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INFLUENCE OF SOWING WINDOWS ON THE PERFORMANCE OF FINGER MILLET (*Eleusine coracana* L. GAERTN.) VARIETIES

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ABSTRACT

A field experiment was conducted during the *Kharif* season of 2022 under rainfed conditions at Ranichauri, Tehri Garhwal, Uttarakhand, to evaluate the effect of different sowing windows on the performance of finger millet (*Eleusine coracana* (L.) Gaertn.) varieties under mid-hill conditions of the Garhwal Himalayas. The experiment was laid out in a factorial randomized block design (FRBD) with three sowing windows, *viz.*, D_1 (1 June), D_2 (10 June) and D_3 (21 June) and three varieties, *viz.*, V_1 (VLM 324), V_2 (PRM 2) and V_3 (VLM 347), with three replications. Data were recorded for growth, yield attributes and yield parameters and analyzed using ANOVA at the 5% probability level. The sowing window significantly influenced several growth and yield traits, with D_3 (21 June) generally showing superior performance. Among the varieties, PRM 2 (V_2) exhibited better performance for important yield attributes and recorded the highest mean seed yield (2,006 kg ha^{-1}). The highest mean seed yield among sowing windows was recorded under D_3 (2,231 kg ha^{-1}), while the $D_3 \times V_2$ combination showed the highest performance for seed yield. The study indicated that sowing on 21 June with PRM 2 was the most promising combination for enhancing finger millet productivity under the tested mid-hill conditions of the Garhwal Himalayas.

Key words : Finger millet, *Eleusine coracana*, Sowing windows, Varietal performance, Growth attributes, Yield attributes, Garhwal Himalayas.

Introduction

Millets are important climate-resilient cereals that contribute to food and nutritional security, livestock feeding and sustainable agricultural production, particularly in marginal and rainfed environments. Their relatively low input requirements, adaptability to diverse agroecological conditions and tolerance to several abiotic stresses make them important crops for climate-resilient agriculture (Dwivedi *et al.*, 2012; Bista *et al.*, 2024; Kaur *et al.*, 2024). Finger millet (*Eleusine coracana* (L.) Gaertn.) is one of the important small millets belonging to the family Poaceae. It is an allotetraploid species (2n = 4x = 36; AABB) and is predominantly self-pollinated (Goron and Raizada, 2015). The crop is believed to have originated in East Africa and subsequently spread to South Asia, where it has been cultivated for several millennia. In India, finger millet is commonly known as ragi, mandua and other regional names and forms an important component of traditional diets, particularly in the hill regions. Its grains are rich in calcium, dietary fibre, protein and other nutritionally important constituents, while bioactive compounds such as polyphenols contribute to its functional properties (O'Kennedy *et al.*, 2006; Goksen *et al.*, 2023; Kaur *et al.*, 2024). Recent research has further

highlighted the potential of finger millet as a nutrient-rich crop with applications in functional foods and sustainable food systems (Sadh *et al*., 2024).

Finger millet is cultivated across diverse agroecological environments, ranging from plains to plateau and hill regions. Its adaptability to relatively dry conditions and low-input production systems makes it particularly suitable for rainfed agriculture. In Uttarakhand, finger millet is traditionally cultivated as an important rainfed cereal and contributes substantially to the food and livelihood systems of hill farming communities. The crop is therefore of particular significance in the Garhwal Himalayas, where fragmented landholdings, undulating terrain, limited irrigation facilities and variable rainfall often constrain agricultural productivity. The climate resilience and adaptability of finger millet provide opportunities for sustaining cereal production under such challenging environments (Bista *et al*., 2024; Kaur *et al*., 2024). However, several production constraints, including suboptimal agronomic management, abiotic and biotic stresses, and limited access to improved varieties, continue to restrict its productivity (Gebreyohannes *et al*., 2024).

The productivity of finger millet is influenced by genotype, sowing time, soil moisture, temperature, nutrient availability and other crop management practices. Among these factors, sowing time is an important and relatively low-cost agronomic intervention, particularly under rainfed conditions. The timing of sowing determines the environmental conditions experienced by the crop during establishment, vegetative growth, flowering and grain development and, consequently, affects crop duration, yield attributes and final grain yield. Under changing climatic conditions, variability in rainfall distribution and temperature further increases the importance of selecting an appropriate sowing window. Therefore, synchronization of crop phenology with favourable environmental conditions through suitable sowing time can contribute to improved crop productivity.

