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Influence of fertilizer levels and plant spacing on growth and growth attributes of foxtail millet (*Setaria italica* L.)

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Abstract
An experiment entitled "Response of Foxtail Millet (*Setaria italica* L.) to Fertilizer Levels and Spacings" was conducted at PG research Farm, RCSM College of Agriculture, Kolhapur during the *kharif* season of 2023. The experiment was conducted in a split plot design with three main plot treatments of plant spacings and five levels of fertilizer as subplots treatments. The experiment was conducted with the objectives of studying the combined effect of fertilizer levels and spacings on growth and yield of foxtail millet, studying the nutrient status of soil and plant and to find the better economics of the foxtail millet cultivation. The highest growth attributes such as leaf area, no of tillers, dry matter accumulation of foxtail millet was recorded with spacing 60 cm x 10 cm along with fertilizer application of 100% GRDF (40:20:00 N, P_2O_5, K_2O Kg + FYM @ 5 t ha^{-1}) except for plant height. Whereas taller plants of finger millets were observed in the spacing of 30 cm x 10 cm among the various treatment combination used in foxtail millet crop.

Keywords: Foxtail millet, fertilizer levels, spacing, growth, growth attributes

Introduction
Foxtail millet [*Setaria italica* (L.)] often known as Italian millet, German millet or *Rala* in marathi belongs to the family of poaceae. It is one of the oldest cultivated millets in the world, mostly grown in Asia and Africa continents. Foxtail millet ranks second in the world millet production and continues to play a vital role in world agriculture, giving food to millions of people dependent on poor or marginal soils in temperate, subtropical and tropical Asia (Hariprasanna, 2016) [4]. In India, foxtail millet is mostly cultivated in Rajasthan, Maharashtra, Tamil Nadu, Karnataka and Andhra Pradesh, contributing about 79 percent of the total area (Munirathnam *et al.,* 2006) [8]. In India 9.10 M. ha. areas is under foxtail millet cultivation with production of 7.3 MT and productivity of 780 kg ha^{-1} (Monisha *et al*., 2019) [9]. Nitrogen is the major nutrient required by the millets for higher growth, yield attributes and yield (Prasad *et al.,* 2014) [14]. Studies of Hasan *et al.,* (2013) [5] and Basavarajappa *et al*., (2003) [2] indicated that there was a good response of foxtail millet to varied levels of nitrogen. Beside nitrogen phosphorus is of paramount Importance for increasing yield. Phosphorus plays an important role in energy transfer in the living cells by means of high-energy phosphate bonds of ATP. Thus, it is considered important for formation and translocation of carbohydrate, fatty acids, glyceroids and other essential intermediate compounds. Therefore, there is need to work out optimum combination of nitrogen and phosphorus fertilization for foxtail millet under prevailing agroclimatic conditions. It is worth mentioning that nutrient management through organic sources plays a major role in maintaining Soil health as it improves the status of soil organic matter, beneficial microbes and enzymes besides improving soil physical and chemical properties (Raviraja *et al.,* 2020) [16]. Cultivation of plants with desirable density has positive effect on crop yield components, so that the suitable yield will be achieved by optimum plant density (Ullah *et al*., 2005) [17]. However, maintenance of optimum planting density is always a big problem to the farmers and they maintain sub-standard plant density, results in high weeds infestation, poor radiation use efficiency and low yield, while dense plant population on the other hand may cause lodging, poor light penetration in the canopy, reduce photosynthesis due to shading of lower leaves and drastically reduce the yield (Jettner, 1998) [6].

Materials and Methods

An experiment entitled "Response of foxtail millet (*Setaria italica L.*) to fertilizer levels and spacings" was conducted at PG research Farm RCSM College of Agriculture, Kolhapur during the *kharif* season of 2023. The experiment was conducted in a split plot design with three main plot treatments of plant spacings and five levels of fertilizer as subplots treatments. The experimental soil was black vertisol with silty loam in texture, having pH of 7.80. electrical conductivity of 0.25 dSm^{-1}, organic carbon content of 0.53 per cent and available N, P_2O_5 and K_2O 325.85, 29.56 and 247.45 kg ha^{-1} respectively. The foxtail millet variety DHFT-109-3 was sown by line sowing at a spacing of 30 cm x 10 cm, 45 cm x 10 cm, 60 cm x 10 cm between rows during the 27th meteorological week. A total 44 rainy days with 673.6 mm rainfall was measured during the experimental period. A minimum temperature of 17.3℃ and maximum 33.3℃ was recorded during the entire experimental period. The application of fertilizer were done according to the treatments. No incidence of pests and diseases were noticed during the experimental period. The experimental field measured 6.00 m by 3.00 m in gross area and net plot for different spacing was different, net plot for spacing 30 cm x 10 cm, 45 cm x 10 cm, 60 cm x 10 cm were 5.40 m x 2.80 m, 5.10 m x 2.80 m and 4.80 m x 2.80 m respectively.

