



Optimizing Planting Geometry and Nutrient Management for Enhanced Growth and Yield of Teff (*Eragrostis tef* (Zucc.) Trotter) in Eastern Dry Zone of Karnataka

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Abstract: Teff (*Eragrostis tef* (Zucc.) Trotter) is an introduced minor millet therefore, among prime areas of research is developing standard agro-techniques for higher productivity. Field experiment was conducted on optimizing planting geometry and nutrient management for enhanced growth and yield of teff during *kharif*-2021 at UAS, GKVK, Bengaluru in factorial randomized block design with ten treatment combinations consisting two planting geometry (30 cm × 10 cm and 45 cm × 10 cm) and five nutrient management (50, 75, 100 and 125 % recommended dose of fertilizers, (RDF) and absolute control). As per UAS, Bengaluru package of practices, RDF is 20 N: 20 P₂O₅: 20 K₂O and FYM @ 6 t ha⁻¹. Growth and yield parameters significantly varied with the treatments. Maintaining 30 cm × 10 cm spacing recorded significantly higher plant height (74.79 cm, 93.57 cm at 60 DAP and at harvest respectively), lodging (56.39%), grain yield (2.37 q ha⁻¹) and straw yield (3.65 q ha⁻¹). Application of 125 % RDF resulted in significantly higher plant height (80.05 and 99.33 cm) and number of tillers (16.45 and 23.07 per plant⁻¹) at 60 DAP and harvest respectively. However, significantly higher grain yield (2.73 q ha⁻¹) was at 100 % recommended dose of fertilizers

Keywords: *Eragrostis tef* (Zucc.) Trotter, Teff, Nutrient management, Planting geometry

Minor/small millets are the best examples of underutilized crops gaining more importance in recent days due to climatic smartness, nutritional richness, health benefits, low risk in production and lower production cost. Karnataka is majorly known for millet cultivation in India, primarily with respect to finger millet and foxtail millet among the other states. Nowadays farmers are much concerned in commercial agriculture and are replacing sustainable crops with cash crops, hence, the area under millets is declining day by day (Durgad et al 2019). Teff (*Eragrostis tef* (Zucc.) Trotter) is an introduced minor millet originated and diversified in Ethiopia and cultivated on an area of 3.01 m ha, with an annual production of 5.01 m t and productivity of 1.664 t ha⁻¹ in Ethiopia (Lee, 2018). Simultaneously, interests in teff cultivation are spreading to other parts of the world viz., Australia, Canada, Cameroon, China, India, South Africa, The Netherlands, UK, Uganda, and the USA. Though teff grass is a boon to Indian farmers, little is known about its cultivation, production, and value addition. The limitations comprise lack of improved varieties, lodging of the crop at later stages of crop growth, lack of mechanization, lack of awareness, and the standard package of practice (agro-techniques). Premier areas of research are need of the hour to promote this crop at the global level. The standard agro techniques viz., planting method, plant geometry, nutrient

management, weed management, pest management, and reduction in post-harvest losses must be intended at reducing the loss in the output. Among these agro techniques, planting geometry and nutrient management play a vital role in increasing yield levels of teff crop as they ensure optimum plant population and ensures an adequate supply of nutrition to the plants. Row spacing is the key component in maximizing crop yield through optimizing plant population, improving light availability, and reducing weed competition. Therefore, it is of principal importance to develop and recommend suitable row spacing for maximizing teff production (Mihretie et al 2020). Dryland soils are 'not only thirsty but hungry too' and will make it mandatory to supply nutrients through external sources viz., organic and inorganic fertilizers, these nutrients are to be applied wisely to achieve maximum yield potentiality of the crop with the least losses. The modern agronomic practices and technologies have the potential to substantially enhance teff productivity to ensure food security. The experiment was conducted with the objectives to study the effect of two levels of rows spacing, five levels of fertilizer rates and their interaction on growth parameters, yield components and yield.

