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Effect of Fertilizer Levels and Row Spacings on Growth and Yield of Foxtail Millet (*Setaria italica* L.)

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Abstract

The field experiment was conducted during *kharif*, 2023 at Experimental Farm, Department of Agronomy, College of Agriculture, Latur, to study effect of fertilizer levels and row spacings on growth and yield. The experiment was laid out in Factorial Randomized Block Design with two factors and replicated thrice. First factorconsisted of three fertilizer levels viz., fertilizer level-1:75% , fertilizer level-2: 100% and fertilizer level-3: 125% recommended dose of fertilizer, second factor consisted of three-row spacing viz., 2 row spacing-1: 22.5 ×10 cm^2, row spacing- 2: 30×10 cm^2 and row spacing-3: 45×10 cm^2. The results revealed that application of 125 % RDF recorded significantly higher plant height (132.27 cm), number of tillers $plant^{-1}$ (4.09), number of functional leaves $plant^{-1}$ (23.84), leaf area $plant^{-1}$ (2.76 dm^2), dry matter $plant^{-1}$ (20.91 g), LAI (3.50), grain (2833 kg ha^{-1}), straw (8398 kg ha^{-1}) and biological yield (11232 kg ha^{-1}). Among row spacings 22.5×10 cm^2 recorded significantly higher plant height (128.95 cm), number of functional leaves $plant^{-1}$ (23.58), leaf area $plant^{-1}$ (2.66 dm^2), Leaf area index (3.45), grain (2829 kg ha^{-1}), straw (8300 kg ha^{-1}) biological yield (11130 kg ha^{-1}) and harvest index (25%) which was comparable with 30×10 cm^2 and significantly superior over 45×10 cm^2. Number of tillers $plant^{-1}$ (3.90) and dry matter $plant^{-1}$ (20.44 g) were significantly higher with 45×10 cm^2 row spacings, which was comparable with 30×10 cm^2 and significantly superior over 22.5×10 cm^2.

Keywords: Fertilizer levels, foxtail millet, RDF, row spacings

1. Introduction

Foxtail millet, belongs to the family Poaceae, is highly drought tolerant crop grown in drylands under rainfed conditions (Brahmachari et al., 2018). Besides, small millets are considered as functional foods containing bioactive ingredients useful to combat against chronic diseases (Banerjee and Maitra, 2020). As a traditional coarse grain in China, foxtail millet is highly valued for its nutritional content, which includes calcium, iron, and zinc. (Hou et al., 2022, Sun et al., 2021 and Yousaf et al., 2021).

Nitrogen (phosphorus and potassium are fundamental nutrients for plant growth and development (Wang et al., 2021). An insufficient N supply has adverse effects on plant height, leaf size, chlorophyll content, photosynthesis, protein and nucleic acid synthesis. (Mu and Chen, 2021, Bassi et al., 2018 and Peng et al., 2021). An insufficient P supply not only retards plant growth but also impedes the absorption of other nutrients by plants. (Kaminsky et al., 2018 and Meng et al., 2021). An adequate K supply promotes plant growth, enhances stress resistance, and improves crop quality. (Yasin et al., 2018 and Wang et al., 2020). Increasing nitrogen fertilizer application rate is the simplest and quickest method to enhance crop yield (Chu et al., 2019). However, despite nitrogen fertilizer's potential to significantly improve crop productivity and quality, excessive nitrogen application rates and low efficiency have led to serious environmental issues (Ren et al., 2020). Therefore, optimizing nitrogen fertilizer management is crucial for achieving agricultural sustainability. Phosphorus is an essential macronutrient for optimal plant growth, development, and metabolism and plays a crucial role in the absorption and utilization of nutrients by plants (An et al., 2021). Phosphorus not only enhances plant growth, disease resistance, stress tolerance, and crop yield and quality by promoting root growth but also participates in physiological and biochemical reactions within the plant body. (Lu et al., 2023). When phosphorus supply is limited, the roots, which are the primary site for phosphorus absorption, undergo morphological changes. These changes include an increased root-to-shoot ratio, longer lateral roots, and extended root hairs (Lynch, 2019). Additionally, roots secrete organic acids and phosphatases to mobilize available phosphorus, thereby enhancing phosphorus accumulation and use efficiency. Potassium contributes to protein synthesis, carbohydrate metabolism, and enzyme activation. (Manjunath et al., 2022)

