# Investigating Different Planting Geometry and Nutrient Management to Enhance Teff Productivity in eastern dry zone of Karnataka, India

## ABSTRACT

A field experiment was conducted at Zonal Agricultural Research Station (ZARS), Gandhi Krishi Vignana Kendra, University of Agricultural Sciences, Bangalore, Karnataka on red sandy loam soil to study the "Investigating different planting geometry and nutrient management to enhance teff productivity". The experiment was laid out in Factorial Randomized Complete Block Design, consisting two factors *viz.*, Factor 1: Two planting geometry ($S_1$: 30 cm × 10 cm and $S_2$: 45 cm × 10 cm) and Factor 2: Five Nutrient management ($N_1$: 50 % RDF, $N_2$: 75 % RDF, $N_3$: 100 % RDF, $N_4$: 125 % RDF and $N_5$: Absolute control (6 t FYM ha$^{-1}$ commonly applied to all except control treatments) and replicated thrice. The uptake of nitrogen, phosphorus and potassium was higher under 30 cm × 10 cm spacing (5.74, 1.04 and 3.29 kg ha$^{-1}$, respectively) and among nutrient levels, application of 125 per cent RDFresulted in statistically higher uptake nitrogen (7.35 kg ha$^{-1}$), phosphorous (1.33 kg ha$^{-1}$) and potassium (4.28 kg ha$^{-1}$).Significantly higher (12.58 %) grain protein content was obtained with application of 125% RDF.Maintaining 30 cm × 10 cm spacing recorded significantly higher grain (2.37 q ha$^{-1}$) and straw yield (3.65 q ha$^{-1}$). Application of 125 % RDF resulted in significantly higher straw yield, however significantly higher grain yield (2.73 q ha$^{-1}$) was obtained under 100 % RDF.Application of 100% RDF along with narrow spacing yielding substantially higher gross returns (₹90,776 ha$^{-1}$), net returns (₹60,021 ha$^{-1}$), and a commendable B:C ratio of 2.77.

*Key words:*Planting geometry, Protein, Nutrient uptake, Teff

## 1. INTRODUCTION

Teff (*Eragrostis tef*) is an introduced minor millet belonging to the family of Poaceae, with diploid chromosome number, 2n = 40. It originated and diversified in Ethiopia [1]. Teff is known asWilliams love grass, teffa, and annual bunch grassin different parts of the world. Teff can grow under diverse climatic conditions, with an annual rainfall ranging from 450 to 550 mm and a daily temperature of 15 to 27 $^0$C [2].Teff can be sown during both *Kharif* (June- July) and *Rabi* (October- November) seasons and is most suitable for drier zones as it is a drought tolerant ($C_4$ photosynthesis mechanism) crop that requires a minimum level of water to grow. In Ethiopia, three major types can be recognized; white (nech), red (quey), and mixed (sergegna). White teff is majorly preferred by the higher-class people over red (brown) teff. White teff grows only in the Ethiopian highlands and needs better favorable conditions for growth and development. However, recently, red teff, which is more nutritious, is gaining popularity among health-conscious consumers in Ethiopia. Concurrently, 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.Teff is “gluten-free”, which is responsible for “celiac disease” (damage of the small intestine’s lining due to inflammation). Celiac disease predominates in western countries, due to the continuous consumption of wheat and its products by the people. Hence, teff can substitute wheat to overcome this disease. Its flour is primarily used to make a fermented, sourdough type, flat bread called “*Injera*”.

The Central Food and Technological Research Institute (CFTRI), Mysore introduced the teff crop to India. Presently, teff is cultivated on a few hundred hectares in Karnataka around Mysore, Sirsi (Uttar Kannada), Haveri, Gadag, and Raichur districts. The very peculiar characteristics of teff *viz.*, drought resistance, short duration, wider adaptability, storability and seed viability for a longer duration, and possessing few or no diseases and pests, make it a boon for farmers under dry zones of Southern Karnataka. Since teff is an introduced crop and no standard package of practice is available for its cultivation in India therefore, premier areas of research are need of the hour to promote this crop at the global level. Among the standard 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.Research results revealed that row spacing the key component in maximizing crop yield through optimizing plant population, improving light availability, and reducing weed competition. Therefore, it is of paramount importance to develop and recommend appropriate row spacing for maximizing teff production [3].The decline in soil fertility is the major constraint in agricultural production and food security in farming systems which demands external application of organic and inorganic fertilizers and these nutrients are to be applied wisely to achieve maximum yield potentiality of the crop with the least losses. 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 nutrientuptake, quality and yield.