Results and Discussions

A) Growth Studies

1) Mean plant height

a) Effect of spacings: By observing plant height, we can gain insight into overall 'plants' health, growth and adaptation to environment. The crop plant showed gradual increase in the mean plant height from 7.55 cm at 15 DAS to 119.81 cm at harvest. At 15 DAS and 30 DAS the mean plant height (7.55 cm and 23 cm respectively) did not show statistical difference however numerically closer plant spacing of 30 cm x 10 cm produced taller plants (8.26 cm and 25.44 cm respectively) compared to the other spacings. From 45 DAS till 75 DAS there was sharp increase in mean plant height. The spacing of 30 x 10 cm (S_1) produced significantly taller plants (54.66 cm, 88.31 cm, 106 cm respectively) as compared to the wider spacing of 45 x 10 cm (S_2) (46.42 cm, 77.30 cm, 96.47 cm respectively) and 60 x 10 cm (S_3) (39.37 cm, 71.02 cm, 87.79 cm respectively). At 90 DAS and at harvest spacing 30 cm x 10 cm (S_1) (124.16 cm and 128.23 cm respectively) and 45 cm x 10 cm (S_2) (120.56 cm and 124.56 cm respectively) noted taller plant and were statistically on par with each other over other spacing. This may be due to closer spacing which might be affecting the inter plant competition and prominently for sunlight and other weather parameters. Shorter plants were observed in 60 cm x 10 cm (S_3) (102.93 cm and 106.65 cm respectively), the wider spacings produced shorter plants which might be due less or marginal competition for sunlight and other growth parameters. The result is in accordance with Narayan *et al.,* (2018) [13], Anandha *et al*., (2020) [1].

b) Effect of fertilizer levels: Increased quantity of fertilizers produced more vigorous plants. At 15 DAS and 30 DAS did not show statistical difference in mean plant height, however numerically 100% GRDF (F_4) produced taller plants (7.7 cm and 24.23 cm respectively) as compared to other fertilizer levels. At 45 DAS till 75 DAS the mean plant height revealed gradual increase. The application of fertilizer @ 100% GRDF (F_4) produced significantly taller plants (50.83 cm, 87.41 cm, 106.46 cm respectively) as compared to other levels of fertilizer. At 90 DAS and at harvest fertilizer levels of 100% GRDF (F_4) noted taller plant (122.81 cm, 126.94 cm respectively) which was on par with 125% RDF (F_1) (120.75 cm and 124.72 cm respectively) and 100% RDF (F_2) (118.25 cm and 122.24 cm respectively) in that order. The 100% GRDF (F_4) might have provided more nutrients to the crop in the labile pool thereby enhanced fertilizer usage for more time resulting in better crop uptake *vis-à-vis* more leaf area, number of tillers and dry matter accumulation noted in the entire crop growth period. The findings are corroborative with Narayan *et al.,* (2018) [13], Mownika *et al*., *(*2021) [11], Nigade *et al*., (2014) [12], Anandha *et al*., (2020) [1], Upadhaya *et al*., (2022) [18].

c) Interaction effects: The treatment combination of spacing of 30 cm x 10 cm (S_1) and 100% GRDF (F_4) continued to produce taller plants at 45 DAS (58.9 cm), 60 DAS (92.1 cm), 75 DAS (109.8 cm), 90 DAS (127.5 cm) and at harvest (131.8 cm). At 45 DAS the treatment combination of spacing of 30 cm x 10 cm (S_1) and 100% GRDF (F_4) (58.9 cm), spacing of 30 cm x 10 cm (S_1) and 125% RDF (F_1) (57.9 cm)and spacing of 30 cm x 10 cm (S_1) and 100% RDF (F_2) (56.8 cm) noted significantly taller plants compared to the rest of other treatment combinations. The shortest crop plants were noted in treatment combinations 60 cm x 10 cm (S_3) and Absolute control (F_5) (37.7 cm), 60 cm x 10 cm (S_3) and 75% RDF (F_3) (38.6 cm), 60 cm x 10 cm (S_3) and 100% RDF (F_2) (38.9 cm), 45 cm x 10 cm (S_2) and Absolute control (F_5) (39.7 cm), 45 cm x 10 cm (S_2) and 75% RDF (F_3) (41.4 cm) in that order. This may be due to closer spacing which induced interplant competition compared to other spacing also application of 100% GRDF (S_4) provided better supply of nutrient compared to other treatment combination.

Table 1: Mean plant height of foxtail millet as influenced by spacing and fertilizer levels

Treatment	Mean plant height (cm)						
	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	At Harvest
Main plot: Spacing							
S_1: 30 cm X 10 cm	8.26	25.44	54.66	88.31	106.0	124.16	128.23
S_2: 45 cm X 10 cm	7.45	21.81	46.42	77.30	96.47	120.56	124.56
S_3: 60 cm X 10 cm	6.96	21.74	39.37	71.02	87.79	102.93	106.65
S.E.(m) ±	0.25	0.81	0.86	1.506	1.96	1.85	1.89
CD @ 5%	NS	NS	3.38	5.91	7.71	7.29	7.44
CV%	12.99	13.70	7.12	7.39	7.86	6.21	6.12
Sub-plot: Fertilizer levels							
F_1: 125% RDF	7.75	23.60	49.53	85.34	101.62	120.75	124.72
F_2: 100% RDF	7.63	23.08	48.05	79.65	96.86	118.25	122.24
F_3: 75% RDF	7.46	22.66	44.96	76.17	94.74	112.08	116.00
F_4: 100% GRDF	7.70	24.23	50.83	87.41	106.46	122.81	126.94
F_5: Absolute Control	7.23	21.41	40.73	65.82	84.25	105.52	109.00
S.E.(m) ±	0.19	0.66	0.88	1.46	2.06	2.25	2.31
CD @ 5%	NS	NS	2.57	4.28	6.03	6.56	6.74
CV%	7.85	8.61	5.64	5.58	6.40	5.82	5.78
Interaction: S X F							
S.E.(m) ±	1.02	1.1	1.5	2.5	3.6	3.9	4.0
CD @ 5%	NS	NS	4.5	7.4	10.5	11.4	11.7
CV%	7.85	8.61	5.64	5.58	6.40	5.82	5.78
General Mean	7.55	23.00	46.82	78.88	96.78	115.88	119.81