Fertilizer application is an important measure to improve crop quality, and it is beneficial for improving soil fertility and achieving a virtuous cycle in the farming system. (Mu and Chen, 2021). "NPK fertilization practices not only enhance the crop yield and quality, , but also increase fertilizer utilization efficiency, leading to optimal economic benefits. (Xing et al., 2023). Higher yield of foxtail millet can be realized with optimum plant density and proportionate use of primary nutrients to provide balanced fertilization to crops (Maitra et al., 2020). Despite its high nutrition value, the average yield of foxtail millet is low as compared to the potentially achievable yield due to in adequate planting density, insufficient fertilizer application and lack of proper management methods. Optimum plant density ensures that plant grow appropriately and make better use of sunlight and soil nutrients" (Reddy et al., 2021).

Several studies have reported the positive effects of integrated fertilization on foxtail millet, emphasizing the importance of achieving a balanced supply of N, P, and K to boost crop productivity and quality (Guan et al., 2022 and Li et al., 2022). Nutrient management and ideal spacing are key issues in achieving higher biomass and also maintaining soil fertility. Very little information is available on agronomical practices in foxtail millet. Hence present study was conducted to evaluate response of foxtail millet to different spacings and fertilizer levels.

2. Materials and Methods

An experiment was conducted to determine the response of foxtail millet (*Setaria italica* L.) to row spacings and fertilizer levels during *kharif*, 2023 at Experimental Farm, College of Agriculture, Latur. Geographically Latur district of Maharashtra state was located at 18^{o} 05' to 18^{o} 75' North latitude and 77^{o} 25' to 77^{o} 36' East latitude with the total geographical area is 7.37 mha. Latur area comes under semi-arid region of Maharashtra. The average annual rainfall of the Latur district was 689.72 mm. The soil of experimental plot was clayey in texture, low in available nitrogen (230 kg ha^{-1}), medium in available phosphorous (16.5 kg ha^{-1}) and very high in available potassium (432 kg ha^{-1}). The soil was moderately alkaline in reaction having pH 7.02. The experiment was laid out in factorial Randomized Block Design with nine treatments combinations, consisting of two factors, fertilizer levels and row spacings which included three levels of each. The first factor consisted of three different fertilizer levels viz., F_1-75% RDF, F_2-100% RDF and F_3-125% RDF and second factor consisted of three row spacings viz., S_1-22.5×10 cm^2, S_2-30×10 cm^2 and S_3-45×10 cm^2. Each treatment was replicated three times. The experimental gross plot size was 5.4×4.5 m^2 and net plot size was as per treatments. Sowing was done on 8th July 2023. The recommended cultural practices and plant protection measures were undertaken. The statistical technique for the analysis of variance was employed to analyse the recorded data Watson (1958).

2.1. Methodology

2.1.1. Plant height (cm)

The plant height was measured in cm from ground level to the base of top most fully opened leaf of five randomly selected plants and the mean plant height was worked out.

2.1.2. Number of tillers plant^{1}

The number of tillers $plant^{-1}$ was recorded by counting tillers of five observation plants at the time of harvesting and then average was worked out.

2.1.3. Number of functional leaves $plant^{-1}$

Total number of functional leaves born on each randomly selected plant was counted and recorded. All the fully opened leaves from each plant were recorded as functional leaves. The leaves which are dried more than half of its area were excluded while counting the functional leaves.

2.1.4. Leaf area $plant^{-1}$ (dm^2)

Leaf area was calculated with randomly selected five plant samples. The leaves of samples were grouped as small, medium and large. The leaf area $plant^{-1}$ (dm^2) was measured by taking length and breadth of each leaf and multiplied it with the leaf factor and number of leaves. Then averaging and converted on plant basis.