## 2. MATERIALS AND METHODS

A field experiment was conducted during *Kharif*-2021 at Zonal Agricultural Research Station (ZARS), Gandhi Krishi Vignana Kendra, University of Agricultural Sciences, Bengaluru. It is situated at 13º 05’ N latitude and 77º 34’ E longitude and at an altitude of 924 m above mean sea level which comes under Eastern Dry Zone (ACZ-5) of Karnataka. During the crop season from August to November, a total of 881.2 mm of rainfall was recorded. In this experiment, the RDF of little millet (20 N: 20 $P_2O_5$: 20 $K_2O$ 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 as compared to other millets. The experiment was laid out in Factorial Randomized Block Design, consisting two factors *viz.*, Factor 1: Two planting geometry ($S_1$: 30 cm × 10 cm and $S_2$: 45 cm × 10 cm) and Factor 2: Five Nutrient management ($N_1$: 50 % RDF, $N_2$: 75 % RDF, $N_3$: 100 % RDF, $N_4$: 125 % RDF and $N_5$: Absolute control, replicated thrice (RDF=20 N: 20 $P_2O_5$: 20 $K_2O$ and FYM @ 6 t $ha^{-1}$). Brown seeded type teff was used for sowing @ 50 g $ha^{-1}$ for transplanting.Recommended dose of fertilizers and farm yard manure @ 6 t $ha^{-1}$ was applied at the time of sowing common to all the treatments except control. Periodical observations were taken on growth parameters at 30, 60 DAP and at harvest. 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.Treatment wise 500 g of seed and plant samples were collected after harvest of the crop and each sample was dried under shade then in a hot air oven at 65°C. Dried samples were grounded to considerable fineness and these grounded seed and plant samples were used for the estimation of N, P and K uptake by the plant is calculated by the uptake formulae.The uptake of nutrients by teff crop was worked out by multiplying the nutrient content and dry matter yield of the plant as given below. Also, nitrogen content was multiplied with factor 6.25 to calculate protein content.

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\%\ \text{Nutrient content} \times \text{Total biomass yield (kg ha}^{-1}\text{)}}{100}$$

***Biochemical analysis***

*Total protein* (%) = % N × 6.25

*Crude fibre*

Crude fibre content in whole plant was estimated by acid-alkali digestion method and was expressed in percentage.

$$\text{CF (\%)} = \frac{\text{(Weight before ashing)} - \text{(Weight after ashing)}}{\text{Weight of the sample taken}} \times 100$$

*Carbohydrate*

Carbohydrate content was calculated by differential method A.O.A.C [4],*i.e*deducting the sum of the value for moisture, crude protein, crude fat and total mineral from 100 for total carbohydrate.

Carbohydrate (g/100 g) = 100-[Protein (g) + Fat (g) + Fiber (g) + Ash (g) + Moisture (g)]

The data recorded on growth and yield parameters were subjected to Fisher's method analysis of variance using FRBD design given by Gomez and Gomez [5] in MS excel. The level of significance used in 'F' and 't' test was P = 0.05. Whenever F-test was significant for comparison amongst the treatments means an appropriate value of critical differences (CD) was worked out. Otherwise against CD values abbreviation NS (Non-Significant) was indicated.

## 3. RESULTS AND DISCUSSION

### NUTRIENT UPTAKE

Data from the table 1 clearly indicates that, the uptake of nitrogen, phosphorus and potassium was higher under 30 cm × 10 cm spacing (5.74, 1.04 and 3.29 kg $ha^{-1}$, respectively) due to higher plant density and higher dry matter production per unit area,in spite the uptake of nutrients per plant was higher under wider spacing. These results are in close conformity with the findings of Jogi Naidu *et* *al.*[6].Significantly higher uptake of nutrients *viz.*, nitrogen (7.35 kg ha$^{-1}$), phosphorous (1.33 kg ha$^{-1}$) and potassium (4.28 kg ha$^{-1}$) were recorded under application of 125 per cent RDF. This is attributed to the fact that sufficient availability ofnutrients in soil solution and also in the rhizosphere ultimately helped the plants to uptake more nutrients. These findings were in line with the results Saraswati *et al.*[7].