The response to sowing time may vary among genotypes because finger millet varieties differ in growth duration, phenology, plant architecture and adaptation to specific agroclimatic conditions. Genetic variability for agronomic and adaptive traits provides an opportunity to identify varieties suited to particular production environments (Gebreyohannes *et al*., 2024). Thus, understanding the interaction between sowing window and variety is important for identifying combinations capable of maintaining higher productivity under variable environmental conditions. Recent reviews have emphasized the need to strengthen agronomic management and varietal improvement strategies to narrow the productivity gap in finger millet (Gebreyohannes *et al*., 2024).

Although, finger millet is well adapted to hill environments, location-specific information on the response of improved varieties to different sowing windows under the mid-hill conditions of the Garhwal Himalayas remains limited. Identification of a suitable sowing window in combination with a better-performing variety could provide a simple, economical and easily adoptable approach for improving finger millet productivity under rainfed conditions. Therefore, the present study was undertaken to evaluate the influence of different sowing windows on the growth, yield attributes and yield of finger millet varieties under the mid-hill conditions of the Garhwal Himalayas, Uttarakhand, and to identify a suitable sowing window × variety combination for enhanced productivity.

Materials and Methods

Study area

The field experiment was conducted during the *Kharif* season of 2022 under rainfed conditions at B Block, Ranichauri Campus, Veer Chandra Singh Garhwali Uttarakhand University of Horticulture and Forestry (VCSG UUHF), Tehri Garhwal, Uttarakhand, India. The experimental site was located in the mid-hill region of the Garhwal Himalayas at an elevation of 1795 m above mean sea level, at approximately 30°18′ 56′′ N latitude and 78°24′ 37′′ E longitude. The experiment was conducted on a terrace field under rainfed conditions.

Planting material

Three finger millet varieties, *viz*., VLM 324 (V_1), PRM 2 (V_2) and VLM 347 (V_3), were used as planting material. The seed material was obtained from Krishi Vigyan Kendra (KVK), Ranichauri, Tehri Garhwal, Uttarakhand. The experiment was conducted to evaluate the performance of these varieties under different sowing windows. A seed rate of 10 kg ha^{-1} was used.

Experimental details

The experiment was laid out in a factorial randomized block design (FRBD) with three replications, comprising nine treatment combinations. [T_1 (D_1V_1) - First date of sowing (01.06.2022) + VLM 324, T_2 (D_1V_2) - First date of sowing (01.06.2022) + PRM 2, T_3 (D_1V_3) - First date of sowing (01.06.2022) + VLM 347, T_4 (D_2V_1) - Second date of sowing (10.06.2022) + VLM 324, T_5 (D_2V_2) - Second date of sowing (10.06.2022) + PRM 2, T_6 (D_2V_3) - Second date of sowing (10.06.2022) + VLM 347, T_7 (D_3V_1) - Third date of sowing (21.06.2022) + VLM 324,



(a) Crop growth at 60 DAS



(b) Crop growth at harvest

Note: DAS – Days After Sowing

Photoplate 1 : General field view of experimental field at 60 DAS and at harvest.



(a) VLM 324 (b) PRM 2 (c) VLM 347

(a) VLM 324, (b) PRM 2 and (c) VLM 347

Photoplate 2 : Seed samples of three finger millet varieties (VLM 324, PRM 2 and VLM 347).

T_8 (D_3V_2) - Third date of sowing (21.06.2022) + PRM 2, T_9 (D_3V_3) - Third date of sowing (21.06.2022) + VLM 347], comprise of three date of sowing *viz.*, D_1 (01.06.2022), D_2 (10.06.2022) and D_3 (21.06.2022) and three finger millet varieties *viz.*, V_1 (VLM 324), V_2 (PRM 2) and V_3 (VLM 347) (Fig. 1). The dimensions of the experimental area were 2 × 6 m. The seed rate was 10 kg ha^{-1}. The spacing between the plants within treatments was consistently maintained at 10 cm between plants and 20 cm between rows. The seeds were planted at three different intervals of 10 days apart to a depth of about 1.5 cm in continuous rows and covered lightly with loose soil.