MATERIAL AND METHODS

Field experiment was conducted during *Kharif* season of

2021 at Zonal Agricultural Research Station (ZARS), Gandhi Krishi Vignana Kendra, University of Agricultural Sciences, Bengaluru which comes under Eastern Dry Zone (Zone-5) of Karnataka. The geographical reference point of the experimental site was 13° 05' North latitude and 77° 34' East longitude and at an altitude of 924 m above mean sea level. The soil was red sandy loam in texture consisting of 53.6 per cent coarse sand, 14.7 per cent fine sand, 14.9 per cent silt and 14.8 per cent clay. The soil was acidic (6.85 pH) in reaction with an electrical conductivity of 0.40 dS m⁻¹, low organic carbon (0.42 %) and medium in available nitrogen (315.2 kg ha⁻¹), phosphorous (28.1 kg ha⁻¹) and potassium (281.3 kg ha⁻¹). During the crop season from August to November, a total of 881.2 mm of rainfall was recorded. The experiment was laid out in factorial randomized block design with ten treatment combinations and replicated three times. Treatments consisting of two factors planting geometry (S₁: 30 cm × 10 cm and S₂: 45 cm × 10 cm) and five nutrient management N₁: 50 % recommended dose of fertilizers (RDF), N₂: 75 %, N₃: 100 %, N₄: 125 % RDF and N₅ (absolute control). Farm yard manure was applied @ 6 t ha⁻¹ commonly to all the treatments except absolute control. In this experiment, as per the UAS, Bengaluru package of practices, RDF of little millet (20 N: 20 P₂O₅: 20 K₂O and FYM @ 6 t ha⁻¹) was taken as base for determining fertilizer application rates in teff as teff morphology is much more similar to that of little millet compared to other millets. Brown seeded type teff was used for sowing. The gross plot size was 4.5 m × 3.0 m and net plot size was 3.9 m × 2.8 m (30 cm × 10 cm), 2.6 m × 2.8 m (45 cm × 10 cm) and treatments were allocated randomly in the plots within the blocks. Recommended dose of fertilizers and farm yard manure were applied at the time of sowing. Periodical observations were taken on growth parameters at 30, 60 DAP and at harvest where, five plants were selected randomly from each net plot and tagged with a label for recording various biometric observations on growth and yield parameters. Crop was harvested at 110 DAS, threshed and yield of the individual plots recorded separately and expressed in terms of per hectare. Lodging percentage was calculated by using formula:

$$\text{Lodging (\%)} = \frac{\text{Number of lodged effective tillers}}{\text{Total number of effective tillers}} \times 100$$

Statistical analysis: The data recorded on growth and yield parameters were subjected to Fisher's method analysis of variance using FRBD in MS excel.

RESULTS AND DISCUSSION

Growth Attributes

Plant height and number of tillers: Plant height was

superior under 30 cm × 10 cm (74.79 and 93.57 cm, respectively) at 60 days after planting and at harvest. It could be attributed to the fact that higher plant population would certainly reduce the amount of light availability to the individual plant, particularly to lower leaves due to greater shading. As the mutual shading increases at higher plant densities, the plant tends to grow taller. Due to the elongation of internodes in narrow spacing leads to increase in plant height. Similar findings were reported by Huli halli and Shantveerayya (2018) in buckwheat genotypes. Significantly higher plant height at 60 DAP (80.05 cm) at harvest (99.33 cm) was under application of 125 per cent RDF due to increased availability of soil nitrogen which leads to improved meristematic activity in terms of increased cell enlargement and elongation. Greater cell elongation resulted in increased plant height. Comparable findings were also described by Prakasha et al (2018). The number of tillers increased with age of the plant, at slower rate during early stages and at rapid rate up to 60 DAP and very few tillers were produced at later stage of plant growth. Wider spacing of teff produced significantly greater number of tillers per plant (14.76 and 20.34 plant⁻¹) at 60 DAP and at harvest respectively, as the individual plants could have effectively utilized the available resources such as space, foraging area for root system, light utilization etc. and thus enhanced the tiller production at wider spaced treatment. Similarly increased number of tillers plant under wider spacing was documented by Kumari et al (2015). Application of 125 per cent RDF resulted in significantly more tillers per plant at 60 and 90 DAP (16.45 and 23.07, respectively) among all the nutrient levels. This indicates that fertilization encouraged tiller formation in the crop due to increased uptake of available form of major nutrients present in the soil under increased fertilizer application. Parallel findings were reported by Kumari et al (2015).