Leaf area (LA)=L×B×N×K

where,

LA=Leaf area (dm^2)
L=Maximum length of leaf (cm)
B=Maximum breadth of leaf (cm)
N=Number of leaves under particular group
K=Leaf area constant (0.786)

2.1.5. Leaf area index (LAI)

Since, the crop yield was to be assessed $unit^{-1}$ of ground area instead of $plant^{-1}$, the leaf area existing on one plant was considered as the leaf area produced on unit ground area was proposed by Watson (1958). The measure was known as leaf area index. It was calculated by the formula,

$$LAI = \frac{\text{Leaf area plant}^{-1}\ (cm^2)}{\text{Ground area plant}^{-1}\ (cm^2)}$$

2.1.6. Total dry matter accumulation $plant^{-1}$ (g)

The weight of dry matter was an index of productive capacity of the plants. Hence, one representative plant from each net plot was randomly uprooted. The roots of the plant uprooted for dry matter study from each net plot were removed. After removal of roots, plant parts were sun dried in the first instance and oven dried at 65±2°C temperature for 48 hrs. The constant weight was recorded as total dry matter weight (g) plant^{-1} for each treatment.

2.1.7. Seed yield (kg ha^{-1})

After harvesting, the plants from each net plot were threshed and seeds were cleaned by winnowing. The cleaned seeds obtained from each net plot were weighed in kg which was then converted into seed yield (kg ha^{-1}) by multiplying with hectare factor.

2.1.8. Straw yield (kg ha^{-1})

Before threshing, weight of sundried biological yield from each net plot was recorded. Weight of dried leaves collected from each net plot was also added in biological yield. Then seed weights were subtracted from total biological yield and remaining weights were counted as straw yield in kg.

Straw yield=biological yield-seed yield

2.1.9. Biological yield (kg ha^{-1})

The biological yield was recorded by the following formula,

Biological yield=Seed yield+Straw yield

3. Results and Discussion

3.1. Growth attributes

Growth attributing characters of foxtail millet *i.e.*, plant height (cm), number of tillers, number of functional leaves plant^{-1}, leaf area (dm^2), dry matter production plant^{-1} (g) and LAI were affected significantly (Table 1) due to difference in fertilizer level of and row spacings.

3.2. Effect of fertilizer levels

Among the fertilizer levels, application of 125% RDF ha^{-1} recorded the highest plant height plant^{-1} (132.27 cm) , number of tiller plant^{-1} (4.09), number of functional leaves plant^{-1} (23.84), mean leaf area (2.76 dm^2), dry matter plant^{-1} (20.91 g) and leaf area index (3.50) of foxtail millet and it was found comparable with the application of 100% RDF ha^{-1}and it was significantly superior over 75% RDF ha^{-1}.The increase in growth characters was attributed to increased availability of nutrients leading to better nutritional environment in root zone for growth and development. Similar results were reported by Divyashree et al. (2018).

3.3. Effect of row spacings

The closer row spacing of 22.5×10 cm^2 recorded the highest plant height plant^{-1} (128.95 cm), number of functional leaves plant^{-1} (23.58) and leaf area plant^{-1} (2.66 dm^2) foxtail millet which was comparable with 30×10 cm^2 and found significantly superior over 45×10 cm^2. The number of tillers plant^{-1} (3.90) and dry matter accumulation plant^{-1} (20.44 g) were higher with wider the spacing of 45×10 cm^2 which was at par with 30×10 cm^2 and found significantly superior over 22.5×10 cm^2. It might be due to completion felt for sunlight under closer row spacing which resulted in higher plant height plant^{-1}. The increase in number of tillers plant^{-1} and dry matter accumulation per

Table 1: Plant height plant^{-1} (cm), number of tillers plant^{-1}, number of functional leaves plant^{-1}, leaf area plant^{-1} (dm^2), dry matter plant^{-1} (g) and LAI of foxtail millet as influenced by fertilizer levels and row spacings