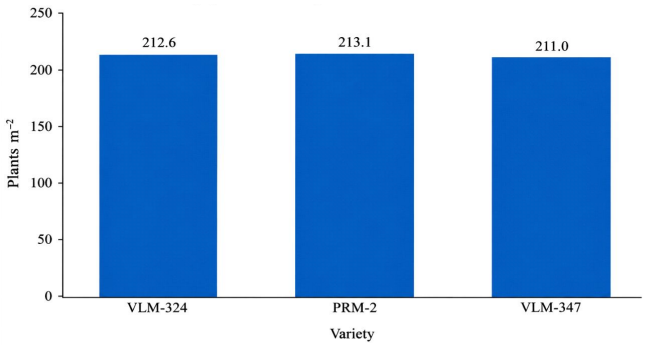


Fig. 1 : Plant population of finger millet varieties at 60 DAS.

Observation recorded (crop growth, yield attributes and yield parameters)

The experiments comprise three varieties, *viz.* VLM 324 (V_1), PRM 2 (V_2) and VLM 347 (V_3) and their performance was observed under the influence of three distinct sowing dates: 1 June (D_1), 10 June (D_2) and 21 June (D_3). The study carefully followed the established standard procedures and practices. To monitor the progress of the crop, regular measurements of plant height were recorded at various intervals during the growing season, precisely 60 (DAS), 90 DAS and at the time of harvest. Five randomly tagged plants from the sites were designated within each plot to assess yield-contributing factors. Upon reaching maturity, attributes associated with yields, such as 1,000 seed weight, yield (kg/ha) and productive tillers, were recorded. At maturity, observations were recorded on productive tillers per plant, finger length and panicle length. Biological yield refers to the total above-ground dry matter produced by a plant in a unit land area weighed in kg/plot and expressed in kg/ha. Straw yield refers to the quantity of crop residues, typically the above-ground plant material such as stems and leaves, remaining after the primary crop product (grains or seeds) has been harvested.

The harvest index is the ratio of economic yield to total biological yield

$$\text{Harvest Index } (\%) = \frac{\text{Economic yield}\left(\frac{\text{kg}}{\text{ha}}\right)}{\text{Biological yield}\left(\frac{\text{kg}}{\text{ha}}\right)} \times 100$$

At the point of maturity, plots were harvested and seeds were manually threshed individually to determine the seed yield. The seed yield was measured in kg/plot and converted to kg/hectare at an optimal moisture content of 12-15%. The total number of grains from tagged plants was counted after threshing and averaged per plant.

Randomly collected samples were obtained from the cleaned seeds of each plot and 1,000 seeds were precisely weighed on an electronic balance and reported as the test weight in grams.

Statistical analysis

The experimental data were subjected to analysis of variance (ANOVA) appropriate for a factorial randomized block design (FRBD) with two factors, *viz*., sowing window and variety, using three replications. The significance of the main effects of sowing window and variety, and their interaction (D × V), was tested at the 5% significance level. The standard error of the mean (SEm) and the critical difference (CD) at P = 0.05 were calculated to compare treatment means. Differences between treatment means were considered statistically significant when they exceeded the corresponding CD value. The statistical analysis was performed using the OPSTAT online statistical analysis tool.

Results and Discussion

Statistical analysis of the data (Table 1) and (Fig. 2) revealed that sowing dates significantly influenced plant height. In contrast, varieties and interaction between D × V had no significant effect on plant height at all stages of observation. The highest plant height was recorded in D_3 at 90 DAS and harvest. The variation in plant height among sowing windows may be associated with differences in environmental conditions during crop establishment and vegetative growth. Therefore, minor fluctuations in weather or soil conditions may not have had a substantial impact on its plant height; this is consistent with the findings of Pedersen and Lauer (2004) on soybean crops. Different sowing dates affected the finger millet plant population per square meter; however, no significant effects of varieties or interactions between D and V were found. The third date of sowing, D3, showed the maximum population per square meter (Table 1). As per findings, early sowing extends the time from sowing to plant emergence, leading to reduced germination and crop density. In contrast, late sowing accelerates the path to physiological maturity, resulting in higher grain moisture content at harvest and taller plants. Higher temperature and moisture conditions during the third sowing date resulted in a maximum plant population per m^2. Maresma *et al.* (2019) and Roshan *et al.* (2021) reported similar findings in maize and wheat crop studies. Sowing at the optimal time and with a suitable variety of choices can positively impact finger millet growth, yield and quality attributes.

