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EFFECT OF CROP ESTABLISHMENT AND NUTRIENT MANAGEMENT PRACTICES ON GROWTH ATTRIBUTES OF FINGER MILLET (*ELEUSINE CORACANA* L.)

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ABSTRACT

A field experiment was conducted during the rainy season *(kharif)* 2024 at institute farm, ICAR-Indian Institute of Millet Research (IIMR), Rajendranagar, Hyderabad, to study the effects of nutrient management practices on finger millet (*Eleusine coracana*) grown under different establishment methods. The experiment was laid out in a split plot design. the main plots treatments comprised two methods of crop establishment (Direct sowing method, transplanting method) and sub-plot treatments consisted of five nutrient management practices (S1-control, S2-100%RDN, S3-100% RDN + FYM @ 7.5 tone ha$^{-1,}$ S4 -100% RDN + Biofertilizer (Azospirillum), S5-100% RDN + FYM @ 7.5 tone ha^{-1} + Biofertilizer (Azospirillum), respectively, with 3 replications. The experimental result revealed that different establishment method and level of nutrient management practice had a remarkable influence on the growth parameters of finger millet. Growth parameters were increased significantly with the transplanting method and S5 - 100% RDN + FYM @ 7.5 tone ha^{-1} + Biofertilizer (Azospirillum).

***Key words*: Nitrogen, FYM, Azospirillum, Finger millet, Growth parameters, Establishment methods**

Introduction

Millets are good source of minerals like iron, zinc and calcium; they are gluten free and also have low glycaemic index (APEDA, 2020). In order to ensure food and nutritional security for the younger generations, millets are recognized as a substitute for major cereal crops. Realizing the potential of these crops, The United Nations General Assembly has declared Year 2023 as the 'International Year of Millets'. Finger millet (*Eleusine coracana* L.) locally called as *Ragi* ranks third among millets in the world after sorghum (*Sorghum bicolor*) and pearl millet (*Pennisetum glaucum*). In India, finger millet is mostly cultivated in Karnataka, Andhra Pradesh, Telangana, Tamil Nadu, Maharashtra, Odisha, Madhya Pradesh, Rajasthan and Uttarakhand states occupied an area of 12.11 lakh ha with an annual production of 16.96 lakh tons and a productivity of 1401kg ha^{-1} (APEDA, 2020). In Telangana, finger millet is cultivated in an area of 10 hacters and production 9.30 tons (FIB, 2022). Ragi contains 9.2 per cent protein, 1.29 percent fat, 76.32 per cent carbohydrates, 2.2 per cent minerals, 3.90 per cent ash and 0.33 per cent calcium (Sarawale *et al*., 2017).

The demand for finger millet grains and products has been increasing among the urban population and the crop has the ability to come up even in soils of low fertility. Under these circumstances, there is scope for popularizing the cultivation of finger millet among the farmers in different districts of Telangana. Suitable crop establishment methods and optimum nutrient management practices play a critical role in enhancing the productivity of finger millet crop. Among the various crop establishment methods, System of Millet intensification has immense potential to increase the finger millet productivity as compared with conventional and direct seeding methods (Bhatta *et al.*, 2017). High yielding fertilizer responsive varieties of finger millet are cultivated with an average yield ranged from 1.0 t ha^{-1} to 3.5 t ha^{-1} and their commended dose of fertilizer in these states varies from 60:30:30 kg NPK ha^{-1} to 90:45:45 kg NPK ha^{-1} (Jeyaraman, 2014) and higher dose of FYM (10 t ha^{-1}).