At 60 DAS the treatment combinations 30 cm x 10 cm (S_1) and 100% GRDF (F_4) (92.1 cm), 30 cm x 10 cm (S_1) and 125% RDF (F_1) (91.1 cm), 30 cm x 10 cm (S_1) and 100% RDF (F_4) (88.5 cm), 45 cm x 10 cm (S_2) and 100% GRDF (F_4) (85.5 cm) noted significantly taller plants in that order of sequence produced the taller plants over the other remaining treatment combinations. At 75 DAS the treatment combinations 30 cm x 10 cm (S_1) and

100% GRDF (F_4) (109.8 cm), 30 cm x 10 cm (S_1) and 125% RDF (F_1) (106.8 cm), 45 cm x 10 cm (S_2) and 100% GRDF (F_4) (105.7 cm), 30 cm x 10 cm (S_1) and 100% RDF (F_2) (105.5 cm), 30 cm x 10 cm (S_1) and 75% RDF (F_3) (104.7 cm), 60 cm x 10 cm (S_3) and 100% GRDF (F_4) (103.8 cm), 45 cm x 10 cm (S_2) and 125% RDF (F_1) (102.4 cm), 45 cm x 10 cm (S_2) and 100% RDF (F_2) (100.2 cm) in that order of sequence produced the taller plants over the other remaining treatment combinations. At 90 DAS and at harvest treatment combinations 30 cm x 10 cm (S_1) and 100% GRDF (F_4) (127.5), 30 cm x 10 cm (S_1) and 125% RDF (F_1) (125.1 cm), 45 cm x 10 cm (S_2) and 100% GRDF (F_4) (124.5 cm), 30 cm x 10 cm (S_1) and 100% RDF (F_2) (124.1 cm), 30 cm x 10 cm (S_1) and 75% RDF (F_3) (123.6 cm), 45 cm x 10 cm (S_2) and 125% RDF (F_1) (122.6 cm), 45 cm x 10 cm (S_2) and 100% RDF (F_2) (121.7 cm), 45 cm x 10 cm (S_2) and 75% RDF (F_3) (118.5 cm), found to be producing the taller crop plants while, the differences among them were of similar magnitude. Moreover, other remaining treatment combinations produced comparatively shorter plants. Significantly shortest plant was produced by treatment combination 60 cm x 10 cm (S_3) and Absolute control (F_5) (80.5 cm) and at harvest (83.1 cm) this may be inadequate supply of nutrients to the plants.

Table 1.1: Mean plant height of foxtail millet as influenced by interaction effect between spacing and fertilizer levels

Interaction Combinations (S X F)	Mean plant height (cm)				
	45 DAS	60 DAS	75 DAS	90 DAS	At Harvest
S_1F_1	57.9	91.1	106.8	125.1	129.1
S_1F_2	56.8	88.5	105.5	124.1	128.1
S_1F_3	54.8	86.9	104.7	123.6	127.5
S_1F_4	58.9	92.1	109.8	127.5	131.8
S_1F_5	44.7	82.1	96.5	110.5	115.5
S_2F_1	50.3	83.6	102.4	122.6	126.6
S_2F_2	48.3	80.4	100.2	121.7	125.8
S_2F_3	41.4	76.7	98.8	118.5	122.5
S_2F_4	52.3	85.5	105.7	124.5	128.5
S_2F_5	39.7	60.1	75.1	114.5	117.5
S_3F_1	40.2	81.2	95.6	114.5	118.5
S_3F_2	38.9	69.2	84.9	108.9	112.9
S_3F_3	38.6	64.8	80.5	94.2	98.1
S_3F_4	41.2	84.5	103.8	116.5	120.0
S_3F_5	37.7	55.2	74.0	80.5	83.1
S.Em±	1.5	2.5	3.6	3.9	4.0
CD @ 5%	4.5	7.4	10.5	11.4	11.7
CV (%)	5.64	5.58	6.40	5.82	5.78
General Mean	46.82	78.88	96.78	115.88	119.81

The shortest crop plants were noted with absolute control of fertilizer levels and wider spacing treatment combinations of spacing 60 cm x 10 cm (S_3) and Absolute control (F_5) this might be due to lower supply of the nutrients during the entire crop growth period. It is pertinent to note that, the combination of closer spacing 30 cm X 10 cm (S_1) along with 100 per cent GRDF (F_4) application produced taller plants which may be due to better supply of the nutrients to the crop plant during the entire growth period of the crop. Furthermore, the other growth parameters were significantly influenced *viz*. higher leaf area, dry matter accumulations, nutrient uptake. Results are in confirmation with those reported by Anandha *et al*., (2020) [1].

