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Performance of Teff under Different Planting Methods and Nutrient Management Practices

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ABSTRACT

An experiment entitled "Performance of teff under different planting methods and nutrient management practices" was carried out on red sandy loam soil at ICAR-KVK, Haveri, Karnataka. The experimental design adopted was RCBD with Factorial concept, with a combination of two methods of planting and five nutrient levels replicated three times. Between the planting methods, transplanting teff seedlings obtained statistically higher grain and straw yields (240 and 407 kg ha^{-1}, respectively), gross and net return (Rs 84999 and Rs 53106 ha^{-1}, respectively). Among varied nutrient management practices, increased fertiliser levels increased grain yield (269 kg ha^{-1}), gross and net return (Rs 95220 and Rs 63136 ha^{-1}, respectively), and B:C ratio (2.96) under supply of 20:10:10 kg NPK ha^{-1}, whereas further increment in fertilizer levels resulted in decreased grain yield due to increased crop lodging.

Keywords Fertilizer, Line sowing, Lodging, Nutrition, Teff, Transplanting.

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INTRODUCTION

Minor millets are grouped under "underutilized crops" despite of their greater importance as climate smart, nutritionally rich and healthy foods with low risk in production and lower production cost and their potentiality to contribute for increasing grain production in both developed and under-developed countries (Sahu 1965). These foods fit into every person's optimum dietary category, regardless of age and they are essential to India's sustainable agriculture. As a result of farmers' increased interest in commercial agriculture and substitution of cash crops for sustainable crops, the area planted to millets is dwindling daily (Durgad *et al.* 2019). On the negative side, since there is petite international trade, these crops are on the list of "Orphan Crops". Teff, fonio, chia, brown top millet, quinoa, are few examples of novel group of millets that are both nutri-rich and fetches higher income for the farmer. The government is trying hard to boost the production of these millets over various schemes to dispel the social stigma i.e., "food for the poor" and to combat undernourishment in the country.

Teff (*Eragrostis tef* (Zucc.) Trotter), generally known by the names, "Williums love grass, teffa and annual bunch grass" in diverse parts of the world and is originated and diversified from Ethiopia (Vavilov 1951). In Ethiopia, teff is prime food for majority of population (85% of the 85 m people). Ethiopia owns lion share in teff cultivation with an area of 3.01 m ha producing 5.01 m t and with an average productivity of 1.664 t ha^{-1} (Lee 2018). Teff is an intriguing grain packed with nutrition and free of gluten (Akansha *et al.* 2018). Teff flour is chief ingredient in the preparation of Injera (fermented, sourdough, flat bread) and many bakery products to substitute either fully or partially other baking flours (Stewart and Getachew 1962). It is also consumed as porridge and is an essential component of traditional alcoholic beverages. Cattle prefer teff straw than any other millet straw because of its high palatability and digestibility (Miller 2007) and straw with mud is best used for thatching the roof. These peculiar characters make teff a potential and viable crop for the agriculturalists of dryland area, which is predominate in sub-tropical and tropical countries like India.

The Central Food and Technological Research Institute (CFTRI), Mysore introduced teff millet to India - an effort to promote it as a "super food" as well as a means of easy earnings for farmers and make it more accessible and less expensive for consumers. Presently, teff is cultivated on a few hundred hectares in Karnataka around Mysore, Sirsi (Uttar Kannada), Haveri, Gadag and Raichur districts. The premier organizations for promotion and cultivation of teff in South and North Karnataka are CFTRI at Mysore and Kadamba Foundation at Sirsi, respectively.

Though, teff is a boon to Indian farmers, less is known about its cultivation, production and value addition in India. The key constraints in cultivation include; dearth of improved plant types, lodging of the crop at advanced stages of crop growth, lack of mechanization (leading to labor intensive cultivation), lack of awareness and standard package of practice (agro-techniques) that suits well to Indian agro-climatic conditions. Among these, establishment method and nutrition management play a dynamic role in improving yield levels of teff crop as they ensure optimum plant stand and passable supply of nutrition to the plants. Broadcasting was the only amenable method followed earlier due to smaller size of the seeds, however, research studies revealed that row planting resulted in significantly higher yield over broadcasting due to ease in easy crop management. Transplanting is the emerging method of planting (Adeyeye *et al.* 2014). Millets are mostly grown on dryland soils which are 'not only thirsty, but hungry too' and make it obligatory to supply nutrients through outside sources viz., organic and inorganic fertilizers (Tilahun 2004 and Gafoor *et al.* 2021). These nutrients are to be applied wisely to attain maximum yield potentiality of the crop with least losses and higher utilization efficiency which demands a standard recommendation that is economically feasible to adopt by the farmers. Hence, the present study is an initiative step in standardizing the planting method and nutrient management practice for teff cultivation and promoting teff as a potential minor millet among the Indian farming community that is capable of overcoming malnutrition and improving the socio-economic standing of farmers in dryland environments.