Material and Methods

The experiment was carried out at institute farm, ICAR-Indian Institute of Millet Research (IIMR), Rajendranagar, Hyderabad during *kharif*, 2024. The farm is geographically located at an altitude of 475.6 meters above the mean sea level (MSL) on 17° 04' N latitude and 75° 54' E longitude. It was located in Southern Telangana Agro-climatic Zone of Telangana state**.** The soil of experimental field was sandy loam in texture with 7.4 Ph. It was low in organic carbon 0.43% and available nitrogen 185.5 kg ha^{-1} available phosphorus 37.25 kg ha^{-1} and available potassium 275.20 kg ha^{-1}. Two establishment methods (direct sowing method, transplanting method, five nutrient management practices (S1-control, S2-100%RDN, S3-100% RDN + FYM @ 7.5 tone ha^{-1}, S4 - 100% RDN + Biofertilizer (Azospirillum), S5 - 100% RDN + FYM @ 7.5 tone ha^{-1}+ Biofertilizer (Azospirillum) were tested in split plot design, keeping as main and subplots, respectively, with 3 replications. The gross and net plot size was 3.6 m × 3m and 3.0 m × 2.8 m, respectively. During the crop season, weekly mean minimum and maximum temperature ranged from 18.5 to 24.4 ^{0}C and 25.2 to 32.6^{0}C respectively, total rainfall 775.9 mm, maximum and minimum relative humidity ranged from 24.7-93.6 % and 13.8-83.9%, respectively, evaporation ranged from 4.3-7.2 mm, respectively. The variety used in the study is indravathi (CFMV1). The nursery area required for raising seedlings for one ha area is 150 m^2.

Clean and healthy seeds of finger millet were selected for sowing according to the planting. On 6th July, 2024 the crop was sown. On the same day, the raised nursery beds were also sown for transplanting of finger millet. Nursery raised finger millet seedlings were transplanted after 30 days in the main plots. Under conventional method of transplanting 30 days old seedlings were transplanted in the field @ 2-3 seedlings hill on 6th August, 2024. The row to row and plant to plant spacing were kept 30 cm × 10 cm. A well decomposed FYM was applied to the field before sowing of the crop and seeds are treated with azospirillum. Recommended doses (80:80:20 kg ha^{-1}) of N, P_2O_5 and K_2O were applied in the form of urea, single super phosphate and muriate of potash. Half dose of N and full dose of P_2O_5 and K_2O were applied as basal dose. Remaining quantity of nitrogen was applied to soil in two equal splits at tillering and panicle emergence. Immediately after sowing, irrigation was given to each plot to bring the soil to field capacity to induce germination. Gap filling was done 7-8 days after sowing wherever it was necessary in order to maintain optimum plant population. Thinning was carried out by direct sowing at 20 days after sowing by retaining one healthy seedling per each hill in every plot. Hand-weeding twice at 20 and 40 DAS were carried out in order to keep the plots free from weed competition and there by soil moisture and nutrient depletion by weeds are minimized. In each net plot, five representative plants were randomly selected and tagged. All the successive biometric observations during the crop growth period were recorded periodically on the selected plants. Growth characters like initial and final plant stand, plant height, leaf area, no of tillers per m^2 and dry matter $plant^{-1}$ were recorded at 30, 60, 90 DAS and at harvest in finger millet. Data were subjected to analysis of variance (ANOVA) using online statistical analysis package (OPSTAT) at 5 % level of significance (p=0.05).

Result and Discussion

Growth parameters

Plant height (cm)

The plant height of finger millet is influenced by different sowing methods and nutrient management practices and their interactions are presented in Table1.

Sowing methods

The plant height of finger millet was affected by the method of crop establishment at all stages of growth, except at 30 days after sowing (DAS). At 30 DAS, although the direct sowing method (S1) showed taller plants (33.33 cm) compared to the transplanting method (S2) with (28.28) cm, the difference was statistically significant. However, from 60 DAS onwards, the transplanting method resulted in taller plants. At 60 DAS, the plant height under transplanting was 74.54 cm, which was higher than the 70.27 cm recorded under direct sowing method. This trend continued at 90 DAS, with the transplanting method produced the plant height of 106.50 cm, compared to 97.04 cm under direct sowing. The same pattern was observed at the time of harvest as well.