2) Mean leaf area

a) Effect of spacings: During the initial period of the crop growth period at 15 DAS and 30 DAS there was no significant influence on mean leaf area of crop plant due to spacings. However significant increase in mean leaf area was observed from 45 DAS to 90 DAS. Later stage of the crop growth *i.e.* at harvest the mean leaf area was found to be reduced which may be due to the senescence of leaf. The spacing of 60 cm x 10 cm (S_3) produced significantly highest mean leaf area at 45 DAS (162.52 dm^2), 60 DAS (255.30 dm^2), 75 DAS (337.69 dm^2), 90 DAS (327.69 dm^2) and at harvest (322.69 dm^2) than rest of the other spacings. This may be due to the wider spacing 60 cm x 10 cm (S_3) which get better opportunity for plant to increase its foliage and increase plant spread leading to accumulation of higher dry matter and higher number of yield attributes *viz*. number of panicles, weight of panicles, length of panicles as well as seed yield. Further grain and straw yield was also noted higher. Findings are in line with those worked by Narayan *et al.*, (2018) [13].

b) Effect of fertilizer levels: Leaf area per plant of foxtail millet was influenced significantly due to fertilizer levels. Application of 100% GRDF (F_4) reported highest mean leaf area per plant than the rest of the other fertilizer levels. At 15 DAS and 30 DAS fertilizer levels did not show statistical difference in mean leaf area, however numerically 100% GRDF (F_4) showed higher leaf area (10.12 dm^2 and 28.50 dm^2as compared to other fertilizer levels. At 45 DAS and 60 DAS the application of fertilizer @ 100% GRDF (F_4) showed significantly mean higher leaf area (165.87 dm^2, 256.46 dm^2 respectively) which was at par with 125% RDF (F_1) (158.57 dm^2, 248.82 dm^2 respectively) as compared to other levels of fertilizer. At 75 DAS, 90 DAS and at harvest fertilizer levels of 100% GRDF (F_4) recorded significantly highest mean leaf area (354.06 dm^2, 344.06 dm^2, 339.2 dm^2 respectively). As graded doses of fertilizer provide the nutrients at critical growth stages promoting healthy developments of crop also ensures balanced nutrient application providing adequate supply of nutrient pool. Furthermore, the growth parameters like plant height, dry matter and number of tillers were found to be better with application of 100% GRDF (F_4). The absolute control (F_5) noted significantly lowest mean leaf area during all the growth stages of the crop. This may be due to lower supply of essential nutrients. The results were in line with work reported by Narayan *et al.*, (2018) [13].

c) Interaction effects: At 45 DAS the higher mean leaf area was noted with treatment combinations 60 cm x 10 cm (S_3) and 100% GRDF (F_4) (178.9 dm^2), 60 cm x 10 cm (S_3) and 125% RDF (F_1) (175.8 dm^2), 60 cm x 10 cm (S_3) and 100% RDF (F_2) (174.2 dm^2), 60 cm x 10 cm (S_3) and 75% RDF (F_3) (172.4 dm^2), 45 cm x 10 cm (S_2) and 100% GRDF (F_4) (160.3 dm^2) in that order of sequence over the other remaining treatment combinations. The lowest mean leaf area per plants were noted in treatment combinations 30 cm x 10 cm (S_1) and absolute control (F_5) (103.6 dm^2), 45 cm x 10 cm (S_2) and absolute control (F_5) (107.6 dm^2), 60 cm x 10 cm (S_3) and absolute control (F_5) (111.0 dm^2), 45 cm x 10 cm (S_2) and 75% RDF (F_3) (115.2 dm^2).

Table 2: Mean leaf area per plant (dm^2) of foxtail millet as influenced by spacing and fertilizer levels

Treatment	Mean leaf area (dm^2)						
	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	At Harvest
Main plot: Spacing							
S_1: 30 cm X 10 cm	8.66	25.41	131.39	217.83	280.71	270.76	265.76
S_2: 45 cm X 10 cm	9.41	26.90	136.20	233.58	304.24	294.25	289.27
S_3: 60 cm X 10 cm	10.27	28.47	162.52	255.30	337.69	327.69	322.69
S.E.(m) ±	0.38	0.75	2.91	3.31	6.13	6.14	6.15
CD @ 5%	NS	NS	11.43	13.02	24.10	24.12	24.15
CV%	15.57	10.91	7.86	5.45	7.73	7.99	8.14
Sub-plot: Fertilizer levels							
F_1: 125% RDF	9.99	27.97	158.57	248.82	328.82	318.82	313.82
F_2: 100% RDF	9.64	27.63	148.59	238.84	327.41	317.41	312.44
F_3: 75% RDF	9.34	27.08	136.38	231.74	302.99	292.99	287.99
F_4: 100% GRDF	10.12	28.50	165.87	256.46	354.06	344.06	339.2
F_5: Absolute Control	8.13	23.46	107.44	202.00	224.46	214.55	209.55
S.E.(m) ±	0.50	1.21	3.73	4.17	7.36	7.36	7.35
CD @ 5%	NS	NS	10.89	12.18	21.49	21.48	21.50
CV%	16.12	13.58	7.81	5.31	7.18	7.42	7.54
Interaction: S X F							
S.E.(m) ±	0.86	1.45	6.46	7.23	12.75	12.55	12.61
CD @ 5%	NS	NS	18.87	21.10	37.22	37.45	37.30
CV%	16.12	13.58	7.81	5.31	7.18	7.42	7.54
General Mean	9.44	26.93	143.37	235.57	307.55	297.57	292.57