MATERIALS AND METHODS

Experimental site

An experiment was accomplished at ICAR-Krishi Vigyan Kendra, Hanumanamatti, UAS, Dharwad, which is situated at a latitude of 14.39' N, longitude of $75^{0}33'$ and at an altitude of 594.36 m above the MSL. Hanumanamatti falls under Northern Transitional Zone (8^{th} Agroclimatic Zone) of Karnataka, which is predominated by red sandy loam soil. The soil chemical status prior to sowing shows that soil reaction was acidic (pH-5.36) with low organic carbon (3.61 g kg^{-1}), available soil nitrogen (226.20 kg ha^{-1}) and available soil potassium (121.35 kg ha^{-1}) and medium range for available soil phosphorus (26.57 kg ha^{-1}). The total annual precipitation occurred during the experimental year was 1276.40 mm, that was 26.47% higher than the average annual precipitation of the past 38 years (1009.24 mm). The 90% of the total annual precipitation occurred during *kharif* season (July to October) as shown in Fig. 1.

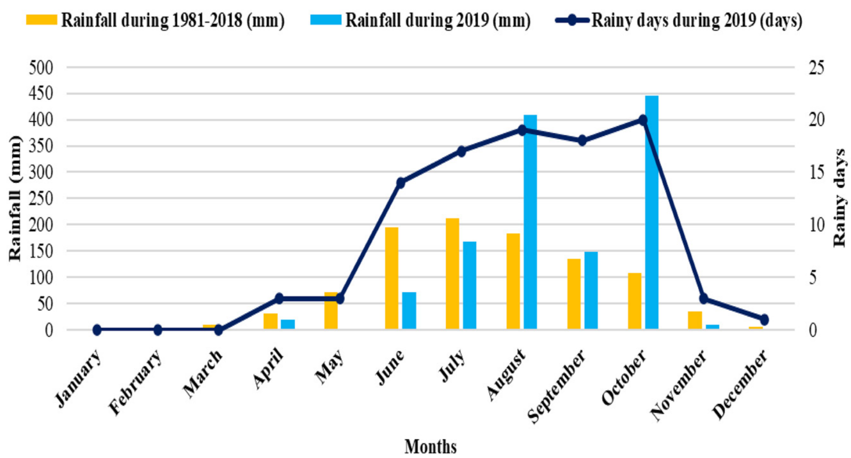

Fig. 1. Monthly mean rainfall for the past 38 years (1981-2018) and during the cropping year (2019) at the ICAR-KVK, Hanumanamatt, UAS, Dharwad.

Treatment details and cultivation practices

The experimental design followed was RCBD with Factorial concept, comprising of two factors viz., methods of planting (M_1: Line sowing and M_2: Transplanting) and five nutrient levels (N_1: Absolute control, N_2: 100% organics (6 t FYM ha^{-1}), N_3: 20:10:10 kg NPK ha^{-1}, N_4: 30:15:15 kg NPK ha^{-1} and N_5: 40:20:20 kg NPK ha^{-1} (*6 t FYM ha^{-1} applied to N_3-N_5 treatments) with three replications.

Brown seeded type teff seeds procured from IIMR, Hyderabad was used for planting. The sowing was taken up during the July month (*kharif* 2019) under line sowing method seeds were directly drilled into soil, while under transplanting 21 days old seedlings raised in nursery were used for transplanting. The NPK fertilizers were supplied according to the treatments imposed in the form of 17:17:17 and urea as basal application. Except N_1: Control treatment, 6 t FYM ha^{-1} was added to soil two weeks prior to planting of the crop. Except the practices of treatment imposed, rest of the field management practices were followed as recommended to little millet cultivation as teff is morphologically much similar to little millet.