The transplanting method likely resulted in taller finger millet plants from 60 DAS onwards due to better initial establishment and stronger root development. Transplanted seedlings might have experienced less competition for nutrients and water during early growth, leading to vigorous vegetative development. Additionally, transplanting allows for better plant spacing and uniformity, which can enhance nutrient uptake, light

Table 1: Effect of crop establishment methods and nutrient management practices on growth attributes of finger millet.

Treatments	Plant height(cm)				Leaf area (cm^2)				Dry matter Production g/m^2				Tillers m^2		
	30	60	90	H	30	60	90	H	30	60	90	H	30	60	90
M1	33.33	70.27	97.04	100.38	475.75	791.27	1386.04	788.16	41.47	216.23	523.46	552.6	35.10	73.45	88.92
M2	28.28	74.54	106.5	110.94	365.95	884.70	1593.34	846.80	38.55	270.53	582.75	617.24	29.04	85.99	102.49
S. Em. ±	1.11	0.73	2.13	2.04	13.04	15.23	38.34	11.43	0.63	7.59	10.41	11.89	0.90	2.79	3.07
C.D. (P=0.05)	3.74	3.15	9.18	8.76	56.10	65.52	164.96	49.17	2,71	32.68	46.07	51.17	3.86	11.99	13.2
S1	18.56	62.10	92.13	97.08	254.17	675.43	1175.78	670.31	29.73	156.9	474.9	506.35	21.77	58.64	73.62
S2	28.97	70.46	98.92	105.08	345.18	796.15	1489.80	775.65	36.49	232.92	534.4	563.25	28.88	78.19	93.28
S3	35.64	76.66	106.17	107.89	506.97	893.15	1593.69	879.82	44.50	273.25	580.1	609.75	37	86.87	100.61
S4	31.35	73.22	102.6	106.86	418.93	863.7	1503.88	845.69	41.75	249	567.9	594.2	33.37	81.37	98.83
S5	39,50	79.57	109.06	111.38	579.01	961.50	1685.28	915.92	47.60	304.83	608.23	651.05	39.33	93.54	112.17
S. Em. ±	1.46	0.76	1.42	1.5	33.26	30.16	45.29	9.83	1.2	11.65	11.21	10.6	0.86	2.90	3.27
C.D. (P=0.05)	3.10	1.61	3.00	3.32	70.52	63.94	96	20.84	2.16	24.7	23.77	22.48	1.83	6.14	6.92
Interaction															
S. Em. ±	2.04	0.98	2.00	2.12	47.04	42.65	64.04	13.9	1.44	16.48	18.02	14.99	1.61	4.09	4.62
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

interception and overall growth. As a result, the plants maintained superior height throughout the later stages of growth and at harvest. Similar results were reported by Thakur *et al*., (2016).

Nutrient management

The plant height of finger millet was significantly influenced by nutrient management practices.

Plant height at 30 DAS as influenced by nutrient management practices revealed that maximum plant height was observed with the application of S5 - 100% RDN + FYM @ 7.5 tonne ha^{-1} + Biofertilizer (Azospirillum) (39.50 cm) which was significantly superior over other treatments. The lowest plant height was observed in the control *viz*., (S1) (18.56 cm). Plant height at 60 DAS revealed that application of 100% RDN + FYM @ 7.5 tonne ha^{-1} + Biofertilizer (Azospirillum) (S5) recorded the maximum plant height of 79.57 cm. It was significantly superior to other combinations of organic and inorganic treatments. The next best treatment was 100% RDN + FYM @ 7.5 tonne ha^{-1} (S3) (76.66 cm). Lowest plant height recorded with control (S1) (62.10). Plant height at 90 DAS as influenced by nutrient management practices revealed that maximum plant height was observed with the application of S5-100% RDN + FYM @ 7.5 tonne ha^{-1} + Biofertilizer (Azospirillum) (109.06 cm) which was significantly superior to other combinations of organic and inorganic treatments. The lowest plant height was produced with control *viz*., (S1) (92.13 cm). Plant height at maturity was significantly affected by nutrient management practices. Among the various treatments, S5 (100% RDN + FYM @ 7.5 tonne ha^{-1} + Biofertilizer (Azospirillum) recorded the maximum plant height (111.38 cm), which was significantly superior over other treatments. The lowest plant height (97.08 cm) was observed in the control (S1). The application of integrated nutrient management significantly enhanced plant height at maturity in finger millet.