Table 1 : Plant population (plants m^{-2}) and plant height (cm) of finger millet as influenced by sowing dates and finger millet varieties.

Treatment	Plant population (plants m^{-2})	Plant height (cm)		
Date of sowing (D)	**60 DAS**	**60 DAS**	**90 DAS**	**At harvest**
D_1: (01.06.2022)	180.6	15.3	48.2	61.1
D_2: (10.06.2022)	217.1	20.6	50.4	64.0
D_3: (21.06.2022)	239.0	16.6	52.7	66.2
SEm ±	3.9	1.05	8.4	1.9
CD (P=0.05)	11.9	3.18	NS	NS
Varieties (V)				
V_1: (VLM-324)	212.6	19.4	53.2	66.6
V_2: (PRM-2)	213.1	16.8	49.8	59.7
V_3: (VLM-347)	211.0	16.3	48.3	65.0
SEm ±	3.9	1.05	8.4	1.9
CD (P=0.05)	NS	NS	NS	NS
Interaction (D×V)	NS	NS	NS	NS

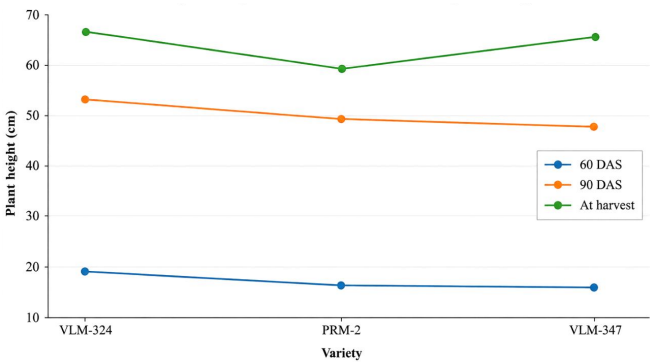


Fig. 2 : Plant height of finger millet varieties at different growth stages.

The results, as detailed in Table 2 and Fig. 3 indicated among the varieties tested, V_2 (PRM 2) exhibited the highest tiller production per plant with D_3 (21.06.2022), revealing that the sowing date, varieties and their interaction (D × V) significantly influenced the number of tillers per plant (Table 2.1), which may be due to favourable climatic conditions during the crop growth period which directly has an impact on the tiller's production. The interpretation is in conformity with Kanjiya *et al.* (2021) in pearl millet. Finger millet varieties exhibit unique genetic traits that impact their tillering capacity. Certain varieties are naturally inclined towards higher tiller production due to their specific genetic makeup. This observation aligns with similar findings reported in rice crops by Singh and Mishra (2022). The observation recorded for 1,000 seed weight of the finger

Table 2 : Productive tillers per plant, finger per plant, finger length (cm), panicle length (cm) and 1,000 seed weight (g) of finger millet as influenced by sowing dates and finger millet varieties.

Treatment	Productive tillers/plant	Finger/plant	Finger length (cm)	Panicle length (cm)	1000 seed weight (g)
Date of sowing (D)	**90 DAS**	**At harvest**			
D_1: (01.06.2022)	2.16	5.62	5.92	6.25	2.6
D_2: (10.06.2022)	2.60	6.01	5.93	6.33	2.83
D_3: (21.06.2022)	3.09	6.13	6.17	6.64	3.31
SEm ±	0.08	0.14	0.04	0.09	0.07
CD (P=0.05)	0.25	NS	0.12	0.27	0.21
Varieties (V)					
V_1: (VLM-324)	2.15	5.54	5.93	6.08	2.89
V_2: (PRM-2)	3.04	6.63	6.16	6.74	3.00
V_3: (VLM-347)	2.64	5.58	5.93	6.40	2.83
SEm±	0.08	0.14	0.04	0.09	0.07
CD (P=0.05)	0.25	0.45	0.12	0.27	NS
Interaction (D×V)	S	NS	S	NS	NS

Table 2.1 : Interaction effect table for tillers/plant (At 90 DAS).

