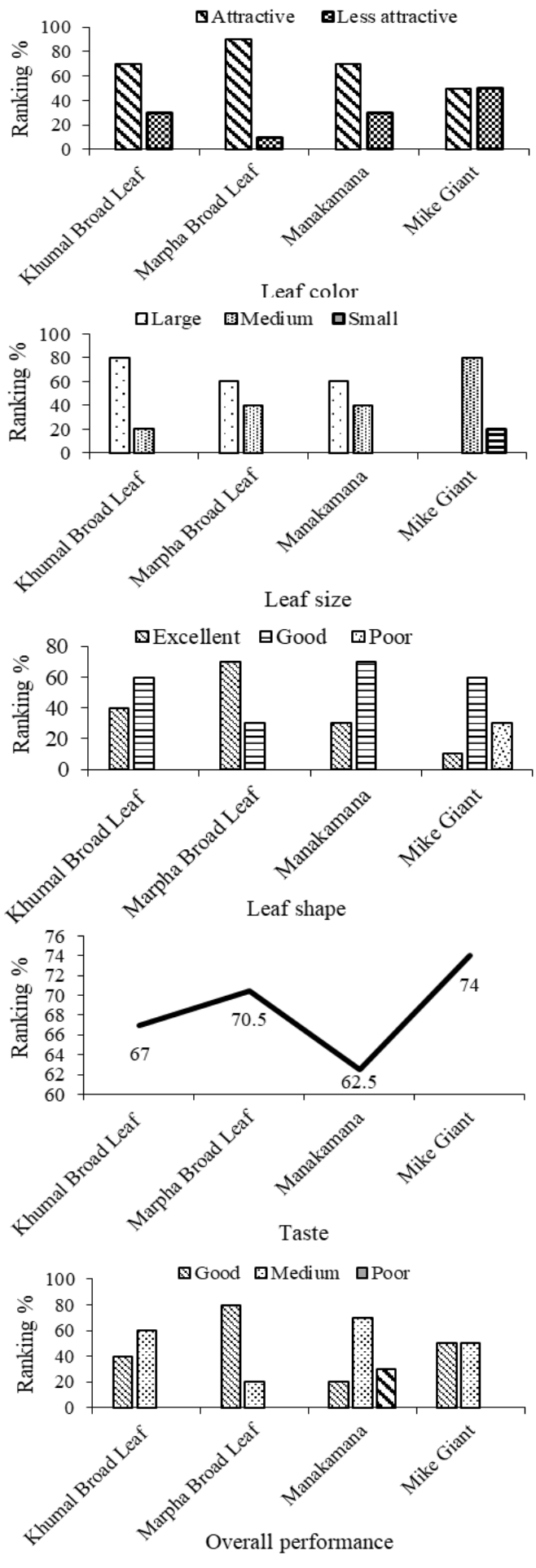

Figure 3. *Evaluation of the respondents to the morphological and organoleptic parameters of Broad Leaf Mustard at Rampur, Chitwan, 2021/022.*

Leaf shape: Majority of the respondents (70 %) rated excellent leaf shape of Marpha Broad Leaf while Manakamana (70 %), Khumal Broad Leaf (60 %) and Mike Giant (60 %) was rated as good leaf shape. Similarly, 30 % of the respondents rated poor leaf shape of Mike Giant.

Taste: Majority of the respondents (74%) reported excellent taste in Mike Giant than other cultivars and mentioned good taste in Marpha Broad Leaf (70.5 %) followed by Khumal Broad Leaf (67 %). While, higher degree of bitterness was observed in the variety Manakamana. Organoleptic test is used as the rating scale of 9-point hedonic scale for testing consumers' preference and acceptability of foods (Peryam & Pilgrim, 1957; Peryam & Girardot, 1952; Chalise *et al.*, 2020). Marpha Broad Leaf had excellent taste according to the respondents. Similar results were observed by (Acharya, 2014). There was variation on the leaf quality of different varieties. Similar results were observed by Chalise *et al.* (2020).

Overall performance

Majority of the respondents (80 %) recorded that the overall performance of Marpha Broad Leaf was good while, by 60 % of the respondents noted medium performance in Khumal Broad Leaf. Manakamana was noted medium performance by 70 % of the respondents and poor performance by 30 % of the respondents.

Conclusion

The growth, yield and quality parameters were affected by the date of transplanting and varieties of Broad Leaf Mustard. Khumal Broad Leaf was superior in terms of growth parameters such as plant height, leaf length and breadth, plant canopy but the longest petiole length, number of leaves harvested per plot and leaf yield was found superior in Mike Giant. The physiological loss in weight was found non-significant among the varieties while recovery percentage of Gundruk was found highest in Mike Giant. The most attractive leaf color, excellent leaf shape, with excellent taste was noted in Marpha Broad leaf while largest leaf size in Khumal Broad Leaf. Mid transplanting on November 9 was better in terms of growth and yield than other transplanting dates. The interaction effect of transplanting dates and different Broad Leaf Mustard varieties resulted better growth and quality in Khumal Broad Leaf and Manakamana varieties when transplanted on November 9. Thus, it can be concluded that Mike Giant transplanted on November 9 produced the highest yield than other treatments.

DECLARATIONS

Author contribution statement

Conceptualization: K.B. and A.S.; Methodology: K.B. and A.S.; Software and validation: K.B., A.S. and H.G.; Formal analysis and investigation: K.B.; Resources: K.B., Data curation: K.B.; Writing -original draft preparation: K.B.; Writing-review and editing: K.B., A.S., H.G., S.J., K.B. and B.B.; Visualization: K.B.; Supervision: A.S. and H.G.; Project administration: K.B.; Funding acquisition: K.B. All authors have read and agreed to the published version of the manuscript.

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Ethics approval: We have adhered to the accepted ethical standards of a genuine research study.

Consent for publication: I, the undersigned, give my consent for the publication of the above manuscript to be published in your Journal.

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