E-ISSN: 2618-0618
P-ISSN: 2618-060X

NAAS Rating (2025): 5.20
www.agronomyjournals.com
2025; 8(9): 192-195
Received: 13-07-2025
Accepted: 17-08-2025

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Effect of sowing dates on seed yield and seed quality of foxtail millet (*Setaria italica* (L.) Beauv.)

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DOI: https://www.doi.org/10.33545/2618060X.2025.v8.i9c.3763

Abstract
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 foxtail millet genotypes along with two checks as the sub plot treatment for the investigation of the effect of sowing dates on seed yield and seed quality of foxtail millet (*Setaria italica* (L.) Beauv.).
The genotype KIFXG-22-02 (V_{11}) was identified as the most productive, as it consistently recorded superior growth parameters like greater plant height**,** extended flag leaf blade length and increased flag leaf blade width which contributed to its higher yield performance in comparison to the rest of the genotypes. The first sowing date S1: 9th MW (29th Feb.2024) resulted significantly higher seed yield and associated yield components in foxtail millet compared to the second sowing date 11th MW (16th Mar. 2024). The later sowing date S2: (11th MW (16th Mar. 2024)) was associated with an accelerated phenological progression, resulting in earlier attainment of both 50% flowering and maturity compared to the earlier sowing date S1: 9th MW (29th Feb. 2024). Superior seed quality was consistently recorded in foxtail millet seeds grown under the first sowing date (9th MW (29th Feb.2024)) compared to the second sowing date (S_2) [11th MW (16th Mar. 2024)]. Among the genotypes evaluated, KIFXG-22-02 (V_{11}) produced maximum seed yield (27.83 q $ha^{-1)}$ under the first sowing date 9th MW (29th Feb. 2024). Growth parameters such as plant height, flag leaf length and width exhibited higher values under the first sowing date 9th MW (29th Feb. 2024) when compared with the second sowing date (S_2) [11th MW (16th Mar. 2024)]. Delayed sowing at S_2 **(**11th MW (16th Mar. 2024)**)** resulted in poorer seed quality compared to S_1 (9th MW (29th Feb. 2024)), with noticeable reductions in 1000-grain weight, germination per cent, seedling vigour indices (SVI-I & SVI-II). Postponing sowing from S_1 **(**9th MW (29th Feb. 2024)**)** to the S_2 [11th MW (16th Mar. 2024)] led to a 14.02 per cent decrease in seed yield.

Keywords: Foxtail millet, sowing dates, seed yield, harvest index, germination, seedling vigour

Introduction
Millets, members of the Poaceae family, represent a diverse collection of climate resilient cereals characterized by small grains and high adaptability to low-input agriculture. These crops are commonly referred to as 'nutri-cereals' owing to their high content of vitamins (particularly B-complex), dietary fiber, protein and essential micronutrients such as iron, calcium and zinc, thereby contributing significantly to nutritional and food security in marginal environments (Sukanya *et al*., 2023) [16].
Foxtail millet (*Setaria italica* L.), widely known as Italian millet and under regional names such as korralu, kangu, kangani and kaon, is one of the oldest cultivated cereals and ranks second in area among small millets grown in India. As a self-pollinated, short-duration C_4 species, it exhibits high photosynthetic efficiency and resource-use optimization, making it an ideal crop for low-input rainfed agriculture. It is cultivated for its nutritional grain, livestock fodder and poultry feed. Its notable drought resistance and broad soil adaptability enhance its suitability for cultivation in marginal environments. Compared to staple cereals such as wheat and rice, foxtail millet offers superior levels of dietary fiber, protein, micronutrients and health-promoting vitamins (Srikanya *et al*., 2020) [15]. It is the best source for essential B vitamins (B1, B2, B3 and B9) which are vital for neurological function and energy metabolism. Consequently, the demand for foxtail millet is rising among health-conscious consumers and diabetic populations

(Hariprasanna, 2016) [5].