Plant sampling

From each net plot, five plants were selected randomly and tagged to record the data on plant height (above ground to nodal base of the fully opened leaf at the tip of the plant and expressed in centimeter), number of leaves per plant, number of tillers m^{-1}, number of effective tillers m^2 and total dry matter production plant^{-1} (plants were shade dried and later oven dried at 70 ^{0}C in hot air oven and dry weight of the whole plant was recorded and expressed as grams plant^{-1}). Lodging percent at harvest was calculated as per Caldicott and Nuttall (1979) method. Teff crop was harvested during the second fortnight of October. Harvesting was done manually with the help of sickle. Five panicles were taken randomly and threshed separately to record the grain weight ear^{-1} and test weight and were expressed in grams. The data on grain and straw yield from net plot were noted and then expressed as kg ha^{-1}. Finally, the data on all the parameters from each plot and replication is presented as mean data of individual treatment.

Statistical analysis

The mean data of individual parameters was subjected to ANOVA as proposed by fisher and data interpretation was done by fallowing Gomez and Gomez (1984) postulates. The critical difference (CD) value was calculated and presented for the parameters with significance for 'F' and 't' tests at 5% level of significance, while 'NS' (Non-significant) is indicated for parameters with no significant difference between the treatment values.

RESULTS AND DISCUSSION

Weather influence on teff performance

The total annual precipitation received during 2019 was 1276.4 mm, distributed in 98 rainy days, which was 29.92% higher than the average annual precipitation received during previous 38 years. More than 90% (1169.6 mm) of the annual precipitation occurred during *kharif* (July-October) due to aberrant variations in the monsoon that caused devasting cyclonic showers, affecting crop production during the experimental year (Fig. 1). The rainfall during the initial stages (2nd fortnight of July to 1st fortnight of August) was sufficient for transplanting without any external supply of water and aided better establishment of the crop under both line sowing and transplanting methods. The amount of precipitation during active tillering stage and panicle initiation stage (September month) was normal compared to initial (August month) and later stages of the crop (October month). Though the lodging was common in teff millet to some extent, heavy rainfall at physiological maturity caused severe lodging of the crop and in turn more loss of grains. This ultimately resulted in lower grain yield (ranging from 159 to 294 kg ha^{-1}) compared to its potential yield. The mean maximum and minimum temperature and relative humidity prevailing throughout the crop growth period were congenial for normal growth and development of the crop and did not affect much of the teff performance.

Effect of planting methods on performance of teff

Significant difference was observed between the planting methods with regard to grain and straw yields (Tables 1–4). An increase of about 17.47 and 24.33 % of grain and straw yields, respectively, were attained under transplanting (240 and 407 kg ha^{-1}, respectively) over line sowing treatment (204 and 327 kg ha^{-1}, respectively). A study reported that planting method has profound influence on crop growth and development, which is seen in plant population, plant height, total dry matter accumulation and other yield attributes (Arioglu *et al.* 2004). Similarly, 19.15% increase in yield under transplanted finger millet over line sowing in *Konkan* region. This is due to improved yield parameters' contribution to total economic yield viz., number of effective tillers m^{-2} (449.00), grain weight ear^{-1} (0.31 g) and thousand grain weight (0.30 g) under transplanting than under line sowing (Sarawale *et al.* 2017). The present findings are in consonance with the results of Kalaraju *et al.* (2011) and Thakur *et al.* (2016) in finger millet. Transplanting ensures better establishment of crop at early stages as it provides selection of healthy and capable seedlings planted under favorable conditions due to which greater yield level was obtained. Wider intra-row spacing adopted under transplanting lowers the intraspecific competition for space, moisture, nutrients and solar radiation. Healthy seedlings when planted under such conditions effectively utilize these available resources and results in accelerated production, accumulation and translocation of photosynthates to the rapidly growing parts till reproductive phase and to the economic parts (grains) of the plants at post reproduction phase, due to which higher grain yields are observed under transplanting method. Similar observations were also recorded by Tesfay and Gebresamuel (2016) in teff at Northern Ethiopia and by Bahure *et al.* (2017) in proso millet.