## AVAILABLE NUTRIENTS

Available nutrients in soil after harvest of the teff crop was varied significantly due to different planting geometry and varied nutrient levels. Wider spacing of 45 cm × 10 cm resulted in significantly higher available N, $P_2O_5$ and $K_2O$ (168.04, 25.74 and 126.35 kg ha$^{-1}$, respectively) status of soil after harvest of crop as compared to narrow spacing of 30 cm × 10 cm. This was attributed to the fact that greater plant population under 30 cm × 10 cm spacing leads to higher nutrient extraction from the soil to feed the higher plant biomass per unit area leading to decreased soil nutrient status. These results are in close conformity with the findings of Balappa[8] in teff.When higher fertilizer levels (125 % RDF)

**Table 1. Effect of planting geometry and nutrient management on nutrient uptake and availability after harvest of teff**

| Treatments | Nutrient uptake (kg ha$^{-1}$) | | | Available nutrients (kg ha$^{-1}$) | | |
|---|---|---|---|---|---|---|
| | Nitrogen | Phosphorous | Potassium | Nitrogen | Phosphorous | Potassium |
| **Factor 1: Planting geometry (S)** | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| **$S_1$:** 30 cm × 10 cm | 5.74 | 1.04 | 3.29 | 161.46 | 23.85 | 118.61 |
| **$S_2$:** 45 cm × 10 cm | 5.51 | 0.94 | 3.21 | 168.04 | 25.74 | 126.35 |
| S. Em. ± | 0.07 | 0.01 | 0.03 | 1.93 | 0.39 | 0.96 |
| C.D. (P = 0.05) | 0.21 | 0.02 | 0.08 | 5.75 | 1.15 | 2.86 |
| **Factor 2: Nutrient levels (N)** | | | | | | |
| **$N_1$:** 50 % RDF | 4.90 | 0.79 | 2.65 | 146.24 | 19.45 | 111.54 |
| **$N_2$:** 75 % RDF | 5.60 | 1.02 | 3.24 | 160.72 | 25.48 | 121.34 |
| **$N_3$:** 100 % RDF | 6.31 | 1.18 | 3.66 | 183.27 | 29.10 | 132.16 |
| **$N_4$:** 125 % RDF | 7.35 | 1.33 | 4.28 | 202.71 | 34.84 | 150.64 |
| **$N_5$:** Absolute control | 3.97 | 0.63 | 2.44 | 130.81 | 15.10 | 96.72 |
| S. Em. ± | 0.11 | 0.01 | 0.04 | 3.06 | 0.61 | 1.52 |
| C.D. (P = 0.05) | 0.33 | 0.04 | 0.12 | 9.08 | 1.82 | 4.53 |

were applied, higher levels of available nitrogen (202.71 kg ha$^{-1}$), phosphorus (34.84 kg ha$^{-1}$), and potassium (150.64 kg ha$^{-1}$) were observed as compared with other treatments and absolute control which is mainly attributed to increased nutrient availability in soil. Ambresha and Shankar [9-10]achieved similar results in foxtail millet and little millet, respectively on *Alfisol*.

## BIOCHEMICAL ANALYSIS

Nitrogen and phosphorous are indispensable constituents of cell organelles and hence helps in forming better cell infrastructure. Potassium is not a constituent of cells; it remains as free mineral content in cell organelles. These nutrients are absorbed by the roots and play vital role in metabolic activities occurring in the shoot with significance on quality of the produce.