The timing of sowing is a critical agronomic factor that significantly influences the vegetative growth, reproductive development and ultimately the grain yield of foxtail millet. Selecting an appropriate sowing window ensures optimal plant growth, shields the crop from early monsoon disruptions and facilitates timely field preparation for the subsequent kharif crop. In light of recent shifts in climatic patterns, including erratic rainfall distribution and fluctuating temperature regimes, identifying the optimal sowing time has become imperative for maximizing productivity. Given the limited availability of region-specific research on this aspect, the present investigation was undertaken to address this gap entitled "Effect of sowing dates on seed yield and seed quality of foxtail millet" with the objective of investigation of the effect of sowing dates on seed yield and seed quality of foxtail millet genotypes during *summer* season.

Materials and Methods

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 foxtail millet genotypes *viz*., V_1: KIFXG-22-27, V_2: BFTM-17, V_3: KIFXG-22-29, V_4: BFTM-Si-4, V_5: KIFXG-22-01, V_6: BFTM-Si-12, V_7: KIFXG-22-09, V_8: KIFXG-22-06, V_9: BFTM-82-S, V_{10}: BFTM-Si-9, V_{11}: KIFXG-22-02 and V_{12}: BFTM-Si-6-1along with two checks V_{13}: DHFt-109-3 (C) and V_{14}: BFTM-82 (C) as the sub plot treatment for the investigation of the effect of sowing dates on seed yield and seed quality of foxtail millet (*Setaria italica* (L.) Beauv.). The experiment was laid in Split plot design with three replications. 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), Productive 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., 2010) [3], Root and shoot length (cm), Vigour indices (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) [4] recommendations. The critical difference (CD) was worked out at 5% level significance.

Results and Discussion

Effect of sowing dates, genotypes and interaction on vegetative and yield attributes of foxtail 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 genotypic variation was evident in foxtail millet with respect to days to 50% flowering and days to maturity as effected by sowing dates. Genotypes sown on the second sowing date 11th MW (16th Mar. 2024) reached 50% flowering in lesser days (53.93) than those sown on the first sowing date 9th MW (29th Feb.2024), which required 55.55 days. Days to maturity also followed a similar trend. Significantly lesser (82.98 days) under S_2 [11th MW (16th Mar. 2024)] compare to S_1 [9th MW (29th Feb.2024)] (86.02 days). The prolonged flowering and maturity under S_1 [9th MW (29th Feb.2024)] suggest a delayed developmental response to lower temperatures. The accelerated phenological development observed under S_2 [11th MW (16th Mar. 2024)] may be attributed to the elevated temperature conditions prevailing during the later sowing period.

The first sowing date S_1 [9th MW (29th Feb. 2024)] recorded highest (118.12 cm) plant height than second sowing date S_2 [11th MW (16th Mar. 2024)] (110.17 cm). Among the genotypes, KIFXG-22-02 (V_{11}) which could be attributed to its susceptibility to high-temperature stress. Similar results were reported by Malmbane *et al*. (2015) and Kavya *et al*. (2017) [6].

The panicle length had significant effected by different sowing dates. Highest panicle length was observed in first sowing date 9th MW (29th Feb. 2024) (19.65 cm) than second sowing date 11th MW (16th Mar. 2024) (18.56). Among the genotypes, KIFXG-22-02 (V_{11}) recorded significantly highest (21.23 cm) panicle length. Number of productive tillers plant^{-1} was significantly influenced by date of sowing and genotypes measured at maturity. The highest number of productive tillers (4.13 plant^{-1}) was recorded in genotype KIFXG-22-02 (V_{11}). A strong photosynthetic source, facilitated by taller plants, promotes more productive tiller production and improved grain yield. The number of productive tillers plant^{-1} had significant effect due to interaction of date of sowing and genotypes. Similar results are documented by Anilrao *et al*. (2024) [2] and Pannase *et al*. (2024) [11].