Treatments	Plant height plant^{-1} (cm)	No. of tillers plant^{-1}	No. of functional leaves plant^{-1}	Leaf area plant^{-1} (dm^2)	Dry matter plant^{-1} (g)	LAI
Fertilizer levels (F)						
F_1: 75% RDF	109.46	3.28	20.20	2.18	18.55	3.20
F_2: 100% RDF	129.61	3.82	22.96	2.54	19.53	3.33
F_3: 125% RDF	132.27	4.09	23.84	2.76	20.91	3.50
SEm±	3.51	0.09	0.55	0.08	0.59	0.077
CD (p=0.05)	10.52	0.28	1.63	0.23	1.77	0.230
Row spacings (S)						
S_1: 22.5×10 cm^2	128.95	3.42	23.58	2.66	18.29	3.45
S_2: 30×10 cm^2	126.99	3.87	22.10	2.52	20.26	3.40
S_3: 45×10 cm^2	115.40	3.90	21.32	2.31	20.44	3.17
SEm±	3.51	0.09	0.55	0.08	0.59	0.077
CD (p=0.05)	10.52	0.28	1.63	0.23	1.77	0.230
Interaction (F×S)						
SEm±	6.08	0.17	0.94	0.13	1.02	0.13
CD (p=0.05)	NS	NS	NS	NS	NS	NS

plant^{-1} under wider row spacing might be due to more space available for individual plant. Plant stature with broader leaves were noted when foxtail millet was raised at wider spacing than closer ones. Though broader leaves and better plant stature have direct relationship with LAI, it could not compensate leaf area obtained with more number of plants per unit area under closer spacing. This might be attributed to higher tillers recorded per unit area which resulted in more leaves leading to higher LAI values. Similar results were found by Anonymous (2017) and Baloch et al. (2002).

3.4. Interaction effect

The effect of interaction between fertilizer levels and row spacings on growth attributes was found to be non -significant.

3.5. Yield

Data shown in Table 2 revealed that grain yield (kg ha^{-1}), straw yield (kg ha^{-1}), biological yield (kg ha^{-1}) and harvest index of foxtail millet were affected significantly (Table 2) due to difference in fertilizer level of and row spacings.

3.6. Effect of fertilizer levels

Higher grain (2833 kg ha^{-1}), straw (8398 kg ha^{-1}) and biological yield (11232 kg ha^{-1}) of foxtail millet were recorded with application of 125% RDF ha^{-1} which was comparable with 100% RDF and found significantly superior over 75% RDF. Highest harvest index (25%) was observed equally with 125% RDF and 100% RDF. It might be due to higher growth attributing character with higher fertilizer levels which enhanced photosynthetic efficiency resulted in higher yield. Similar results were reported by Divyashree et al. (2018).

3.7. Effect of row spacings

The closer row spacing of 22.5×10 cm^2 recorded higher grain yield (2829 kg ha^{-1}), straw yield (8300 kg ha^{-1}) and biological yield (11130 kg ha^{-1}) which was at par with 30×10 cm^2 and found significantly superior over 45×10 cm^2. Highest harvest index (25%) was recorded equally with 22.5×10 cm^2 and 30×10 cm^2. it might be due to higher plant population per unit area with closer row spacing resulted in higher yield. Similar findings were reported by Anonymous (2017).

Table 2: Grain yield (kg ha^{-1}), straw yield (kg ha^{-1}), biological yield (kg ha^{-1}) and harvest index of foxtail millet as influenced by fertilizer levels and row spacings

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
Fertilizer levels (F)				
F_1: 75% RDF	2433	7590	10023	24
F_2: 100% RDF	2727	8031	10758	25
F_3: 125% RDF	2833	8398	11232	25
SEm±	70	193	259	-
CD (p=0.05)	210	578	777	-
Row spacings (S)				
S_1: 22.5×10 cm^2	2829	8300	11130	25
S_2: 30×10 cm^2	2703	8135	10837	25
S_3: 45×10 cm^2	2461	7584	10046	24
SEm±	70	193	259	-
CD (p=0.05)	210	578	777	-
Interaction (F×S)				
SEm±	122	334	449	-
CD (p=0.05)	NS	NS	NS	-

3.8. Interaction effect

The effect of interaction between fertilizer levels and row spacings on yield was found to be non-significant.

4. Conclusion

Foxtail millet responded to application of 125% RDF for getting higher growth attributes and yield, closely followed by application of 100% RDF. Among different row spacings sowing of foxtail millet with 22.5×10 cm^2 produced higher yield, followed by 30×10 cm^2.

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