Treatment	Varieties (V)		
	V_1: (VLM-324)	**V_2: (PRM-2)**	**V_3: (VLM-347)**
Date of sowing (D)			
D_1: (01.06.2022)	1.34	2.73	2.40
D_2: (10.06.2022)	2.53	2.93	2.34
D_3: (21.06.2022)	2.60	3.47	3.19
Interaction	**SEm ±**		**CD (P=0.05)**
D×V	0.14		0.44

Table 2.2 : Interaction effect table for finger length (At harvest).

Treatment	Varieties (V)		
	V_1: (VLM-324)	**V_2: (PRM-2)**	**V_3: (VLM-347)**
Date of sowing (D)			
Date of sowing (D)			
D_1: (01.06.2022)	5.79	6.07	5.90
D_2: (10.06.2022)	5.91	5.96	5.90
D_3: (21.06.2022)	6.08	6.45	5.97
Interaction	**SEm ±**		**CD (P=0.05)**
D×V	0.07		0.20

millet crop was found to be influenced by the dates of sowing. Among the three dates of sowing, the third sowing, *i.e.*, 21 June, proved to be superior, whereas, among the varieties and interaction (D × V), a non-significant observation was recorded.

The statistical analysis of the data revealed that both sowing dates and varieties had a significant impact on finger length and panicle length (Table 2 and Fig. 3). Specifically, variety V_2 produced the most extended finger and panicle lengths when sown on the third sowing window (D_3). The interaction between sowing date (D) and variety (V) significantly affected finger length (Table 2.2). The most favourable panicle and finger length results were observed when using the combination of D_3 and V_2, as shown in Table 2. This finding is consistent with the study of Veeraputhiran *et al.* (2009), which also highlighted the significant impact of finger millet variety on yield attributes. According to the findings, the most optimal date for improving yield was determined to be D3, *i.e.*, (21 June), likely corresponding to periods of sufficient rainfall, which likely contributed to better growth components in the plant. A significantly higher yield on finger millet in the second fortnight of June is mainly due to the increase in yield attributing characters like ear head length, grain yield/plant and test weight Mubeena *et al*. (2019). The influence of sowing dates and varieties was found to be significant (Table 5). The crops sown on 21 June (D_3) seemed to be benefited from favourable weather conditions and a prolonged photoperiod during the investigation. This resulted in higher assimilates being translocated towards the panicle, leading to increased productive tillers, number of grains per panicle, test weight and ultimately higher grain yield. These findings align with a previous study on pearl millet by Detroja *et al.* (2018).

Data regarding seed yield per plant and kg per hectare are presented in Table 3 and Fig. 5. The Mean value of sowing dates indicated that seed yield significantly