Leaf area and Dry matter production: The wider spacing of 45 cm × 10 cm resulted in larger leaf area at 60 days after planting and at harvest (5.93 and 6.10 cm² plant⁻¹ respectively) encouraging better nutrient availability and reducing competition for growth promoting factors (Table 1). Wider spacing also favoured higher dry matter production (4.17 and 29.46 g plant⁻¹) at 60 DAP and harvest, attributed to increased tillers and better assimilating area (LAI). Improvement of LAI might have increased the radiation use efficiency and photosynthetic efficiency of crop and have induced to produce more DMP per plant under wider spacing. Application of 125 RDF significantly increased leaf area (6.85 and 7.12 cm² plant⁻¹) and dry matter (4.95 and 35.46 g plant⁻¹) at 60 DAP and harvest, respectively. This higher RDF provided more available nitrogen, phosphorus and

potassium leading to rapid cell division and leaf expansion, reflected in terms of increased leaf area is similar to the findings in finger millet by Veeresh and Ramachandrapa (2016) and Hebbal et al (2018). Also, the adequate nutrient supply enhanced root development, photosynthetic rate, and carbohydrate utilization for more dry matter accumulation as reported by Charate et al (2018).

Lodging: Significantly higher lodging (56.39 %) was observed under narrow spacing of 30 cm × 10 cm (Table 2) which was due to competition for light under narrow spacing to utilize more incoming solar radiation which made the stem lean and when the plant grows taller, the nodes near the ground are unable to keep higher above ground biomass which resulted in greater lodging of teff. Similarly, with increased nitrogen application, the plant height was increased linearly and lean stems became more succulent

and were unable to keep the plant in upright position. Due to this, lodging per cent was significantly higher under application of 125 per cent RDF than other lower nitrogen treatments. In contrary, under absolute control plants were short and stems were strong due to lack of sufficient nitrogen availability. Hence lodging per cent was least (39.89) in absolute control at harvest. Similar trend was observed by Mahantesh (2020).

Yield Attributes and Teff Yield

Number of productive tillers: Narrow spacing (30 cm × 10 cm) resulted in significantly a greater number of effective tillers (428.16 m⁻²) compared to wider spacing of 45 cm × 10 cm (383.07 m⁻²). Under wider spacing in spite of higher number of the tillers per plant, the number of productive tillers per unit area were less due to lower plant density. Significantly greater number of effective tillers were under

Table 1. Effect of planting geometry and nutrient management on growth parameters of teff

Treatments	Plant height (cm)		Number of tillers plant ⁻¹		Leaf area (cm ² plant ⁻¹)		Dry matter (g plant ⁻¹)	
	60 DAP	At harvest	60 DAP	At harvest	60 DAP	At harvest	60 DAP	At harvest
Factor 1: Planting geometry (S)								
S ₁ : 30 cm × 10 cm	74.79	93.57	12.95	18.13	5.45	5.62	3.92	27.61
S ₂ : 45 cm × 10 cm	63.92	86.20	14.76	20.34	5.93	6.10	4.17	29.46
CD (p = 0.05)	10.86	7.24	0.51	0.47	0.18	0.11	0.15	0.70
Factor 2: Nutrient levels (N)								
N ₁ : 50 % RDF (10:10:10)	66.98	86.75	12.74	17.91	5.10	5.16	3.53	26.10
N ₂ : 75 % RDF (15:15:15)	67.65	88.00	14.02	19.33	5.70	5.89	4.06	28.28
N ₃ : 100 % RDF (20:20:20)	78.23	95.33	15.65	21.03	6.23	6.61	4.38	32.02
N ₄ : 125 % RDF (25:25:25)	80.05	99.33	16.45	23.07	6.85	7.12	4.95	35.46
N ₅ : Absolute control	53.87	80.00	10.40	14.83	4.57	4.54	3.33	20.83
CD (p = 0.05)	17.17	11.44	0.81	0.74	0.28	0.17	0.23	1.11

Table 2. Effect of planting geometry and nutrient management on Lodging, yield parameters and yield of teff