At 60 DAS treatment combinations 60 cm x 10 cm (S_3) and 100% GRDF (F_4) (278.3 dm^2), 60 cm x 10 cm (S_3) and 125% RDF (F_1) (276.1 dm^2), 60 cm x 10 cm (S_3) and 100% RDF (F_2) (261.7 dm^2), 60 cm x 10 cm (S_3) and 75% RDF (F_3) (259.0 dm^2) found to be producing the higher mean leaf area while the differences among them were of similar magnitude. Moreover, other remaining treatment combinations produced comparatively less leaf area. The lowest mean leaf area per plant was produced by treatment combination 30 cm x 10 cm (S_1) and absolute control (F_5) (170.8 dm^2). At 75 DAS treatment combinations 60 cm x 10 cm (S_3) and 100% GRDF (F_4) (370.6 dm^2), 60 cm x 10 cm (S_3) and 125% RDF (F_1) (369.0 dm^2), 60 cm x 10 cm (S_3) and 100% RDF (F_2) (367.3 dm^2), 45 cm x 10 cm (S_2) and 100% GRDF (F_4) (349.1 dm^2), 30 cm x 10 cm (S_1) and 100% GRDF (F_4) (342.3 dm^2) found to be producing the higher mean leaf area while the differences among them were of similar magnitude. Moreover, other remaining treatment combinations produced comparatively less leaf area. The lowest mean leaf area per plant was produced by treatment combination 30 cm x 10 cm (S_1) and absolute control (F_5) (193.8 dm^2) and 45 cm x 10 cm (S_2) and absolute control (F_5) (195.6 dm^2).

Table 2.1: Mean leaf area per plant (dm^2) of foxtail millet as influenced by interaction effect between spacing and fertilizer levels

Interaction Combinations (S X F)	Mean leaf area (dm^2)				
	45 DAS	60 DAS	75 DAS	90 DAS	At Harvest
S_1F_1	148.7	223.7	290.7	280.7	275.7
S_1F_2	124.8	208.9	289.3	279.3	274.3
S_1F_3	121.4	207.3	287.3	277.3	272.3
S_1F_4	158.3	243.2	342.3	332.3	327.3
S_1F_5	103.6	170.8	193.8	184.0	179.0
S_2F_1	151.1	246.5	326.7	316.7	311.7
S_2F_2	146.7	245.8	325.5	315.5	310.6
S_2F_3	115.2	228.9	324.1	314.1	309.1
S_2F_4	160.3	247.7	349.1	339.1	334.2
S_2F_5	107.6	198.8	195.6	185.6	180.6
S_3F_1	175.8	276.1	369.0	359.0	354.0
S_3F_2	174.2	261.7	367.3	357.3	352.3
S_3F_3	172.4	259.0	297.4	287.4	282.4
S_3F_4	178.9	278.3	370.6	360.6	365.6
S_3F_5	111.0	201.2	284.0	274.0	269.0
S.Em±	6.46	7.23	12.75	12.55	12.61
CD @ 5%	18.87	21.10	37.22	37.45	37.30
CV (%)	7.81	5.31	7.18	7.42	7.54
General Mean	143.37	235.57	307.55	297.57	292.57

At 90 DAS and at harvest the treatment combinations spacing of 60 cm x 10 cm (S_3) and 100% GRDF (F_4) noted significantly higher mean leaf area (360.6 dm^2 and 365.6 dm^2) compared to rest of the other treatment combinations and were statically on par with treatment combinations 60 cm x 10 cm (S_3) and 125% RDF (F_1) (359.0 dm^2, 354.0 dm^2 respectively), 60 cm x 10 cm (S_3) and 100% RDF (F_2) (357.3 dm^2, 352.3 dm^2 respectively), 45 cm x 10 cm (S_2) and 100% GRDF (F_4) (339.1 dm^2, 334.2 dm^2 respectively), 30 cm x 10 cm (S_1) and 100% GRDF (F_4) (332.3 dm^2, 327.3 dm^2 respectively) in that descending order. This may be due to wider spacing and optimum fertilizer dose of 100% GRDF provided better supply of nutrient during critical crop

growth period, promote vigorous growth, accumulating dry matter, increment in the yield attributing characters and thereby boosting the leaf area. The lower mean leaf area was observed with treatment combinations as 30 cm x 10 cm (S_1) and absolute control (F_5), 45 cm x 10 cm (S_2) and absolute control (F_5) which continued till the harvest this might be due to lower supply of the nutrients during entire crop growth period.

3) Mean number of tillers per running meter

a) Effect of spacings: There was no significant influence on mean number of tillers per running meter due to spacing at early growth period of 15 DAS and 30 DAS. The mean number of tillers per running meter were significantly increased with the advancement of the growth of the crop from 45 DAS to 90 DAS and later it declined this may be due the maturity of crops, older tillers may die off or become less productive as the plant redirect resources towards seed or grain development. At 45 DAS, 60 DAS, 75 DAS significantly highest mean number of tillers per running meter (33.6, 53.4, 73.4 respectively) were observed under the spacing of 60 cm x 10 cm (S_3). At 90 DAS significantly, higher mean number of tillers per running meter observed under the spacing of 60 cm x 10 cm (S_3) (89.8) which was on par with 45 cm x 10 cm (S_2) (85.7) over the other treatment. At harvest mean number of tillers per running meter declined in every treatment, but the spacing of 60 cm x 10 cm (S_3) noted higher mean number of tillers per running meter (81.7) and was on par with 45 cm x 10 cm (S_2) (73.2) over other spacings. This may be due the maturity of crops as older tillers may die off or become less productive as the plant redirect resources towards seed or grain development. Wider spacing might be providing better space for the crop growth which has influence on the growth attributes and the yield attributing characters also reflecting the better uptake of nutrients. These findings are corroborative with Narayan *et al.*, (2018) [13], Mownika *et al.*, (2021) [11], Kumar *et al.*, (2022) [7].

