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AGRONOMY

Effect of Different Row Spacing, Levels of Nitrogen and Phosphorus Fertilizers on Yield Attributes, Productivity and Economics of Tef (Eragrostis Tef)

Kumela Bodena Jabesa and Thomas Abraham*

Department of Plant Sciences, College of Agriculture, Ambo University, Ambo, Ethiopia

*Corresponding author: drthomasabraham7@gmail.com

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ABSTRACT

A field experiment was conducted to investigate the effect of three rows spacing, four levels of N and P_2O_5 fertilizer rates and their interaction on growth parameters, yield and yield components of tef during *meher* cropping season of 2015 at the research farm of Ambo University. Treatments were: three level of row spacing viz. 10cm, 20cm and 30cm and four levels of N and P_2O_5 fertilizer rates (50/50,60/60, 70/70 and 80/80kg of N/P_2O_5 ha^{-1}) with application of DAP as basal dose and Urea after 21 days of sowing. Highest growth parameters recorded were 10.9 for effective tillers for 80/80 kg N/P_2O_5 ha^{-1} with 10cm row spacing, 111cm in plant height, 37cm in panicle length at 50% flowering, 45cm in panicle length at 90% maturity for 80/80 kg N/P_2O_5 ha^{-1} with 20cm row spacing plant^{-1} respectively. Highest yield and yield components recorded were 3766.7 kg ha^{-1}, 7350 kg ha^{-1}, 11166.7 kg ha^{-1} and 34% in treatment of 80/80 kg N/P_2O_5 ha^{-1} with 10cm row spacing for grain yield, straw yield, biomass yield and harvest index respectively. Yield components were affected significantly by treatments with highest results observed in their interaction effects, where increments were 41.7% kg ha^{-1}, 113.21% kg ha^{-1}, 35.28% kgha^{-1} and 55.45% kg ha^{-1} for grain harvest index, yield, straw yield and biomass yield respectively from 80/80kg of N/P_2O_5 with 10cm spacing. Economic partial budget analysis shows that with 80/80 kg of N/P_2O_5 ha^{-1} fertilizer rate at 10cm row spacing resulted in maximum relative net return of ETB 50178ha^{-1} followed by ETB 48017 ha^{-1} for 70/70 kg of N/P_2O_5 ha^{-1} and ETB 38121 ha^{-1}for 60/60 kgN/P_2O_5 ha^{-1}.

Highlights

- 80/80 kg of N/P_2O_5 ha^{-1} with 10cm spacing followed by 70/70 kg of N/P_2O_5 ha^{-1} with 10cm spacing resulted in maximum economical return and yield.

Keywords: Tef, yield, row spacing, nitrogen and phosphorus

Tef [*Eragrostis tef* (Zucc.) Trotter] occupies 24% of the cultivated area (3017914 hectares) and 17% of the total grain production (5020440 tons) is the most important staple food crop in Ethiopia (CSA 2017). Tef crop has the adaptability to the changing environments in the country, thus reducing production risks. However, the major limitation for tef production in the country has been its low productivity. Tef has the lowest yield per hectare compared to other major cereals, as the national average yield is meager 1.66 tons ha^{-1} (CSA 2017). Most crucial reasons for this low yield are poor soil fertility and lack of appropriate sowing methods with appropriate crop density. Most common practice among farmers is the traditional sowing method of broadcasting, which increases crop density and competition among plants for nutrients, water, sun light, CO_2 and other resources, which reduces productivity of tef. Further, broadcasting method requires higher seed rate compared to row sowing method, therefore farmers will be able to save a substantial amount of seed with row sowing method.

Farmers in Ethiopia prefer to cultivate tef due to its adaptability to different environmental and soil conditions, resistance to water stress, diseases and insects. Among cereals, tef also has high acceptance in the diet of the country and thus fetches premium market price. Usually, tef is grown in Ethiopia as a cereal grain for human food but its stover is also an important animal feed in the dry season.

Tef production system is currently unable to meet the consumers demand, due to the fact that most Ethiopian farmer's practice traditional farming practices without much modern technology. Tef production system in Ethiopia is not effectively supported by modern technology due to research gap in adapting modern technology and its inadequate extension services. The research gaps on the inadequate plant population and balanced amount of fertilizer dose per hectare have been identified as the significant constraints for the low productivity of tef in West Show a zone among others. Row spacing method to maintain optimum crop density and adequate quantity of Nitrogen and P_2O_5 fertilizer application rate are the most important solutions for the low tef productivity. The local farmers practice broadcasting method of sowing which requires much more seed rate instead of row sowing method which requires low seed rate and inadequate fertilizer rates. Moreover, farmers are unaware of the optimum precise fertilizer rate of N and P_2O_5 to get maximum yield per unit area, which will substantially increase farmer's income and their lively hoods. These modern agronomic practices and technologies, in turn, ensures food security and an increase in farmer's income to generate additional resources to eradicate poverty.

