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Effect of sowing dates on seed yield and seed quality of Barnyard millet (*Echinochloa frumentacea* (Roxb.) Link)

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Abstract
For the investigation of the effect of sowing dates on seed yield and seed quality of barnyard millet (*Echinochloa frumentacea* (Roxb.) Link). The field experiment was undertaken during *summer* season of the year 2024 with two sowing dates S1: 9th MW (29th Feb. 2024) and S2: 11th MW (16th Mar. 2024) as the main plot treatment and 12 barnyard millet genotypes along with two checks as the sub plot treatment. First sowing date S1-9th MW (29th February 2024) recorded highest (146.98 cm) plant height than second sowing date S2-11th MW (16th March 2024) (136.66cm). The genotype KIBMG-22-09 (V_5) had significantly higher plant height (157.67cm). Significant varietal differences were found in characters *viz.* days to 50 per cent flowering in barnyard millet genotypes when sown on second sowing date S2-11th MW (16th March 2024) required significantly less (63.31 days) number of days to 50 per cent flowering. Number of days required to maturity follows same trend. Number of tillers per plant was significantly influenced by date of sowing and genotypes. The highest number of tillers (7.22 per plant) was recorded in genotypes KIBMG-22-09 (V_5), which was followed by genotypes KIBMG-22-11(V_8) (6.93 per plant). The genotypes KIBMG-22-09 (V_5) recorded significantly highest grain yield in first sowing date S1-9th MW (29th February 2024) (27.05 q ha^{-1}). The grain yield recorded by the genotype KIBMG-22-09 (V_5) for second sowing date S2-11th MW (16th March 2024) was 19.86 q ha^{-1}. The genotypes KIBMG-22-09 (V_5) recorded significantly highest fodder yield in first sowing date S1-9th MW (29th February 2024) (80.30 q ha^{-1}).
The highest seed germination percentage (97.67%) was recorded in genotypes KIBMG-22-09 (V_5), which was followed by genotypes KIBMG-22-11(V_8) (96.17%). Seedling vigour index-I was not significantly influenced by date of sowing but it is significantly influenced by genotypes. The highest seedling vigour index-I (1535.02) was recorded in genotype KIBMG-22-09 (V_5), which was followed by genotype KIBMG-22-11(V_8) (1483.87). Seedling vigour index II was not significantly influenced by date of sowing but it is significantly influenced by genotypes. The higher (2.73) Seedling vigour index II was recorded in genotype KIBMG-22-09 (V_5), which was followed by genotype KIBMG-22-11(V_8) (2.60).

Keywords: Barnyard millet, sowing dates, genotypes, seed yield, harvest index, germination

Introduction
Barnyard millet, also known as *Echinochloa frumentacea* (Roxb.) Link, is a small-grain cereal that is widely grown in Asia and parts of Africa. It is a nutritious and drought-resistant crop, making it well-suited to areas with poor soil and low rainfall. It is a staple food in those areas where climatic and edaphic conditions are unsuitable for rice cultivation (Yabuno, 1987) [21]. Though in the recent years, the said crop has gained renewed interest due to its rich nutritional profile and high dietary fiber content. The demand of barnyard millet has increased due to its highly nutritious grains and presence of strong antioxidative compounds. In India, barnyard millet is grown from Deccan plateau in the south to higher Himalayan region in the North. It is cultivated in many countries such as India, China, Japan, Malaysia, East Indies, Africa and United States of America (Anuradha *et al.*, 2014) [3]. In India it is mainly cultivated in Orissa, Maharashtra, Madhya Pradesh, Tamil Nadu, Bihar, Punjab, Gujarat and hills of Uttarakhand (Kumar *et al.*, 2000) [11]. In most regions, barnyard millet is sown during the monsoon season

(June to July) and harvested in September to October.