b) Effect of fertilizer levels: The mean number of tillers per running meter of foxtail millet was influenced significantly due to different fertilizer levels. Application of 100% GRDF (F_4) reported higher mean number of tillers per running meter (14.7) than rest of the other fertilizer levels. At 30 DAS fertilizer levels did not show statistical differences in mean number of tillers per running meter, however numerically 100% GRDF (F_4) showed more mean number of tillers per running meter (14.7) as compared to other fertilizer levels. At 45 DAS and 60 DAS the application of fertilizer @ 100% GRDF (F_4) showed significantly highest mean number of tillers per running meter (28.3 and 49.1 respectively) than the rest of other levels of fertilizer. At 75 DAS, 90 DAS and at harvest fertilizer levels of 100% GRDF (F_4) recorded significantly higher mean number of tillers per running meter (68.5, 88.9, 76.1 respectively) than the rest of other fertilizer levels. As graded doses of fertilizer provide the nutrients at critical growth stages promoting healthy developments of crop also ensures balanced nutrient application providing adequate supply of nutrient pool. Furthermore, the growth parameters like plant height, dry matter and number of tillers were found to be better with application of 100% GRDF. The results were in line with work reported by Narayan *et al.*, (2018) [13], Mownika *et al.*, (2021) [11], Kumar *et al.*, (2022) [7], Mubeena *et al.*, (2019) [10], Upadhaya *et al.*, (2022) [18]. The absolute control (F_5) noted significantly lower mean number of tillers per running meter during all the growth stages of the crop. This may be due to lower supply of essential nutrients and the available nutrients failed to supply nutrients for crop in required quantities.

Table 3: Mean number of tillers per running meter of foxtail millet as influenced by spacing and fertilizer levels

Treatments	Mean number of tillers per running meter					
	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	At Harvest
Main plot: Spacing						
S_1: 30 cm X 10 cm	12.70	15.50	34.60	51.50	73.50	60.90
S_2: 45 cm X 10 cm	13.10	26.60	47.30	64.50	85.70	73.20
S_3: 60 cm X 10 cm	14.80	33.60	53.40	73.40	89.80	81.70
S.E.(m) ±	0.70	0.80	1.20	1.60	2.00	2.20
CD @ 5%	NS	3.20	4.90	6.50	7.80	8.80
CV%	17.52	12.77	10.84	10.25	9.34	12.06
Sub-plot: Fertilizer levels						
F_1: 125% RDF	14.20	27.40	47.40	66.10	86.20	75.30
F_2: 100% RDF	13.70	25.40	44.70	64.20	83.30	74.30
F_3: 75% RDF	12.70	23.40	43.40	62.10	81.10	70.00
F_4: 100% GRDF	14.70	28.30	49.10	68.50	88.90	76.10
F_5: Absolute Control	12.30	21.90	40.80	54.70	75.50	63.90
S.E.(m) ±	0.60	0.60	0.90	1.50	1.70	1.80
CD @ 5%	NS	1.90	2.90	4.30	5.00	5.40
CV%	13.64	7.74	6.60	7.12	6.26	7.79
Interaction: S X F						
S.E.(m) ±	0.9	1.1	1.7	2.5	3.0	3.2
CD @ 5%	NS	3.3	5.0	7.5	8.7	9.4
CV%	13.64	7.74	6.60	7.12	6.26	7.79
General Mean	13.50	25.20	45.10	63.10	83.00	71.90

c) Interaction effect: At 45 DAS and 60 DAS significantly more mean number of tillers per running meter was noted with treatment combinations of spacing 60 cm x 10 cm (S_3) with the fertilizer application of 100% GRDF (F_4) (35.0 and 55.7 respectively) which was at par with 60 cm x 10 cm (S_3) and 100% GRDF (F_4) (34.0 and 54.2 respectively), 60 cm x 10 cm (S_3) and 100% RDF (F_2) (33.3 and 53.4 respectively), 60 cm x 10 cm (S_3) and 75% RDF (F_3) (33.0 and 52.1 respectively),in that order of sequence over the other remaining treatment combinations. At 75 DAS treatment combinations in the order of 60 cm x 10 cm (S_3) with the fertilizer 100% GRDF (F_4) (76.0), 60 cm x 10 cm (S_3) with the fertilizer 125% RDF (F_1) (74.4), 60 cm x 10 cm (S_3) with the fertilizer 100% RDF (F_2) (73.5), 60 cm x 10 cm (S_3) with the fertilizer 75% RDF (F_3) (72.2) were found to be producing the higher mean number of tillers per running meter over the remaining treatment combinations. At 90 DAS and at harvest significantly higher mean number of tillers per running meter was found in treatment combination of 60 cm x 10 cm (S_3) with the fertilizer 100% GRDF (F4) (94.2 and 83.5 respectively) which was at par with 60 cm x 10 cm (S_3) with the fertilizer 125% RDF (F1) (91.0 and 82.9 respectively), 60 cm x 10 cm (S_3) with the fertilizer 100% RDF (F_2) (89.1 and 81.4 respectively), 45 cm x 10 cm (S_2) with the fertilizer 100% GRDF (F_1) (87.8 and 80.7 respectively), 60 cm x 10 cm (S_3) with the fertilizer 75% RDF (F_3) (87.6 and 80.7 respectively) in that order over the rest of other treatment combinations. This might be due to higher nutrient supply during the critical growth stages of the crop which may have influenced plant height, dry matter accumulation leading to higher growth attributes and yield of foxtail millet. Significantly lower mean number of tillers per running meter was observed under absolute control (F_5) during all growth stages of crop. The finding is in line with Mownika *et al.*, (2021) [11], Kumar *et al.*, (2022) [7].