Further, the higher yield levels under transplanting were attributed to better growth determining parameters viz., height of the plant (78.36 cm), number of leaves plant^{-1} (142.14), number of tillers m^{-1} row length (147.77) and dry matter production (32.12 g plant^{-1}). These observations also supported by the conclusions of Kalaraju *et al.* (2011), Patil *et al.* (2018) and Sarawale *et al.* (2017) in finger millet at different locations in India. This led to more lodging of the teff crop under transplanting (58.42%) than under line sowing (54.78%). However, a greater number of effective tillers per unit area and grain weight ear^{-1} were sufficient enough under transplanting method that compensated in overcoming the loss of grain yield due to lodging effect. The reduced growth of plants (a smaller number of tillers plant^{-1} and shortened height of the plant) and higher plant population (that helped in withstanding the adverse effect of strong winds) under line sowing had positively impacted in lesser lodging of the teff crop compared to transplanting. Similar observations in finger millet were also noted by Thakur *et al.* (2016) and Chandan (2018) on red sandy loam soil.

Table 1. Effect of planting methods and nutrient management on growth parameters of teff at harvest.

Treatments	Plant height (cm)	No. of leaves per hill	No. of tillers (m^{-1})	Dry matter production (g $plant^{-1}$)
Factor 1: Planting method (M)				
M_1: Line sowing	69.86	60.48	136.59	26.72
M_2: Transplanting	78.36	142.14	147.77	32.12
SEm ±	1.10	4.20	3.49	0.71
CD (p = 0.05)	3.26	12.48	10.36	2.11
Factor 2: Nutrient management (N)				
N_1: Control	64.83	75.09	108.86	23.20
N_2: 100 % organics (FYM 6 t ha^{-1})	67.53	86.15	122.88	25.34
N_3: 20:10:10 kg NPK ha^{-1}	75.57	109.57	152.53	30.63
N_4: 30:15:15 kg NPK ha^{-1}	79.09	113.38	157.69	32.54
N_5: 40:20:20 g NPK ha^{-1}	83.52	122.37	168.93	35.38
SEm ±	1.73	6.64	5.51	1.12
CD (p = 0.05)	5.15	19.73	16.38	3.34
Interaction (M × N)				
M_1N_1	60.78	44.52	104.73	20.52
M_1N_2	63.17	50.90	117.48	22.43
M_1N_3	70.98	65.12	145.86	27.93
M_1N_4	74.87	68.13	151.86	30.06
M_1N_5	79.50	73.73	163.00	32.68
M_2N_1	68.87	105.65	112.98	25.88
M_2N_2	71.89	121.40	128.28	28.25
M_2N_3	80.17	154.01	159.23	33.34
M_2N_4	83.32	158.63	163.51	35.02
M_2N_5	87.54	171.01	174.86	38.09
SEm ±	2.45	9.39	7.80	1.59
CD (p = 0.05)	NS	NS	NS	NS

Effect of nutrient management practices on performance of teff

Increasing the nutrient levels resulted in statistically improved growth and development of teff in terms of higher plant height (83.52 cm), number of leaves $plant^{-1}$ (122.37), tillers m^{-1} row length (168.93) and dry matter production (35.38 g $plant^{-1}$) at harvest were achieved in treatment supplied with 40:20:20 kg NPK ha^{-1}, however, it was found on par with the treatment that received 30:15:15 kg NPK ha^{-1} (Table 1). The findings of Asefa *et al.* (2014) and Assefa *et al.* (2016) in teff and Patel *et al.* (2022) in forage oat also confirm the results of present investigation. A favorable growth environment (both above and below ground) for enhanced the metabolic processes of teff crop at higher nutrient levels application was established through more and abundant nutrient accessibility under an optimum soil moisture regime during the entire crop growth period coupled with uninterrupted accessibility of solar radiation. This led to an effective photosynthetic structure that allowed for increased photosynthates synthesis, accumulation, partitioning and translocation of accumulated photosynthates to various sections of the plants. As a result of this, the crop grew and developed more effectively. The supply of mineral nutrition, which was greater when 40:20:20 kg NPK ha^{-1} fertilizer dose was supplied to soil determines the generation and translocation of produced photosynthates. Shankar (2017) and Ambresha (2017) observed the similar trends in plant growth of little millet and foxtail millet, respectively on red sandy loam soils of Bengaluru. Thus, significantly higher values of growth parameters under supply of 40:20:20 Kg NPK ha^{-1} fertilizers ultimately resulted in higher teff straw yield (433 kg ha^{-1}), yet, found on par with the treatment that received 30:15:15 kg NPK ha^{-1} (405 kg ha^{-1}).