The combination of 100% RDN with FYM @ 7.5 tonne ha^{-1} and biofertilizer (Azospirillum) (S5) proved most effective, resulted in the taller plants. However, the treatment with 100% RDN + FYM alone (S3) also performed comparably well, indicating the crucial role of organic amendments in promoting vegetative growth. In contrast, the control treatment with only (S1) resulted in the shortest plants.

The higher plant height under FYM application probably due to the regular supply of the essential nutrients by continuous mineralization of organic manures, besides enhanced nutrient supplying capacity of soil and its favorable effect on growth Parameters (Hati *et al*., 2001). The results coincide with the findings of Ghosh (2003). Similar significant effect of FYM and bio fertilizers on plant height in sorghum was reported by Parasuraman *et al*., (2000).

Nitrogen as an essential component of plant cells plays a crucial role in various physiological processes such as cell division, cell elongation and chlorophyll synthesis ultimately leading to improved growth attributes reported by Umesh *et al*., (2006). These results are consistent with the findings of Thesiya *et al*., (2019), Thimmaiah *et al*., (2016) and Shubha shree *et al*., (2017).

Leaf Area (cm^2 hill^{-1})

The data relating to leaf area of finger millet as influenced by establishment methods and nutrient management practices at various crop growth stages are presented in Table 1.

Sowing methods

The leaf area (cm^2) of finger millet was significantly affected by the methods of crop establishment at all growth stages, except at 30 DAS. At 60 DAS, the transplanting method (S2) showed significantly larger leaf area (884.70 cm^2) compared to the direct sowing method (S1). Similarly, at 90 DAS, the transplanting method (S2) recorded significantly higher leaf area (1593.34 cm^2) than the direct sowing method (S1). However, at the time of harvest, the higher leaf area (846.80 cm^2) was observed in the transplanting method (S2) and this value was statistically superior to the direct sowing method (S1).

Among the methods, the transplanting method (S2) consistently recorded the highest leaf area per plant, particularly at 60, 90 DAS and at harvest. This superiority could be attributed due to better seedling vigor, stronger root development and improved nutrient and water uptake in transplanted plants. The increased root surface area in transplanting supports more efficient nutrient absorption, resulted in better vegetative growth and larger leaf area development reported by Newase *et al*., (1995). Similar results were consistent with Thavaprakash *et al*., (2008) and hebbal *et al*., (2018).

Nutrient management practices

The leaf area of finger millet is significantly influenced by nutrient management practices.

Leaf area at 30 DAS was significantly affected by nutrient management practices. The maximum leaf area (579.01 cm^2) was recorded with the application of S5-100% RDN + FYM @ 7.5 tonne ha^{-1} + Biofertilizer (Azospirillum), which was significantly superior over other treatments. The minimum leaf area (254.17 cm^2) was observed in the control (S1). Leaf area at 60 DAS, by the application of 100% RDN + FYM @ 7.5 tones ha^{-1} + Biofertilizer (Azospirillum) (S5) recorded the highest leaf area (961.50 cm^2), which was significantly superior over other treatments. The lowest leaf area (675.43 cm^2) was observed in the control (S1). Leaf area at 90 DAS, by the application of 100% RDN along with FYM at 7.5 tones ha^{-1} and Biofertilizer (Azospirillum) (S5) resulted in the highest leaf area of (1685.28 cm^2). This was significantly better than all other organic and inorganic treatment combinations. The lowest leaf area (1175.78 cm^2) was observed in the control (S1). At the harvest stage, the highest leaf area (915.92 cm^2) was recorded with the application of 100% RDN + FYM @ 7.5 tonne ha^{-1} + Biofertilizer (Azospirillum) (S5). This treatment was significantly better than all other organic and inorganic combinations. The next best was observed in S3-100% RDN + FYM @ 7.5 tonne ha^{-1}, which recorded leaf area of 879.82 cm^2. The lowest leaf area (670.31 cm^2) was observed in the control (S1). Highest leaf area was consistently recorded under the S5 treatment with 100% RDN + FYM @ 7.5 tones ha^{-1} + Biofertilizer (Azospirillum) at all critical crop growth stages.