### *CRUDE PROTEIN*

The data pertaining to grain protein content is presented in table 2.There was no significant difference between different planting geometry however, significantlyhigher grain protein content was attained with supply of 125 per cent RDF(12.58 %), which was on par with 100 per cent RDF(12.25 %). The positive relation between applied nitrogen and grain protein content mainly owes to the fact that nitrogen is the basic structural component of amino acids. Production of more amino acids in turn results in production of more protein content in grains. Raghavendra and Halikatti, Jadhav *et al*. and Mahantesh [11-13]observed similar results in different millets and protein content in grains varied non-significantly with respect to interaction effect.

**Table 2. Effect of planting geometry and nutrient management on biochemical parameters and economics of teff**

### *CARBOHYDRATE AND CRUDE FIBRE*

Grain carbohydrate and crude fibre content were varied non significantly with increasing fertilizer levels irrespective of the planting geometry.However, numerically higher carbohydrate (73.25 g 100$^{-1}$) and lower crude fibre (3.06%)was observed under narrow spacing. Among different nutrient management the treatment with no fertilizer application (Absolute control) has shown numerically higher carbohydrate (73.65 g 100 g$^{-1}$) and crude fibre content(3.10%). Interaction effect remained non-significant with respect to carbohydrate and crude fibre content.

### ECONOMICS

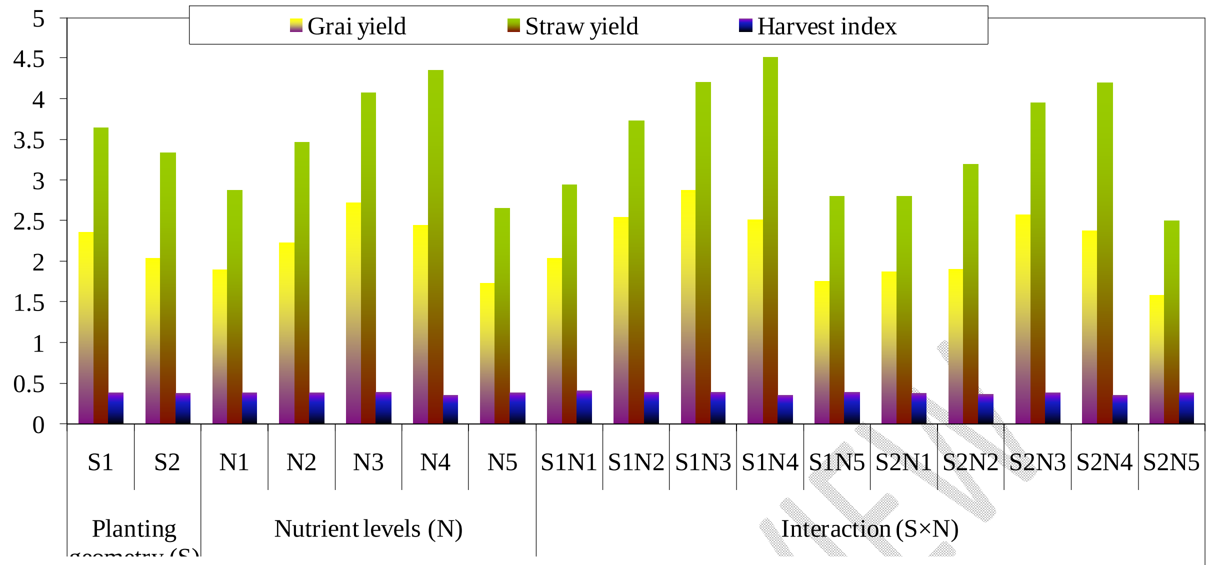
From the table 2, data depict that plant population had a significant effect on gross returns, net returns, and the B:C ratio. Under 30 cm × 10 cm, the greatest gross and net returns, as well as the B:C ratio, were obtained. This could be because the optimum plant population maintained per unit area leading to higher economic yield coupled with reduced cost of cultivation in teff crop. This was in line with Balappa [8] previous studies.Application of 100 per cent RDF resulted in significantly higher gross returns (₹ 90,776 ha$^{-1}$), net returns (₹ 60,021 ha$^{-1}$) and B:C (2.77). The higher returns were solely because of higher grain yield coupled with higher grain price in the market. Significantly lower gross returns (₹ 55,732 ha$^{-1}$), net returns (₹ 25,560 ha$^{-1}$) and B:C ratio (1.74) were observed under absolute control, due to lower grain and straw yield. Increased nutrient application in foxtail millet and little millet provided higher economic returns was reported by Ambresha and Shankar [9-10],