Foxtail millet grain yield was significantly influenced by both sowing dates and genotypic variation. First sowing S_1 [9th MW (29th Feb.2024)] recorded higher yield (23.21 q ha^{-1}) than second sowing S_2 [11th MW (16th Mar. 2024)] (20.03 q ha^{-1}), likely due to optimal temperature and longer crop duration. Among genotypes, KIFXG-22-02 (V_{11}) was recorded highest grain yield (26.43 q ha^{-1}), followed by KIFXG-22-27 (V_1) (26.09 q ha^{-1}) and BFTM-Si-4 (V_4) (24.58 q ha^{-1}), while KIFXG-22-01 (V_5) had the lowest yield (15.74 q ha^{-1}). Larger yield reductions under S_2 in certain genotypes indicate varying tolerance to delayed sowing and heat stress as well as differential adaptation of genotypes to the environmental conditions prevailing at different sowing dates, including temperature, soil moisture and photoperiod, as well as genotypic differences in resource use efficiency and stress tolerance. Same results were observed by Maurya *et al.* (2016) [10], Anilrao *et al.* (2024) [2], Pannase *et al.* (2024) [11].

The fodder yield was significantly influenced by sowing dates and varieties and their interaction at harvest. The first sowing date S_1 [9th MW (29th Feb.2024)] recorded highest fodder yield (38.91 q ha^{-1}). The highest fodder yield (41.45 q ha^{-1}) was attained by genotype KIFXG-22-02 (V_{11}). The high fodder yield of KIFXG-22-02 may be due to its genetic vigour, which promotes increased plant height and higher tiller production. Harvest index was found to be statistically unaffected by the sowing dates, genotypes and their interaction. Significant effect of sowing dates, genotypes and their interaction were evident in test weight at harvest. Among the genotypes, KIFXG-22-02 (V_{11}) ranked first with the highest test weight (3.02 g). The significant variation among genotypes reflects inherent genetic differences in sink capacity, translocation efficiency and grain filling potential. Similar results were reported by Pannase *et al.* (2024) [11]. Enhanced growth and yield attributes, including plant height, panicle length, number of productive tillers plant^{-1}, grain yield, fodder yield, harvest index and test weight were recorded better at the first sowing date 9th MW (29th Feb. 2024). Such improvements can be linked to favourable temperatures and supportive environmental conditions during the cropping period. In contrast, delayed sowing at 11th MW (16th Mar. 2024) was associated with adverse temperature effects, leading to significant declines in yield related parameters.

Effect of sowing dates, genotypes and interaction on seed quality attributes of foxtail millet

The sowing dates and genotypes showed significant effect on seed quality attributes of foxtail millet and is presented at table 2. Seed germination percentage of foxtail millet was significantly affected by sowing dates and genotypes, but not by their interaction. Seeds from S_1 [9th MW (29th Feb.2024)] showed higher germination percentage (92.59%) than those from S_2 [11th MW (16th Mar. 2024)] (87.63%). Among the genotypes, KIFXG-22-02 (V_{11}) showed higher germination percentage (92.96%). Favourable environmental conditions during S_1, particularly adequate temperature and humidity during seed filling and maturation, likely contributed to improved seed quality and vigour, while the delayed sowing in S_2 subjected the crop to stress conditions, reducing germination percentage. Similar results were reported by Krishnappa *et al*. (2001) [7].

In foxtail millet, seedling shoot and root lengths were significantly influenced by genotypic differences, with no significant effect of sowing dates and their interaction. Although seeds from S_1 (9th MW (29th Feb.2024)) showed numerically greater shoot (8.53 cm) and root (6.49 cm) lengths than those from S_2 (8.47 cm and 6.45 cm), the differences were not statistically significant. Genotype KIFXG-22-02 (V_{11}) produced the highest seedling root length (6.99 cm) and seedling shoot length (9.09 cm). This indicates that root elongation is predominantly governed by genetic factors and inherent seed vigour, which are relatively insensitive to moderate environmental variation during seed development. These findings match with previous reports indicating the stability of early seedling traits across environments and their strong genetic basis. Similar results were noticed by Patil *et al.* (1999) [13] and Kumar *et al*. (2011) [8].