In contrast to straw yield and growth parameters, grain yield was significantly higher under supply of 20:10:10 kg NPK ha^{-1} (269 kg ha^{-1}), which was statistically on par with application of 30:15:15 kg NPK ha^{-1} (249 kg ha^{-1}) followed by 40:20:20 kg NPK ha^{-1} (215.78 kg ha^{-1}) (Table 3). It is because of more lodging of the crop under 40:20:20 kg NPK ha^{-1} nutrients supply and rainfall during advanced stages of the crop. These findings are in line with the results of Raghavendra and Halikatti (1998) and Shashidhara *et al.* (1998) in little millet and Habtegabrial and Singh (2006) in teff. Vandelden *et al.* (2010) noted that lodging was common in teff and accounts for 11-12% reduction in yield. The severity of lodging in the present investigation mainly owes to instability of roots under continuous saturation of soil owing to unexpected hefty precipitation at advanced phases of teff growth and insufficient strength of the stem to support the increasing weight of shoot due to heavy winds prevailing at pre- and post-grain filling stage (Rawson and Macpherson 2000). With differed nutrient levels, lodging was observed before grain filling stage under 40:20:20 Kg NPK ha^{-1} application, while,

Table 2. Effect of planting methods and nutrient management on lodging and yield attributes of teff.

Treatments	Lodging (%)	Number of effective tillers per m^{-2}	Grain weight per ear (g)	Thousand seeds weight (g)
Factor 1: Planting method (M)				
M_1: Line sowing	54.78	380.96	0.26	0.28
M_2: Transplanting	58.42	449.00	0.31	0.30
SEm ±	0.95	9.98	0.01	0.009
CD (p = 0.05)	2.84	29.66	0.02	NS
Factor 2: Nutrient management (N)				
N_1: Control	37.88	342.05	0.24	0.28
N_2: 100 % organics (FYM 6 t ha^{-1})	44.86	365.76	0.26	0.28
N_3: 20:10:10 kg NPK ha^{-1}	55.36	436.27	0.33	0.29
N_4: 30:15:15 kg NPK ha^{-1}	68.62	453.03	0.31	0.30
N_5: 40:20:20 kg NPK ha^{-1}	76.28	477.80	0.29	0.31
SEm ±	1.51	15.78	0.01	0.014
CD (p = 0.05)	4.49	46.89	0.03	NS
Interaction (M×N)				
M_1N_1	36.50	307.20	0.21	0.27
M_1N_2	43.18	331.41	0.24	0.28
M_1N_3	54.06	402.58	0.30	0.28
M_1N_4	65.00	419.60	0.29	0.29
M_1N_5	75.17	444.01	0.27	0.30
M_2N_1	39.26	376.90	0.26	0.28
M_2N_2	46.54	400.10	0.28	0.29
M_2N_3	56.67	469.95	0.36	0.29
M_2N_4	72.25	486.45	0.33	0.31
M_2N_5	77.39	511.58	0.31	0.32
SEm ±	2.13	22.32	0.02	0.02
CD (p = 0.05)	NS	NS	NS	NS

Table 3. Effect of planting methods and nutrient management on yield of teff.

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index (%)
Factor 1: Planting method (M)			
M_1: Line sowing	204	327	38.50
M_2: Transplanting	240	407	37.03
SEm ±	5.95	6.38	0.38
CD (p = 0.05)	17.68	18.97	1.12
Factor 2: Nutrient management (N)			
N_1: Control	170	281	37.81
N_2: 100 % organics (FYM 6 t ha^{-1})	206	327	38.82
N_3: 20:10:10 kg NPK ha^{-1}	269	390	40.83
N_4: 30:15:15 kg NPK ha^{-1}	249	405	38.07
N_5: 40:20:20 kg NPK ha^{-1}	216	433	33.30
SEm. ±	9.41	10.10	0.59
CD (p = 0.05)	27.95	30.00	1.76
Interaction (M×N)			
M_1N_1	159	249	38.88
M_1N_2	192	285	40.19
M_1N_3	244	349	41.12
M_1N_4	227	361	38.57
M_1N_5	199	392	33.72
M_2N_1	182	312	36.75
M_2N_2	220	368	37.45
M_2N_3	294	431	40.53
M_2N_4	271	449	37.58
M_2N_5	232	474	32.87
SEm ±	13.30	14.28	0.84
CD (p = 0.05)	NS	NS	NS

under the treatment supplied with 20:10:10 Kg NPK ha^{-1} it was observed immediately after grain filling stage due to early taller plants and higher vegetative growth coupled with enlarged length of lower internodes (due to self-shading) and decreased upper internodal length (Rajkumara, 2008). Applying entire dose of recommended nitrogen at establishing (basal application) itself favours lodging irrespective of soil nutrient status due to pronounced vegetative growth of the crop. Several earlier researchers viz., Asefa *et al.* (2014) and Assefa *et al.* (2016) in teff and Tian *et al.* (2018) in foxtail millet also noted the similar observations.