Table 3.1: Mean number of tillers per running meter of foxtail millet as influenced by interaction effect between spacing and fertilizer levels

Interaction Combinations (S X F)	Mean number of tillers per running meter				
	45 DAS	60 DAS	75 DAS	90 DAS	At Harvest
S_1F_1	19.8	40.0	57.6	80.2	69.4
S_1F_2	14.6	33.9	54.9	76.3	67.9
S_1F_3	11.7	31.2	52.8	71.3	57.0
S_1F_4	21.0	42.7	59.8	84.6	69.9
S_1F_5	10.7	25.3	32.4	55.0	40.3
S_2F_1	28.4	48.2	66.4	87.5	73.7
S_2F_2	28.1	47.0	64.3	84.6	73.5
S_2F_3	25.5	46.8	61.4	84.4	72.5
S_2F_4	28.8	49.0	69.9	87.8	74.9
S_2F_5	22.2	40.5	60.5	81.0	71.3
S_3F_1	34.0	54.2	74.4	91.0	82.9
S_3F_2	33.3	53.4	73.5	89.1	81.4
S_3F_3	33.0	52.1	72.2	87.6	80.7
S_3F_4	35.0	55.7	76.0	94.2	83.5
S_3F_5	29.6	48.9	66.5	83.0	71.0
S.Em±	1.1	1.7	2.5	3.0	3.2
CD @ 5%	3.3	5.0	7.5	8.7	9.4
CV (%)	7.74	6.60	7.12	6.26	7.79
General Mean	25.20	45.10	63.10	83.00	71.90

4) Mean dry matter

a) Effect of spacing: The mean dry matter accumulation in plants was significantly influenced by different spacings. At 30 DAS there is no significant effect on mean dry matter production. However, with the advancement of age of the crop from 45 DAS, 60 DAS, 75 DAS, 90 DAS and at harvest the mean dry matter accumulation was noted significantly highest (13.25 g, 22.96 g, 30.02 g, 42.14 g and 49.89 g respectively) in 60 cm x 10 cm (S_3) spacing over rest of the other plant spacings. This may be due to the increased leaf area, no of tillers and yield attributing characters. The findings are corroborative with Narayan *et al.*, (2018) [13], Kumar *et al.*, (2022) [7].

Table 4: Mean dry matter per plant accumulation (g) of foxtail millet as influenced by spacing and fertilizer levels

Treatment	Mean dry matter plant^{-1} (g)						
	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	At Harvest
Main plot: Spacing							
S_1: 30 cm X 10 cm	0.31	2.20	8.27	11.72	18.60	23.80	31.94
S_2: 45 cm X 10 cm	0.34	2.32	9.67	17.78	24.31	32.63	40.25
S_3: 60 cm X 10 cm	0.38	2.45	13.25	22.96	30.02	42.14	49.89
S.E.(m) ±	0.013	0.08	0.51	0.86	0.82	1.68	1.89
CD @ 5%	NS	NS	2.02	3.40	3.23	6.60	7.44
CV%	15.23	14.56	19.17	19.21	13.10	19.81	18.05
Sub-plot: Fertilizer levels							
F_1:125% RDF	0.36	2.41	11.63	19.33	29.08	35.10	43.38
F_2: 100% RDF	0.35	2.38	10.80	17.92	25.11	33.30	42.24
F_3: 75% RDF	0.34	2.33	10.09	16.93	23.93	32.47	39.40
F_4: 100% GRDF	0.37	2.44	11.84	21.41	30.14	40.17	45.35
F_5: Absolute Control	0.30	2.06	7.63	11.84	13.31	23.25	33.11
S.E.(m) ±	0.017	0.13	0.42	0.69	1.21	1.36	1.08
CD @ 5%	NS	NS	1.23	2.01	3.55	3.99	3.17
CV%	14.72	17.80	12.21	11.85	15.03	12.5	8.01
Interaction: S X F							
S.E.(m) ±	0.022	0.19	0.73	1.19	2.11	2.37	1.88
CD @ 5%	NS	NS	2.14	3.49	6.16	6.92	5.50
CV%	14.72	17.80	12.21	11.85	15.03	12.5	8.01
General Mean	0.34	2.32	10.40	17.49	24.31	32.86	40.70