The seedling dry weight of foxtail millet was significantly affected by genotype, whereas sowing dates and their interaction had no significant impact. Seeds from S_1 exhibited slightly higher dry weight (21.29 mg) compared to S_2 (20.27 mg), though not statistically significant. The highest dry weight was observed in KIFXG-22-02 (V_{11}) (26.50 mg), followed by KIFXG-22-27 (V_1) (24.33 mg) and BFTM-Si-4 (V_4) (24.23 mg). These findings suggest that seedling biomass is mainly governed by genetic potential rather than by sowing time.

Seedling vigour indices (SVI-I and SVI-II) of foxtail millet were significantly influenced by genotypic differences, whereas sowing dates and their interaction had no significant effect. Seeds produced under the first sowing date (9th MW (29th Feb.2024)) recorded slightly higher SVI-I (1388.35) and SVI-II (1.98) compared to the second sowing date (11th meteorological week) (1348.73 and 1.80 respectively), the differences were statistically non-significant. Among the genotypes, KIFXG-22-02 (V_{11}) recorded the highest seed vigour, with SVI-I and SVI-II of 1509.50 and 2.46, respectively. Seed quality parameters like seed germination percentage, seedling root and shoot length, seedling dry weight and seedling vigour indices I and II were recorded slightly higher in seeds produced under the first sowing date 9th MW (29th Feb.2024) in comparison to the second sowing date 11th MW (16th Mar. 2024). This may be due to favourable temperature and other environmental factors prevailing during the reproductive stage, which promoted the production of high quality seeds. These findings emphasize that seed vigour is predominantly determined by genetic potential, with negligible influence from sowing dates. The similar results are reported by Krishnappa *et al.* (2001) [7], Tripathi and Verma (2011) [17], Partha *et al*. (2016) [12] and Rawat *et al*. (2022) [14].

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

No.	Treatment	Days to 50% flowering	Days to maturity	Plant height (cm)	Productive tillers plant^{-1}	Grain yield (q ha^{-1})	Panicle length(cm)	Fodder yield (q ha^{-1})	Harvest index (%)	Test weight(g)
A.	**Main plot: Sowing Dates**									
S_1:	9th MW (29th Feb. 2024)	55.55	86.02	118.12	3.81	23.21	19.65	38.91	37.25	2.86
S_2:	11th MW (16th Mar. 2024)	53.93	82.98	110.17	3.53	20.03	18.56	35.71	35.46	2.68
	SE (±)	0.25	0.28	0.95	0.04	0.19	0.18	0.50	0.33	0.02
	CD at 5%	1.55	1.72	5.81	0.22	1.15	1.07	3.02	NS	0.12
B.	**Sub plot: Genotypes**									
V_1:	KIFXG-22-27	57.33	84.83	121.00	3.90	26.09	21.12	41.23	38.75	2.98
V_2:	BFTM-17	58.17	84.67	108.83	3.32	16.39	16.95	32.75	34.05	2.63
V_3:	KIFXG-22-29	69.00	106.00	106.17	3.23	16.19	16.92	31.95	33.68	2.63
V_4:	BFTM-Si-4	50.83	80.33	120.33	3.88	24.58	20.50	39.48	38.64	2.86
V_5:	KIFXG-22-01	51.33	81.50	101.17	2.88	15.74	14.88	30.09	33.07	2.56
V_6:	BFTM-Si-12	50.17	80.17	117.00	3.81	22.91	19.88	39.00	36.94	2.82
V_7:	KIFXG-22-09	56.67	82.33	111.50	3.62	21.97	19.47	37.33	36.06	2.68
V_8:	KIFXG-22-06	50.33	81.50	118.33	3.85	23.06	20.02	39.22	37.24	2.84
V_9:	BFTM-82-S	51.50	81.67	113.33	3.75	22.06	19.58	37.54	36.31	2.70
V_{10}:	BFTM-Si-9	58.50	92.67	115.37	3.80	22.57	19.83	38.95	36.81	2.79
V_{11}:	KIFXG-22-02	53.33	82.50	121.17	4.13	26.43	21.23	41.45	38.93	3.02
V_{12}:	BFTM-Si-6-1	46.33	75.50	119.83	3.87	23.67	20.32	39.41	38.54	2.85
V_{13}:	DHFt-109-3 (C)	57.17	84.50	109.67	3.50	18.92	17.12	35.03	34.72	2.67
V_{14}:	BFTM-82 (C)	55.67	84.83	114.33	3.80	22.17	19.67	38.88	36.35	2.72
	SE (±)	0.64	0.69	3.74	0.13	1.19	0.76	0.72	1.61	0.07
	CD at 5%	1.82	1.96	10.62	0.36	3.38	2.16	2.03	NS	0.19
	Interaction (A x B)									
	SE (±)	0.91	0.97	5.29	0.18	1.69	1.07	1.01	2.27	0.09
	CD at 5%	NS	NS	NS	0.50	4.78	3.05	2.88	NS	0.26
	General mean	54.74	84.50	114.15	3.67	21.62	19.11	37.31	36.36	2.77