MATERIALS AND METHODS

The field experiment was conducted at the experimental plots in Ambo University research site in Ambo, which is located 114 km far from Addis Ababa towards the west of the country,this town has a latitude and longitude of 8°59′N 37°51′E as well as an elevation of 2101 meters. The study was conducted on tef variety *Kora* during the *meher* cropping season of 2015 at the research farm of Ambo University on vertisols of Ambo district in west Shoa zone, western Oromia, Ethiopia. The objectives of the experiment were to study the effect of three level of rows spacing, four levels of N and P_2O_5 fertilizer rates and their interaction on growth parameters, yield and yield components. The experiment was statistically laid out in Randomized Complete Block Design with three replications. The treatments were: three level of row spacing 10cm, 20cm and 30cm and four levels of N and P_2O_5 fertilizer rates 50/50kg of N/P_2O_5 ha^{-1}, 60/60 kg of N/P_2O_5 ha^{-1}, 70/70 kg of N/P_2O_5 ha^{-1} and 80/80 kg of N/P_2O_5 ha^{-1}with application of Di-ammonium Phosphate (DAP) asbasal dose and Urea after 21 days of sowing (DAS). Each harvestable plot had an area of 1.6m by 1.25m (2m^2) with 0.5m spacing between plots and 1m between blocks. The treatments were assigned to plots by randomization method.

After seedbeds were leveled, *Kora* variety of tef was sown with seed rate of 25kg ha^{-1} in rows as per the treatments of the experiment with recommended plant density manually by drilling on 24th July 2015. Harvesting of tef was carried out at physiological maturity on 10th November 2015 from net plots size after leaving border rows to determine the per plot yields of tef.

RESULTS AND DISCUSSION

The analysis of panicle lengths of tef measured at 50% flowering were significantly ($p<0.001$) affected among the 12 treatments of rows spacing and N/ P_2O_5 fertilizer rates (Table 1). The highest number of panicle length per plant was recorded from the combination of 80/80 kg of N/P_2O_5 ha^{-1} with 20cm rows spacing (37cm), followed by 70/70 kg of N/P_2O_5 ha^{-1} with 20cm rows spacing was 35.73 (Table 1), over the N/P_2O_5 combination of fertilizer rates and rows spacing of the other, but the shortest panicle length than the others treatment was at 50/50kg of N/P_2O_5 ha^{-1} combination of fertilizer rates with 30cm rows spacing of tef founded was 24.83cm. As the rate of the fertilizer rate increased from the lower of 50/50kg of N/P_2O_5 ha^{-1} combination of fertilizer rates with 30cm rows spacing to 80/80 kg of N / P_2O_5/ha with rows space of 20cm the panicle lengths was increased by 49.2%. This might be due to availability of adequate crop nutrients and the crop density, as N availability leads to promotion of rapid growth of panicle lengths of tef. These finding were in agreement with results reported by Sewenet (2005), who reported that cereals grown under adequate growth factors and space, delayed

Table 1: Main and interaction effects on panicle length at 50% flowering and at 90% physiological maturity plants^{-1}

Fertilization	Panicle length at 50% flowering plant^{-1} (cm)				Panicle length at 90% physiological maturity plant^{-1}			
	Row spacing							
N/P_2O_5(kg ha^{-1})	10cm	20cm	30cm	Mean	10cm	20cm	30cm	Mean
50/50	26.20^h	31.96^f	24.83^i	27.67^d	30.3^g	34.0^{ef}	30.2^g	31.52^d
60/60	30.53^g	32.96^e	30.10^g	31.20^c	36.6^{de}	40.6^{bc}	32.8^{fg}	36.71^c
70/70	32.83^e	35.73^b	31.73^f	33.43^b	41.3^b	42.0^b	38.4^{cd}	40.60^b
80/80	33.83^d	37^a	34.83^c	35.22^a	42.0^b	45.0^a	42.3^{ab}	43.10^a
Mean	30.85^b	34.42^a	30.36^c		37.58^b	40.42^a	35.95^c	
LSD (5%) RS = 0.38					LSD (5%) RS = 1.53			
LSD (5%) FR = 0.44					LSD (5%) FR = 1.77			
LSD (5%) RS × FR = 0.69					LSD (5%) RS × FR = 2.73			
CV(%) 1.4					CV (%)4.78			

N.B: *Means of the same letter along columns and rows are not significantly different*

their 90% physiological maturity compared to those under competition for space and other growth factors. Thus an increase in panicle length of cereals was noted with P fertilization.