| Treatments | Protein (%) | Carbohydrate (g 100 g$^{-1}$) | Fibre (%) | Gross returns (₹ ha$^{-1}$) | Net returns (₹ ha$^{-1}$) | B-C ratio |
|---|---|---|---|---|---|---|
| **Factor 1: Planting geometry (S)** | | | | | | |
| **$S_1$:** 30 cm × 10 cm | 11.58 | 73.25 | 3.06 | 78171 | 47586 | 2.40 |
| **$S_2$:** 45 cm × 10 cm | 11.48 | 73.41 | 3.05 | 68821 | 38235 | 2.11 |
| S. Em. ± | 0.07 | 0.50 | 0.02 | 2390 | 1447 | 0.07 |
| C.D. (P = 0.05) | - | - | - | 7102 | 4300 | 0.22 |
| **Factor 2: Nutrient levels (N)** | | | | | | |
| **$N_1$:** 50 % RDF | 10.81 | 73.56 | 3.06 | 65160 | 34688 | 2.01 |
| **$N_2$:** 75 % RDF | 11.76 | 72.28 | 2.99 | 74182 | 43559 | 2.28 |
| **$N_3$:** 100 % RDF | 12.25 | 73.10 | 3.02 | 90776 | 60021 | 2.77 |
| **$N_4$:** 125 % RDF | 12.58 | 73.04 | 3.09 | 81629 | 50724 | 2.48 |
| **$N_5$:** Absolute control | 10.27 | 73.65 | 3.10 | 55732 | 25560 | 1.74 |
| S. Em. ± | 0.11 | 0.79 | 0.03 | 3779 | 2288 | 0.12 |
| C.D. (P = 0.05) | 0.33 | - | - | 11229 | 6799 | 0.34 |

respectively and the interaction impact of different plant population and nutrient levels did not differ significantly.

## GRAIN YIELD, STRAW YIELD AND HARVEST INDEX

Between different planting geometry, significantly greater (2.37 q $ha^{-1}$) grain yield was obtained under the narrow spacing of 30 cm × 10 cm compared to wider spacing (2.04 q $ha^{-1}$) of 45 cm × 10 cm which might be due to greater yield attributes, thus making larger sink size along with translocation of photosynthates to the sink efficiently. These results are in line with the findings of Rajesh [14]. Concurrently, due to higher plant density under closer spacing might which have contributed to maximum dry matter production per unit area which ultimately increased the straw yield. Similar findings were reported by Thakur *et al*.[15]. 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. While, application of 100 per cent RDF lodging was observed immediately after grain filling stage which has reduced impact on development of panicles. These results were in conformity with the findings of Mahantesh [13]in teff. 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. Also, similar results in foxtail and little millet respectively observed by Ambresha andShankar [9-10].Harvest index of teff varied non-significantly due to plant geometry andnutrient levels. However, numerically higher harvest index of teff) was registered under narrow(30 cm × 10 cm) and among the different nutrient levels, numerically higher harvest index was attained under application of 100 per cent RDF.However, there was non-significant influence with respect to interaction of different planting geometry and nutrient management.



**Planting geometry;** $S_1$: 30 cm × 10 cm, $S_2$: 45 cm × 10 cm

**Nutrient management;** $N_1$: 50 % RDF, $N_2$: 75 % RDF, $N_3$: 100 % RDF, $N_4$: 125 % RDF, $N_5$: Absolute control

**Fig.1 Effect of planting geometry and nutrient management on grain yield (q ha$^{-1}$), straw yield (q ha$^{-1}$) and harvest index of teff**

## 4. CONCLUSION

Maintaining narrow spacing of 30 cm × 10 cm andsupply of 100 %RDF(20 N: 20 $P_2O_5$: 20 $K_2O$) along with farm yard manure @ 6 t ha$^{-1}$ results in statistically higher yield and net returns and ultimately increased productivityof teff crop.

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