Table 2: Effect of sowing dates, genotypes and interaction on seed quality attributes of foxtail 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)	92.59 (74.20)	6.49	8.53	21.29	1388.35	1.98
S_2:	11th MW (16th Mar. 2024)	87.63 (69.41)	6.45	8.47	20.27	1348.73	1.80
	SE (±)	0.78	0.03	0.06	0.21	6.88	0.03
	CD at 5%	4.74	NS	NS	NS	NS	NS
B.	Sub plot: Genotypes						
V_1:	KIFXG-22-27	92.83 (70.47)	6.75	8.98	24.33	1474.04	2.26
V_2:	BFTM-17	87.87 (69.62)	6.49	8.48	17.50	1363.21	1.54
V_3:	KIFXG-22-29	85.77 (67.84)	6.21	8.39	17.67	1292.00	1.55
V_4:	BFTM-Si-4	91.75 (73.31)	6.79	8.55	24.23	1434.62	2.23
V_5:	KIFXG-22-01	85.53 (67.64)	5.81	7.87	17.17	1179.47	1.51
V_6:	BFTM-Si-12	90.82 (72.36)	6.62	8.52	22.83	1407.55	2.07
V_7:	KIFXG-22-09	90.18 (71.74)	6.17	8.30	18.50	1328.15	1.67
V_8:	KIFXG-22-06	91.15 (72.69)	6.69	8.58	23.17	1405.08	2.11
V_9:	BFTM-82-S	90.35 (71.90)	6.15	8.24	19.83	1321.77	1.79
V_{10}:	BFTM-Si-9	91.15 (72.69)	6.46	8.42	22.50	1308.54	2.05
V_{11}:	KIFXG-22-02	92.96 (74.69)	6.99	9.09	26.50	1509.50	2.46
V_{12}:	BFTM-Si-6-1	91.79 (73.35)	6.62	8.69	17.83	1395.21	1.64
V_{13}:	DHFt-109-3 (C)	88.87 (70.51)	6.22	8.11	17.68	1307.25	1.63
V_{14}:	BFTM-82 (C)	90.49 (72.04)	6.67	8.76	21.17	1433.22	1.91
	SE (±)	1.68	0.12	0.16	0.77	22.75	0.07
	CD at 5%	4.76	0.33	0.45	2.18	64.55	0.21
	Interaction (A x B)						
	SE (±)	2.37	0.17	0.23	1.09	32.17	0.10
	CD at 5%	NS	NS	NS	NS	NS	NS
	General mean	90.11	6.47	8.50	20.78	1368.50	1.89

(* Values in parenthesis are arcsine transformed.)

Conclusion

The first sowing date 9th MW (29th Feb.2024) resulted significantly higher seed yield and associated yield components in foxtail millet compared to the second sowing date 11th MW (16th Mar. 2024). The genotype KIFXG-22-02 (V_{11}) was identified as the most productive, as it consistently recorded superior growth parameters like greater plant height and productive tillers contributed to its higher yield performance in comparison to the rest of the genotypes.

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