Because of organic and in organic combination fertilizers improves soil structure, water-holding capacity, supplies micronutrients and promotes root development enhancing vegetative growth. 100% RDN ensures a sufficient supply of nitrogen, a critical element for leaf growth and chlorophyll formation. These findings are consistent with the results reported by Senthamil and Tamil mounika (2023), Udapudi *et al*., (2024) and Reddy *et al*., (2018).

Dry matter production

The data pertaining to dry matter production of finger millet as influenced by establishment methods and nutrient management practices at various crop growth stages are presented in Table 1.

Sowing methods

The dry matter production (g/m^2) of finger millet was noticeably affected by the method of crop establishment at all growth stages, except at 30 DAS. At 60 DAS, the transplanting method (S2) produced the highest dry matter (270.53 g/m^2), which was significantly better than the direct sowing method. Similarly, at 90 DAS, the transplanting method again recorded the highest dry matter production (582.75 g/m^2), clearly prevailed over direct sowing. At harvest stage, transplanting resulted in the highest dry matter production (617.24 g/m^2), compared to 552.60 g/m^2 from direct sowing method.

The transplanting method recorded higher dry matter production compared to direct method of sowing, because the transplanting method plants developed more fibrous roots and these roots absorbed more nutrients from the soil, leading to greater dry matter production. The higher dry matter could be due to improved growth of plant parts (morphological traits), which boosted the plant's ability to carry out photosynthesis, resulted in higher overall plant growth or biological yield. Similar studies were reported by Newase *et al.*, (1995) that higher dry matter and grain yield in finger millet (ragi) using the transplanting method and Singh and Singh (2006) and Jagtap (2010) found similar results in rice.

Nutrient management practices

The dry matter production (g/m^2) of finger millet was significantly influenced by nutrient management practices.

Dry matter production at 30 DAS was significantly affected by nutrient management practices. The maximum dry matter production (47.60 gm/m²) was recorded with the application of S5-100% RDN + FYM @ 7.5 tonne ha^{-1} + Biofertilizer (Azospirillum), which was significantly superior over other treatments. The minimum dry matter production (29.73g/m²) was observed in the control (S1). Dry matter production at 60 DAS, showed that application of 100% RDN along with FYM at 7.5 tonne ha^{-1} and Biofertilizer (Azospirillum) (S5) resulted in the higher dry matter production of (304.83g/m²). This was significantly better than all other organic and inorganic treatment combinations. The second best result was from the treatment with 100% RDN + FYM @ 7.5 tonne ha^{-1} (S3), which recorded the dry matter production with 273.25 gm/m². The lowest dry matter production (156.90 gm/m²) was observed in the control (S1). Dry matter production at 90 DAS was significantly affected by nutrient management practices. The maximum dry matter production (608.23 gm/m²) was recorded with the application of 100% RDN + FYM @ 7.5 tonnes ha^{-1} + Biofertilizer (Azospirillum), which was significantly superior over other organic and inorganic treatments. The minimum dry matter production (474.90 g/m²) was observed in the control (S1).

Dry matter production at harvest stage, by the application of 100% recommended nitrogen (RDN) along with farmyard manure (FYM) at 7.5 tonne ha^{-1} and Azospirillum biofertilizer (S5) obtained higher dry matter production (651.05 g/m²). This was better than all other treatments. The lowest dry matter production (506.35 g/m²) was recorded in the control (S1).