Millets are valued for their adaptability to diverse geographic locations, which makes them predominantly cultivated as rainfed crops (Ulaganathan and Nirmalkumari, 2014) [19]. Barnyard millet is the minor millet which is emerged as very essential dual-motive crop for feed and fodder. They have specific adaptation properties for negative degraded land and capacity to tolerate the abiotic strain and grown in extreme climatic condition. Nutritional composition of barnyard millet in per 100 g is 10.1 per cent protein, 8.7 per cent moisture, 3.9 per cent fat, 6.7 per cent crude fiber, 2.0 per cent total fat, 68.8 per cent carbohydrate and 398 kcal/100 g energy. In the barnyard millet total dietary fiber content was high (12.5%) including soluble (4.2%) and insoluble (8.4%) fractions is recorded (Ugare *et al.*, 2014) [18]. Optimum sowing time plays an important role to fully exploit the genetic potential of a genotypes as it provides optimum growth conditions such as temperature, light, humidity and rainfall. The growth phase of the crop should synchronize with optimum environmental conditions for better expression of growth and yield. Coupling the proper time of sowing with newly developed genotypes can help in increasing the yield of barnyard millet.

Materials and Methods

The experiment was laid in Split plot design with three replications during *summer* season of the year 2024 with two sowing dates S1: 9th MW (29th Feb. 2024) and S2: 11th MW (16th Mar. 2024) as the main plot treatment and 12 barnyard millet millet genotypes *viz*., V_1: BBM-8, V_2: KIBMG-22-04, V_3: KIBMG-22-08, V_4: BBM-18, V_5: KIBMG-22-09, V_6: BBM-8-10, V_7: BBM-EF-4, V_8: KIBMG-22-11, V_9: BBM-18-8, V_{10}: KIBMG-22-12, V_{11}: BBF-EF-3 and V_{12}: KIBMG-22-13 along with two checks V_{13}: DHBM-93-3 (C) and V_{14}: Phule Barti-1(C) as the sub plot treatment for the study of the effect of sowing dates on seed yield and seed quality of barnyard millet (*Echinochloa frumentacea* (Roxb.) Link). The recommended package of practice was undertaken for conduct of experiment. The growth and yield parameters *viz*., Days to 50% flowering and Maturity, Plant height (cm), Panicle length(cm), Number of tillers plant-1, Grain and fodder yield (q ha-1), Harvest index (%) and Test weight (g) was recorded. The seed quality parameters *viz*., Germination (%) worked out as per ISTA rules (Anon., 1999) [2], Root and shoot length (cm), Vigour indces (I and II) were computed by adopting the formula as suggested by Abdul Baki and Anderson (1973) [1]. The data was statistically evaluated by analysis of variance and significance was established according to Gomez and Gomez (1984) [8] recommendations. The critical difference (CD) was worked out at 5% level significance. For the treatment comparison, where ever the F test revealed significant, the treatment effects are presented by preparing the Table of mean of important character with the appropriate standard error of mean and critical difference (CD) value.

Results and Discussion

1. Effect of sowing dates, genotypes and interaction on growth and yield attributes of barnyard millet.

The sowing dates and genotypes showed significant effect on vegetative growth and yield attributes of foxtail millet and is presented at table 1. From the table, it is revealed that, Significant varietal differences were found in characters *viz.* days to 50 per cent flowering in barnyard millet genotypes when sown on second sowing date S2-11th MW (16th March 2024) required significantly less (63.31 days) number of days to 50 per cent flowering. Same results are reported by Rawat *et al.* (2020) [14]. Number of days required to maturity were also significantly less (95.50 days), when genotypes were sown on second sowing date S2-11th MW (16th March 2024). The crop had attained the late flowering in first sowing date S1-9th MW (29th February 2024), days to maturity also recorded in similar trend late maturity First sowing date S1-9th MW (29th February 2024) recorded highest (146.98 cm) plant height than second sowing date S2-11th MW (16th March 2024) (136.66cm). The genotype KIBMG-22-09 (V_5) had significantly higher plant height (157.67cm) followed by the genotypes KIBMG-22-11(V_8) (155.75cm). High temperature during the growing period of crop and underlying genetic differences across genotypes are responsible for the variation in plant height. Sood *et al.* (2015) [16] observed similar findings