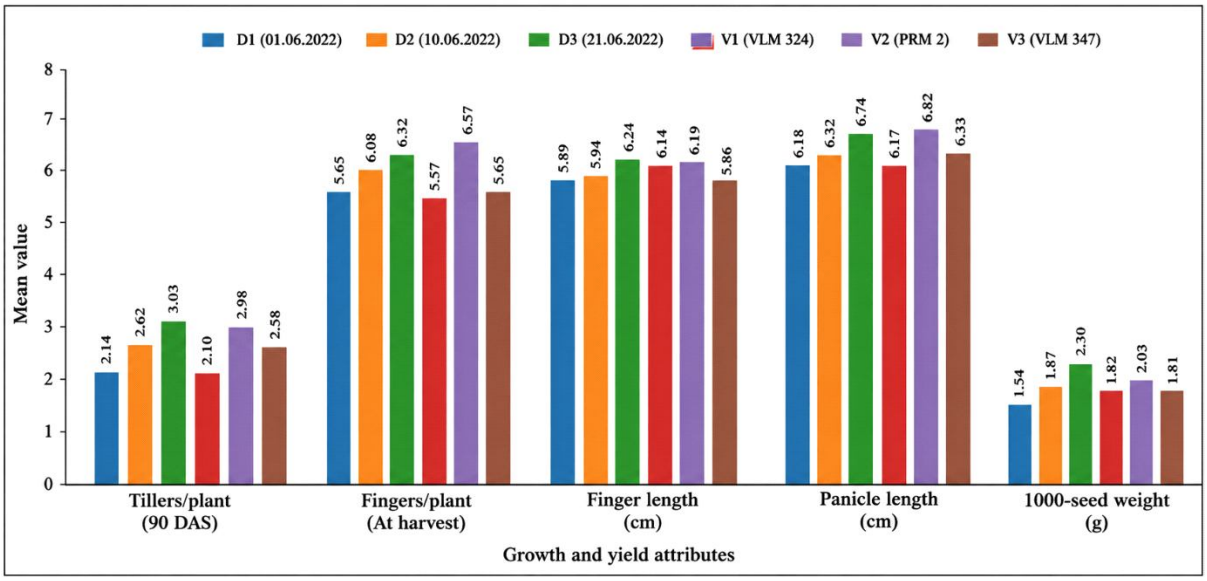


Fig. 3 : Growth and yield attributes of finger millet as influenced by sowing dates and varieties.

Table 3 : Seed yield per plant (g), seed yield (kg/ha), straw yield (kg/ha), biological yield (kg/ha) and harvest index (%) of finger millet as influenced by sowing dates and finger millet varieties.

Treatment	Seed yield/ plant	Seed yield (kg/ha)	Straw yield (kg/ha)	Biological yield (kg/ha)	Harvest Index (%)
Date of sowing (D)	**At harvest**				
D_1: (01.06.2022)	3.23	1134	3310	4444	24.64
D_2: (10.06.2022)	3.31	1650	4236	5885	29.57
D_3: (21.06.2022)	3.96	2231	5671	7902	29.35
SEm ±	0.08	101	384.4	426	2.3
CD (P=0.05)	0.02	307	1162.2	1288	NS
Varieties (V)					
V_1: (VLM-324)	3.31	1461	4305	5766	24.57
V_2: (PRM-2)	3.78	2006	4884	6890	30.3
V_3: (VLM-347)	3.41	1548	4027	5575	28.71
SEm ±	0.08	101	384	426	1.77
CD (P=0.05)	0.02	307	NS	NS	NS
Interaction (D×V)	N.S.	S	NS	NS	NS

reduced within the first sowing (D_1). Sowing on 21 June (D_3) had a significantly higher maximum seed yield, while the minimum seed yield was recorded when the crop was sown on 1 June (D_1). Significant yield variation was observed among three varieties, with PRM 2 (V_2) producing the highest yield. In the case of D × V interaction, a significantly higher seed yield was recorded in D3V2 (Table 3.1). This aligns with the findings of Sarawale *et al*. (2016), who reported that varieties significantly impact the yield attributes of finger millet. The yield of finger millet might be influenced by solar radiation, particularly during ripening. Bright sunshine during the crop's ripening period helps develop seeds. Similar findings were also reported by Sudhishree and Dass (2006) in finger millets. The combination of grain/

Table 3.1 : Interaction effect table for seed yield (kg/ha).

Treatment	Varieties (V)		
	V_1: (VLM-324)	**V_2: (PRM-2)**	**V_3: (VLM-347)**
Date of sowing (D)			
D_1: (01.06.2022)	599.72	1241.67	1560.28
D_2: (10.06.2022)	1510.83	2142.78	1295.00
D_3: (21.06.2022)	2271.95	2633.33	1788.33
Interaction	**SEm ±**		**CD (P=0.05)**
D×V	175.80		531.58

Suitable sowing time and variety combination can enhance finger millet productivity under rainfed Himalayan conditions.