b) Effect of fertilizer levels: Mean dry matter accumulation in plants was significantly influenced by different fertilizer levels. Significantly highest mean dry matter accumulation was observed by the application of 100% GRDF (S_4) over the rest of other fertilizer levels. At 15 DAS and 30 DAS there is no significant influence on mean dry matter accumulation. With advancement of age of the crop from 45 DAS significantly higher mean dry matter accumulation (11.84 g) was observed by the application of 100% GRDF (F_4) which was at par with 125% RDF (F_1) (11.63 g) and 100% RDF (F_2) (10.80 g) over rest of treatments. At 60 DAS significantly, highest mean dry matter accumulation (21.41 g) reported by 100% GRDF (S_4) over the rest of fertilizer levels. At 75 DAS and 90 DAS significantly, higher mean dry matter accumulation was recorded by application of 100% GRDF (F_4) (30.14 g and 40.17 g respectively) which was at par with 125% RDF (F_1) except at 90 DAS over other levels of fertilizer. At harvest significantly, higher mean dry matter accumulation (45.35 gm) was recorded by the with application of 100% GRDF (F_4) which was at par with 125% RDF (F_1) (43.38 g) and 100% RDF (F_2) (42.24 g). This is because FYM support beneficial soil microorganism, which contribute to nutrient recycling, also the healthy plant

with improved nutrient uptake can focus energy on photosynthesis, leading to increased biomass production. The findings are corroborative with Narayan *et al.*, (2018) [13], Kumar *et al.*, (2022) [7], Upadhaya *et al*., (2022) [18].

c) Interaction Effect: At 45 DAS higher mean dry matter accumulation (15.61 g) was observed in the treatment combination of spacing 60 cm x 10 cm (S_3) and application of fertilizer dose of 100% GRDF (F_4), which was found to be statically at par with 60 cm x 10 cm (S_3) and 125% RDF (F_1) (15.45 g), 60 cm x 10 cm (S_3) and 100% RDF (F_2) (14.04 g), over the rest of the other treatment combinations.

Table 4.1: Mean dry matter per plant accumulation (g) of foxtail millet as influenced by interaction effect between spacing and fertilizer levels

Interaction Combinations (S X F)	Mean dry matter plant^{-1} (g)				
	45 DAS	60 DAS	75 DAS	90 DAS	At Harvest
S_1F_1	8.90	12.54	25.29	23.89	33.31
S_1F_2	8.29	11.40	14.29	21.90	32.27
S_1F_3	7.50	10.48	13.74	21.16	30.71
S_1F_4	9.15	14.48	26.57	35.50	34.81
S_1F_5	7.55	9.71	13.14	16.58	28.62
S_2F_1	10.55	19.60	28.25	34.65	41.66
S_2F_2	10.09	17.76	27.53	32.26	40.82
S_2F_3	9.44	16.20	25.60	32.05	39.25
S_2F_4	10.77	22.83	29.00	38.21	44.42
S_2F_5	7.49	12.51	11.20	25.99	35.12
S_3F_1	15.45	25.85	33.70	46.76	55.19
S_3F_2	14.04	24.62	33.52	45.75	53.63
S_3F_3	13.34	24.13	32.47	44.21	48.23
S_3F_4	15.61	26.91	34.86	46.81	56.83
S_3F_5	7.84	13.31	15.59	27.19	35.59
S.Em±	0.73	1.19	2.11	2.37	1.88
CD @ 5%	2.14	3.49	6.16	6.92	5.50
CV (%)	12.21	11.85	15.03	12.5	8.01
General Mean	10.40	17.49	24.31	32.86	40.70

At 60 DAS,75 DAS, 90 DAS higher mean dry matter accumulation (22.83 g, 34.86 g, 46.81 g respectively) was observed in the treatment combination of spacing 60 cm x 10 cm (S_3) and application of fertilizer dose of 100% GRDF (F_4), which was found to be at par with 60 cm x 10 cm (S_3) and 125% RDF (F_1) (25.85 g, 33.70 g, 46.76 g respectively), 60 cm x 10 cm (S_3) and 100% RDF (F_2) (24.62 g, 33.52 g, 45.45 g respectively), 60 cm x 10 cm (S_3) and 75% RDF (F_3) (24.13 g, 32.47 g, 44.21 g respectively), while the treatment combinations 45 cm x 10 cm (S_2) and application of fertilizer dose of 100% GRDF (F_4) (29.00 g) and 45 cm x 10 cm (S_2) and 100% RDF (F_2) (27.53 g) was found to be on par with each other at 75 DAS over the rest of treatment combinations. At harvest higher mean dry matter accumulation (56.83 g) observed in the treatment combination of spacing 60 cm x 10 cm (S_3) and application of fertilizer dose of 100% GRDF (F_4), which was found to be at par with 60 cm x 10 cm (S_3) and 125% RDF (F_1) (55.19 g), 60 cm x 10 cm (S_3) and 100% RDF (F_2) (53.63 g) over the rest of treatment combination. This is because wider spacing and FYM application can help plant tolerate stress like drought, heat and disease, leading to increased dry matter production. The result is in line with Kumar *et al.* (2022) [7].

Conclusion

This experiment aimed to assess the combined impact of fertilizer levels and plant spacing on the growth, yield, nutrient status, and economic viability of foxtail millet (*Setaria italica* L.) cultivation during the *kharif* season of 2023. The study found that while a closer spacing of 30 cm x 10 cm, particularly in combination with 100% GRDF (General Recommended Dose of Fertilizer), consistently resulted in taller plants, wider spacing of 60 cm x 10 cm significantly promoted other crucial growth attributes such as higher mean leaf area and a greater number of tillers per running meter. The application of 100% GRDF consistently enhanced overall plant vigor, leading to increased leaf area, dry matter accumulation, and tiller development across various growth stages. These findings suggest that an optimized approach to foxtail millet cultivation involves balancing plant density for plant height with wider spacing and adequate graded fertilizer application to maximize other vital growth parameters, ultimately contributing to better yield attributes and nutrient uptake.

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