The higher total dry matter accumulation at all growth stages with the treatment of 100% recommended nitrogen (RDN), farmyard manure (FYM) at 7.5tones ha^{-1} and Azospirillum (S5) may be due to better nutrient availability. This promoted more tillering and overall plant growth, leading to increased dry matter. This treatment improves soil health by enhancing its physical and biological properties and provides almost all the essential nutrients needed for plant growth. The balanced supply of macro and micronutrients from FYM and Azospirillum, especially under favorable conditions, likely supported better nutrient uptake. This in turn, boosted the formation of new tissues and shoots, resulted in greater total dry matter accumulation. These findings were agreed with the results reported by Thakral *et al*., (2000), Yadav and Beniwal (2003) in pearl millet.

This might be due to the favorable effects of FYM in conjunction with fertilizers on growth and yield parameters which resulted in more dry matter yield and consequently more utilization of nutrients by the crop. These findings are in close conformity with those of Singh and Singh (2005) and Kushwaha *et al*., (2014).

Total Number of tillers per m^{-2}

The data pertaining to Number of tillers m^{-2} of finger millet as influenced by establishment methods and nutrient management practices at various crop growth stages are presented

Sowing methods

At 30 DAS, the highest number of tillers m^{-2} was formed with direct sowing method (35.10 tillers m^{-2}) and it was noticeably larger than transplanting method (29.04 tillers m^{-2}). However, at 60 DAS, the highest number of tillers m^{-2} (84.78 tillers m^{-2}) was recorded with transplanting method over direct sowing method. Further, the lowest (73.45 tillers m^{-2}) was observed with (Direct line sowing) method of establishment. Correspondingly, at 90 DAS the same trend as that of 60 DAS was noticed with highest number of tillers m^{-2} (102.49 tillers m^{-2}) with Transplanting method and the lowest (88.92 tillers m^{-2}) no. of tillers was recorded with Direct sowing method.

In early stages, more no of tillers m^{-2} was observed in direct sowing method significantly higher than transplanting method. After 60 DAS, 90DAS more no of tillers m^{-2} were observed in transplanting method compared to direct sowing method because of better spacing, root development and nutrient uptake of plants. These results are similar with Thakur *et al*., (2016) and Hebbal *et al.,* (2018)

Nutrient management practices

The no of tillers per m^2 of finger millet is significantly influenced by nutrient management practices

At 30 DAS, significantly higher number of tillers m^{-2} were recorded with S5-100% RDN + FYM @ 7.5 tonne ha^{-1} + Biofertilizer (Azospirillum) (S5) (39.33) which was significantly superior over other organic and inorganic treatments. While the minimum number of tillers m^{-2} was recorded with Control (21.77). At 60 DAS, 100% RDN + FYM @ 7.5 tonne ha^{-1} + Biofertilizer (Azospirillum) (S_5) (93.55) recorded maximum number of tillers m^{-2} which was significantly superior to other combinations of organic and inorganic treatments. The lowest total number of tillers m^{-2} were recorded with control (S1) (58.64) at 90 DAS the higher no of tillers m^{-2} was resulted with 100% RDN + FYM @ 7.5 tone ha^{-1} + Biofertilizer (Azospirillum) (S5) (112.17) which was significantly superior over other organic and inorganic treatments. The smaller number of tillers m^{-2} at harvest were observed with control (S1) (73.62).

Total no of tillers m^{-2} of finger millet was recorded with 100% RDN + FYM @ 7.5 tone ha^{-1} + Biofertilizer (Azospirillum) (S5) at all crop growth stages. Organic manures had a major role in supply of all vital nutrients required by plants and nitrogen is known to help increase the number of tillers. In the present study, using both manures and fertilizers together improved plant growth better than using either manures or fertilizers alone these results similar with the findings of Thumar *et al.,* (2016), Husain *et al*., (2017) and Monisha *et al., (*2019).

Conclusion

Based on the present investigation, kharif finger millet established through transplanting and supplemented with 100% RDN along with FYM @ 7.5 t ha^{-1} and Azospirillum (S5) recorded significant improvement in growth attributes. This integrated nutrient management practice enhanced plant vigor, ensured efficient nutrient uptake and contributed to superior crop establishment and development.

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