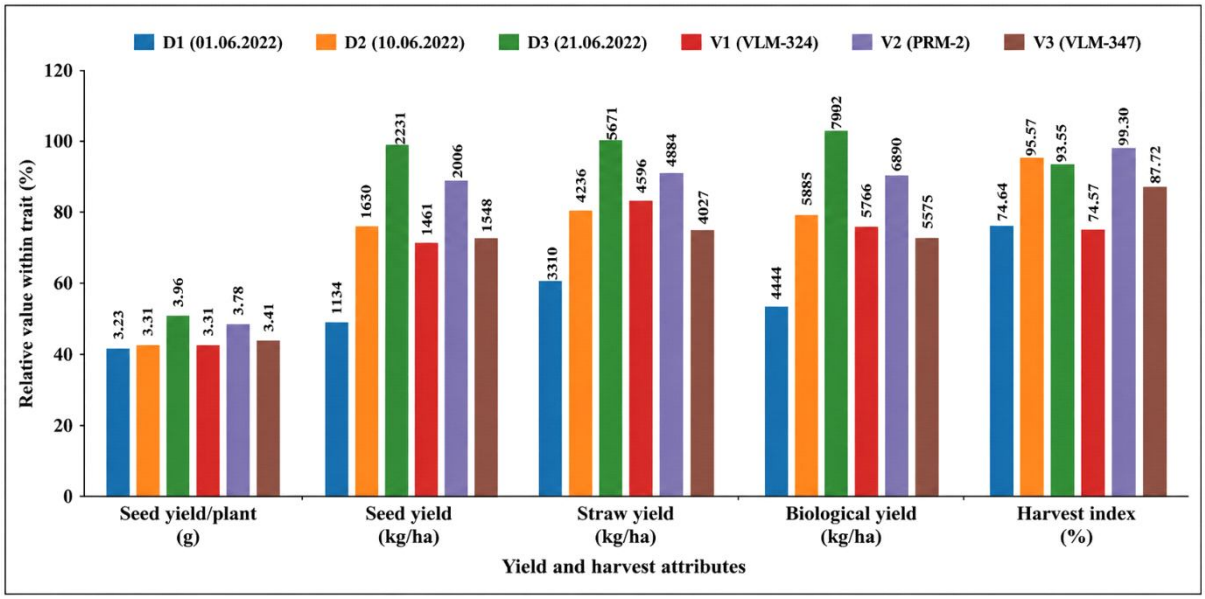


Fig. 4 : Yield and harvest attributes of finger millet as influenced by sowing dates and varieties.

seed and straw yields conformed to the biological yield and recorded a maximum in D_3, while the lowest value was observed in D_1 (Table 3). A statistically non-significant relation was found in the case of variety and interaction. High temperature increases seed weight, suggesting that it may favor seed coat development.

Similarly, it was reported in soybean seeds (Keigley and Mullen, 1986). The higher grain and straw yields were due to increases in growth and yield parameters. This was mainly due to an increase in grain yield and an optimum straw yield, resulting in a higher harvest index. These results were consistent with findings from Revathi *et al.* (2018) and Kumar *et al.* (2019).

Conclusion and Recommendations

The study demonstrated that sowing window significantly influenced the growth and yield performance of finger millet under the mid-hill conditions of the Garhwal Himalayas. 21 June (D_3) recorded the highest mean seed yield (2,231 kg ha^{-1}), while PRM 2 (V_2) recorded the highest varietal mean (2,006 kg ha^{-1}). The significant D × V interaction for seed yield indicated that $D_3 \times V_2$ (21 June × PRM 2) was the most productive combination, recording 2,633.33 kg ha^{-1}. Thus, sowing on 21 June with PRM 2 may be considered a promising combination under the agroclimatic conditions of the study area.

Highlights

- Sowing window significantly influenced growth and yield performance of finger millet under mid-hill conditions of the Garhwal Himalayas.
- **21 June sowing** recorded the highest mean seed yield among the evaluated sowing windows.
- **PRM 2** exhibited superior yield performance compared with VLM 324 and VLM 347.
- The **21 June × PRM 2** combination recorded the highest seed yield (2,633.33 kg ha^{-1}).

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Author contributions

Shubham Thapa: Conceptualization, methodology, field experimentation, investigation, data collection, data analysis, visualization, writing—original draft, and manuscript preparation.

Sumit Chaudhary: Research supervision and guidance, conceptualization of the study, methodology, interpretation of results, critical review, and revision of the manuscript.

Ajay Kumar: Field experimentation, data collection, investigation, and review of the manuscript.

Pankaj Kumar: Field experimentation, data collection, interpretation of results, and review of the manuscript.

R. K. Bijalwan: Academic guidance, critical review and revision of the manuscript.

All authors read and approved the final version of

the manuscript and agreed to be accountable for all aspects of the work.

Conflict of interest : The authors declare that they have no conflict of interest related to this research or its publication.

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