The earhead length had significant effect on sowing dates. More earhead length was observed for first sowing date S1-9th MW (29th February 2024) than second sowing date S2-11th MW (16th March 2024). The genotypes KIBMG-22-09 (V_5) recorded significantly highest (24.48 cm) ear head length.Number of tillers per plant was significantly influenced by date of sowing and genotypes. The highest number of tillers (7.22 per plant) was recorded in genotypes KIBMG-22-09 (V_5), which was followed by genotypes KIBMG-22-11(V_8) (6.93 per plant). The photosynthetic source affects the grain production of crops. In terms of plant height, it can develop more tillers per plant, which results in a better grain production.

The genotypes KIBMG-22-09 (V_5) recorded significantly highest grain yield in first sowing date S1-9th MW (29th February 2024) (27.05 q ha^{-1}). The grain yield recorded by the genotype KIBMG-22-09 (V_5) for second sowing date S2-11th MW (16th March 2024) was 19.86 q ha^{-1}. Hence there is 26.46% reduction in S2 as compared to S1-9th MW (29th February 2024). The higher grain yield in genotype KIBMG-22-09 (V_5) might be due to the genetic potential to convert greater per cent of photosynthates to the grain yield and more adaptability to environmental conditions. The total 8.5 per cent grain yield was reduced in S2-11th MW (16th March 2024) as compared to S1-9th MW (29th February 2024). The same genotypes recorded significantly highest fodder yield in first sowing date S1-9th MW (29th February 2024) (80.30 q ha^{-1}). An increase in temperature coupled with longer photoperiods affect the grain yield adversely of barnyard millet due to sterility, reduction in number of grains and lower partitioning of assimilates the grain. Similar findings were recorded by Bandyopadhyay (2003) [5] and Djanaguiraman *et al.* (2018) [7] while working with finger millet and pearl millet respectively. The high fodder yield in KIBMG-22-09 (V_5) was due to the genetic potential of genotypes to grow taller with good number of tillers during successive stages of growth of crop and more suitability to sowing date. Harvest index was not significantly influenced by sowing dates and genotypes. The genotype KIBMG-22-12 (V_{10}) recorded significantly highest harvest index (24.64%) and 1000 seed weight (2.79 g). Similar results were recorded by Basavaraja and Sheriff (1991) [6], Kumar *et al.* (2000) [11] and Nanja Reddy and Gowda (2020) [12] in finger millet. Most of the growth parameters *viz.* plant height and yield parameters like ear head length, number of tillers per plant, grain yield and fodder yield were significantly highest in first sowing date S1-9th MW (29th February 2024) which may be due to the optimum temperature for growth and more congenial environmental conditions during the crop growth period.

2. Effect of sowing dates, genotypes and interaction on seed quality attributes of barnyard millet

Seed germination percentage was not significantly influenced by date of sowing but it is significantly influenced by genotypes. The highest seed germination percentage (97.67%) was recorded in genotypes KIBMG-22-09 (V_5), which was followed by genotypes KIBMG-22-11(V_8) (96.17%). Similar results were obtained by Rehman *et al.* (2013). Seedling root length was not significantly influenced by date of sowing but it is significantly influenced by genotypes. The highest seedling root length (8.45 cm) was recorded in genotypes KIBMG-22-09 (V_5), which was followed by genotypes KIBMG-22-11(V_8) (8.40 cm). Seedling shoot length was not significantly influenced by date of sowing but it is significantly influenced by genotypes. The highest seedling shoot length (7.27 cm) was recorded in genotypes KIBMG-22-09 (V_5), which was followed by genotypes BBM-8-10 (V_6) (6.67 cm). Similar results were observed by Arya *et al.* (2015) [4]. Seedling dry weight was not significantly influenced by date of sowing but it is significantly influenced by genotypes. The highest seedling dry weight (28.00 mg) was recorded in genotypes KIBMG-22-09 (V_5), which was followed by genotypes KIBMG-22-11(V_8) (27.90 mg).