Further, higher grain yield was also attributed to higher values of grain weight (0.33 g ear^{-1}), number of effective tillers (477.80 m^{-2}) and harvest index (40.83%) under supply of 20:10:10 kg NPK ha^{-1} as compared to other nutrient management practices (Tables 2–3) resulting in statistically higher grain yield under supply of 20:10:10 kg NPK ha^{-1}. This is mainly because of greater synthesis, accumulation and partitioning of the photosynthates into all the plant parts. These were in consonance with the findings of Jagathjyothi *et al.* (2008) and Govindappa *et al.* (2009) in finger millet.

The enhanced availability of applied nutrients during the investigation is attributed to prevalence of sufficient soil moisture due to uninterrupted rain showers during the cropping season 2019. These showers also had great influence on lodging of the

Table 4. Effect of planting methods and nutrient management on economics of teff.

Treatments	Gross returns (Rs ha^{-1})	Net returns (Rs ha^{-1})	B:C ratio
Factor 1: Planting method (M)			
M_1: Line sowing	72306	42934	2.46
M_2: Transplanting	84999	53106	2.66
SEm ±	2093	2093	0.07
CD (p = 0.05)	6219	6219	0.19
Factor 2: Nutrient management (N)			
N_1: Control	60297	36149	2.49
N_2: 100 % organics (FYM 6 t ha^{-1})	72965	42242	2.37
N_3: 20:10:10 kg NPK ha^{-1}	95220	63136	2.96
N_4: 30:15:15 kg NPK ha^{-1}	88175	55411	2.69
N_5: 40:20:20 kg NPK ha^{-1}	76607	43163	2.29
SEm ±	3309	3309	0.10
CD (p = 0.05)	9833	9833	0.31
Interaction (M×N)			
M_1N_1	56112	32724	2.40
M_1N_2	67913	38575	2.31
M_1N_3	86346	55648	2.81
M_1N_4	80360	48981	2.56
M_1N_5	70800	38742	2.21
M_2N_1	64481	39573	2.59
M_2N_2	78017	45908	2.43
M_2N_3	104094	70625	3.11
M_2N_4	95991	61482	2.81
M_2N_5	82413	47585	2.37
SEm ±	4680	4680	0.15
CD (p = 0.05)	NS	NS	NS

crop due to thinner and weaker nature of the stem.

The effect of interaction of different planting methods and varied nutrient levels was non-significant with respect to all the growth and yield attributes considered during the course of experimentation.

Economics of teff cultivation

Among different planting methods, significantly higher gross returns (Rs 84999 ha^{-1}), net returns (Rs 53106 ha^{-1}) and B:C ratio (2.66) were obtained under transplanting than under line sowing. The present outcomes are in consonance with the results of Narayan (2017) and Kumar (2018). The treatment receiving 20:10:10 kg NPK ha^{-1} resulted in significantly higher gross returns (Rs 95220 ha^{-1}), net returns (Rs 63136 ha^{-1}) and B:C ratio (2.96), yet it was on par with the treatment supplied with 30:15:15 kg NPK ha^{-1} (Rs 88175 ha^{-1}, Rs 55411 ha^{-1} and 2.69, respectively). The higher monetary returns were solely because of higher grain yield rather than straw yield coupled with higher grain price in the market. Ambresha (2017) and Shankar (2017) also obtained higher economic returns with increased applications of nutrients in foxtail millet and little millet, respectively.

The economic analysis of teff cultivation reveals that, farmers can attain three to four times higher net returns compared to cultivation of little millet and foxtail millets (Ambana Gouda *et al*. 2019). This is mainly attributed to higher market price of the teff grains compared to other minor millets.

CONCLUSION

Transplanting method of planting allows efficient utilization of all the resources ultimately resulting in improved growth development of teff crop than line sowing method. Among the varied fertilizer levels, supply of 20:10:10 kg NPK ha^{-1} in addition to 6 t FYM ha^{-1} results in statistically higher grain yield of teff crop. However, it was found on par with the treatment receiving 30:15:15 kg NPK ha^{-1} in addition to 6 t FYM ha^{-1}. 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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