Treatments	Lodging (%)	Productive tillers (m ⁻²)	Grain weight (g ear ⁻¹)	Grain yield (q ha ⁻¹)	Straw yield (q ha ⁻¹)
Factor 1: Planting geometry (S)					
S ₁ : 30 cm × 10 cm	56.39	428.16	0.287	2.37	3.65
S ₂ : 45 cm × 10 cm	52.97	383.07	0.296	2.04	3.34
CD (p = 0.05)	2.55	44.74	0.007	0.30	0.11
Factor 2: Nutrient levels (N)					
N ₁ : 50 % RDF (10:10:10)	44.84	385.50	0.277	1.90	2.88
N ₂ : 75 % RDF (15:15:15)	55.37	423.17	0.290	2.23	3.47
N ₃ : 100 % RDF (20:20:20)	62.60	485.41	0.314	2.73	4.08
N ₄ : 125 % RDF (25:25:25)	70.69	425.00	0.305	2.45	4.36
N ₅ : Absolute control	39.89	309.00	0.270	1.74	2.66
CD (p = 0.05)	4.03	70.74	0.012	0.48	0.18

application of 100 per cent RDF (485.41 m²), however, it was on par with application of 125 and 75 per cent RDF due to higher number of tillers per plant that were erect enough to produce harvestable panicles. On the contrary, with increased nitrogen application the plants were much prone to lodging prior to panicle initiation itself, resulting in higher number of non-panicle bearing tillers.

Grain weight per ear: Wider spacing resulted in significantly higher grain weight per ear (0.296 g) compared to narrow spacing (0.287 g) which is mainly attributed to greater efficiency of the plants through nutrient absorption, photosynthetic activity and photosynthates translocation within the plants under leisure availability of growth resources in a wide spaced environment. Significantly higher grain weight per ear was observed under application of 100 per cent RDF (0.314 g) and was on par with application 125 per cent RDF (0.305 g). This is mainly attributed to the poor panicle initiation at higher nutrient application due to lodging of crop. There was poor photosynthate formation and supply to economic parts under lower nutrient supply levels and under absolute control. Balappa (2021) also observed similar trend.

Grain yield and straw yield: Among different planting geometry, significantly higher (2.37 q ha⁻¹) grain yield was attained under the narrow spacing of 30 cm × 10 cm compared to wider spacing (2.04 q ha⁻¹) of 45 cm × 10 cm. The higher grain yield in narrow spacing might be due to enhanced yield attributes, thus forming larger sink size coupled with efficient translocation of photosynthates to the sink. Simultaneously, due to higher plant population under closer spacing at 30 cm × 10 cm might have contributed to maximum dry matter production per unit area which ultimately enhanced the straw yield. Similar trend was observed by Thakur *et al* (2019). Grain yield was significantly higher under application of 100 per cent RDF (2.73 q ha⁻¹) as lodging was observed before grain filling stage under 125 per cent RDF causing severe yield reduction in teff. However, under application of 100 per cent RDF it was observed immediately after grain filling stage which has reduced impact on development of panicles. Unlike grain yield, the treatment supplied with highest fertilizers *i.e.*, 125 per cent RDF resulted in statistically higher straw yield (4.36 q ha⁻¹) due to a more effective photosynthetic structure that allowed for more photosynthates to be synthesized, accumulated, partitioned and translocated to different regions of the plant. The crop was able to grow and develop more effectively reflecting in higher straw yield. Shankar (2017) and Ambresha (2017) also found similar results in little and foxtail millet respectively. However, the influence was non-significant with respect to interaction of different planting geometry and nutrient management.

CONCLUSION

Maintaining narrow spacing of 30 cm × 10 cm allows efficient utilization of growth factors ultimately leading to improved growth and development of teff crop than wider spacing. Among varied nutrient levels, supply of 100 % RDF (20 N: 20 P₂O₅: 20 K₂O) along with farm yard manure @ 6 t ha⁻¹ results in statistically higher yield of teff crop. Further, increase in fertilizer levels is not recommended as it leads to greater lodging of the crop because of lean and long nature of the stem which cannot support the higher shoot biomass.

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