Seedling vigour index-I was not significantly influenced by date of sowing but it is significantly influenced by genotypes. The highest seedling vigour index-I (1535.02) was recorded in genotype KIBMG-22-09 (V_5), which was followed by genotype KIBMG-22-11(V_8) (1483.87). Seedling vigour index II was not significantly influenced by date of sowing but it is significantly influenced by genotypes. The higher (2.73) Seedling vigour index II was recorded in genotype KIBMG-22-09 (V_5), which was followed by genotype KIBMG-22-11(V_8) (2.60). Similar findings were also recorded by Sooganna (2015) [17], Iswariya *et al.* (2019) [9] and Soniya *et al.* (2022) [15] in finger millet.

The genotypes are crucial in determining the crop's yield. Environment has an impact on genotype's yield potential within genetic constraints. The genotype's capacity for yield depends on several physiological processes that are regulated by both genetic make-up and environmental factors.

The interaction effect between sowing dates and genotypes for growth, yield parameters and seed quality parameters were found non-significant except for number of tillers, earhead length, grain yield, fodder yield.

Table 1: Effect of sowing dates, genotypes and interaction on vegetative and yield attributes of barnyard millet.

No.	Treatment	Days to 50% flowering	Days to maturity	Plant height (cm)	Productive tillers plant^{-1}	Grain yield (q ha^{-1})	Earhead length(cm)	Fodder yield (q ha^{-1})	Harvest index (%)	Test weight(g)
A.	**Main plot: Sowing Dates**									
S_1:	9th MW (29th Feb. 2024)	67.79	100.62	146.98	6.38	20.10	20.39	68.56	23.74	2.58
S_2:	11th MW (16th Mar. 2024)	63.31	95.50	136.99	6.07	18.39	19.43	59.94	22.52	2.55
	SE (±)	0.48	0.68	0.69	0.03	0.15	0.14	1.27	0.28	0.00
	CD at 5%	2.93	4.11	4.20	0.16	0.90	0.88	7.74	NS	0.02
B.	**Sub plot: Genotypes**									
V_1:	BBM-8	62.67	93.50	150.58	6.42	22.44	20.47	72.35	23.70	2.19
V_2:	KIBMG-22-04	78.00	105.67	138.33	5.65	15.49	19.38	48.38	24.41	2.52
V_3:	KIBMG-22-08	64.17	97.50	148.23	5.65	21.47	19.83	70.33	23.44	2.74
V_4:	BBM-18	58.00	92.83	141.23	6.15	18.03	19.63	65.02	22.09	2.75
V_5:	KIBMG-22-09	68.33	100.00	157.67	7.22	23.45	24.48	75.80	23.53	2.79
V_6:	BBM-8-10	60.50	92.50	154.33	6.87	23.21	22.98	74.33	23.81	2.43
V_7:	BBM-EF-4	55.83	84.33	141.33	5.95	16.10	18.83	50.84	24.01	2.66
V_8:	KIBMG-22-11	62.17	98.50	155.75	6.93	23.26	23.32	75.76	23.48	2.76
V_9:	BBM-18-8	65.17	97.17	153.08	6.57	22.66	20.67	72.27	23.87	2.22
V_{10}:	KIBMG-22-12	60.17	101.50	135.00	5.88	15.31	18.22	46.87	24.64	2.61
V_{11}:	BBM-EF-3	54.00	82.50	76.00	5.38	12.51	11.47	45.17	22.97	2.50
V_{12}:	KIBMG-22-13	83.83	117.33	145.50	5.87	18.95	20.38	69.01	21.68	2.75
V_{13}:	DHBM-93-3 (C)	64.83	96.67	143.17	5.93	17.05	19.57	67.04	20.48	2.60
V_{14}:	Phule Barti-1(C)	80.00	112.83	147.58	6.23	19.51	19.50	66.35	23.03	2.68
	SE (±)	1.92	1.36	3.22	0.12	0.89	0.44	1.97	0.50	0.01
	CD at 5%	5.44	3.86	9.15	0.34	2.51	1.25	5.60	1.52	0.04
	Interaction (A x B)									
	SE (±)	2.71	0.11	4.56	0.18	1.25	0.63	2.79	1.41	0.01
	CD at 5%	NS	NS	NS	0.50	3.55	1.77	7.92	NS	NS
	General mean	65.55	98.06	141.99	6.22	19.25	19.91	64.26	23.13	2.57

Table 2: Effect of sowing dates, genotypes and interaction on seed quality attributes of barnyard millet.

No.	Treatment	Seed germination* (%)	Seedling root length (cm)	Seedling shoot length (cm)	Seedling dry weight (mg)	Seedling vigour index-I	Seedling vigour index-II
A.	**Main plot: Sowing Dates**						
S_1:	9th MW (29th Feb. 2024)	88.31 (70.00)	7.29	5.61	23.82	1148.11	2.11
S_2:	11th MW (16th Mar. 2024)	87.52 (60.31)	7.26	5.59	23.78	1134.04	2.09
	SE (±)	0.25	0.01	0.01	0.01	3.15	0.01
	CD at 5%	NS	NS	NS	NS	NS	NS
B.	**Sub plot: enotypes**						
V_1:	BBM-8	94.33 (76.22)	7.90	5.77	24.45	1289.25	2.29
V_2:	KIBMG-22-04	80.67 (63.91)	6.27	4.90	23.00	900.78	1.86

V_3:	KIBMG-22-08	92.67 (74.29)	7.78	5.40	23.12	1221.01	2.13
V_4:	BBM-18	85.00 (67.21)	6.74	5.10	23.34	1006.48	1.96
V_5:	KIBMG-22-09	97.67 (74.29)	8.45	7.27	28.00	1535.02	2.73
V_6:	BBM-8-10	85.83 (67.21)	8.08	6.67	25.00	1265.82	2.15
V_7:	BBM-EF-4	86.17 (68.16)	6.57	5.00	23.00	996.67	1.98
V_8:	KIBMG-22-11	96.17 (67.88)	8.40	6.43	27.90	1483.87	2.60
V_9:	BBM-18-8	94.67 (69.29)	8.07	6.03	25.00	1334.78	2.37
V_{10}:	KIBMG-22-12	77.50 (61.38)	5.98	4.87	22.50	840.23	1.63
V_{11}:	BBM-EF-3	76.00 (60.66)	5.37	4.77	22.01	769.72	1.67
V_{12}:	KIBMG-22-13	87.17 (69.01)	7.35	5.37	23.01	1108.47	2.00
V_{13}:	DHBM-93-3 (C)	87.50 (61.29)	7.24	5.55	23.00	1119.41	2.01
V_{14}:	Phule Barti-1(C)	89.50 (71.09)	7.35	5.37	23.00	1160.55	2.06
	SE (±)	1.32	0.06	0.11	0.04	18.86	0.03
	CD at 5%	3.75	0.18	0.32	0.11	53.52	0.09
	Interaction (A x B)						
	SE (±)	1.87	0.09	0.16	0.09	26.67	0.04
	CD at 5%	NS	NS	NS	NS	NS	NS
	General mean	87.92 (69.66)	7.28	5.60	23.80	1141.08	2.10

(* Values in parenthesis are arcsine transformed.)

Conclusion

Based on one season of experimental research taking into consideration with objectives of current research among different treatment combinations, all the barnyard millet genotypes can be cultivated in the *summer* season. The 9th MW (16th March) can be proper time for sowing of *summer* barnyard millet crop. Further, set of characters can be used for large scale screening of barnyard millet germplasm lines for identification of suitable line for *summer* cultivation. The genotypes KIBMG-22-09 (V_5) was found to be best among all genotypes in terms of growth and yield parameters.

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