Whereas the analysis of panicle lengths of tef measured at 90% physiological maturity were significantly ($p<0.001$) affected among 12 treatments of row spacing and N/P_2O_5 fertilizer rates. Panicle length recorded were 45cm and 42.30cm at 80/80kg of N/P_2O_5 ha^{-1} with 20cm and 30cm rows spacing respectively in their interaction effect (Table 1). However, the shortest panicle length recorded was 42.0cm at 50/50kg of N/P_2O_5 ha^{-1} combination of fertilizer with 10cm rows spacing. Plots treated with fertilizer rates of 80/80 kg of N/P_2O_5 ha^{-1} with 20cm and 30cm rows spacing showed a panicle length increment by 37.19% and 28.96% respectively compared to treatments with fertilizer rates 50/50kg of N/P_2O_5 ha^{-1} with 30cm rows spacing. Panicle lengths increased by 49% as the rate of the fertilizer rate increased from the combination of 50/50kg of N/P_2O_5 with 30cm to 80/80kg of N/P_2O_5 with rows spacing of 20cm. The panicle length differences at 90% physiological maturity and at 50% flowering were 8cm and 7.5cm for 80/80kg of N/ P_2O_5 ha^{-1} with 20cm and 30cm rows spacing respectively, this might be due to long duration of time for 90% physiological maturity. This difference between the highest and the lowest result of the panicle lengths at the measured time might be due to the optimum crop nutrients and the rows spacing leads to high intra -specific crops competition among each other. More N and density of the crop leads to promotion of rapid growth of panicle lengths. These finding were in agreement with results reported by Legesse A. (2004) who reported that as application of N rates increased,the plant height, panicle length, straw yield and grain filling and yield also increased.

Similarly, results of analysis revealed that plots treated with (80/80kg of N/ P_2O_5 ha^{-1} with 10cm row spacing and (70/70 kg of N/ P_2O_5) ha^{-1} with 10cm row spacing showed significantly higher effective tiller, grain yield, straw yield, biomass and harvest index compared to the other treatments of the study. This was due to low crop density which favored tiller number per plant and higher yield per plot due to more availability and effective utilization of nutrients, water, sunlight, CO_2 and other resources along with more plot area covered by crop. However, plots treated with 50/50kg of N/P_2O_5 ha^{-1} with 30cm row spacing recorded the lowest of tiller number, yield and yield components compared to all other treatments. Further, plot treated with 80/80kg of N/ P_2O_5 ha^{-1} and 70/70kg of N/P_2O_5 ha^{-1} with 20cm row spacing showed higher mean value plant of panicle length (37cm and 45cm) at 50% flowering and 90% crop physiological maturity as well as crop mean value of plant height (111cm) plant^{-1} respectively compared to other treatments. Tekalign and Teklu (2000) reported yield improvement due to effective management of soil fertility and plant nutrition in their research conducted on tef. However, plant heights were the lowest in plot treated by 50/50kg of N/P_2O_5 ha^{-1} with 10cm row spacing. These plots showed panicle length at 50% flowering and 90% physiological maturity, negatively affected by low fertilizer rates and high crop density. As the space between rows increase,area covered by crop becomes less and vice versa.

Likewise, treatments with 70-80/70-80kg of N/P_2O_5 ha^{-1} with 10 cm row spacing recorded higher mean value of tiller number $plant^{-1}$, grain yield ha^{-1}, straw yield ha^{-1}, biomass ha^{-1} and harvest index percentage. However, plot treated with 80/80kg of $N/P_2O_5ha^{-1}$ with 20 cm rows spacing was higher in mean of panicle length at 50% flowering and 90% physiological maturity. Plot treated with 80/80kg of N/P_2O_5 ha^{-1} with 30 cm row spacing recorded increased lodging % than the other treatments. Lodging did not affect grain yield when compared with the other treatments as lodging was controlled after crop maturity. Temesgen (2001) reported adequate nitrogen fertilization had substantial influence on yield and related traits of tef in his study.

Regarding grain yield the most important attribute, the analysis of the grain yields ha^{-1} of tef were significantly ($p<0.001$) affected among 12 treatments of row spacing and combination of N/P_2O_5 fertilizer rates (Table 2). The highest grain yield of 3766.67kg ha^{-1} was recorded from the combination of 80/80 kg of N/P_2O_5 ha^{-1} with 10cm rows spacing followed by 3633.4kg ha^{-1} from 70/70kg of N/P_2O_5 ha^{-1} with 10cm rows spacing. Moderate grain yield of 3050kg ha^{-1}, 2933kg ha^{-1} and 3036.7kg ha^{-1} were recorded from 80/80 kg of N/P_2O_5 ha^{-1} with 20cm row spacing, 70/70 kg of $N/P_2O_5ha^{-1}$ with 20cm rows spacing and 60/60 kg of N/P_2O_5 ha^{-1} with 10cm spacing between the rows respectively. While, the lowest grain yield of 1766.6 kg ha^{-1} was obtained from the combination of 50/50kg of $N/P_2O_5ha^{-1}$ with 30cm rows spacing (Table 2). Legesse (2004) had also reported grain yield improvement in tef to nitrogen and phosphorus fertilization in his research.

Further, highest mean value of grain yield of the treatments with 80/80kg of N/P_2O_5 ha^{-1} with 10cm rows spacing and 70/70kg of N/P_2O_5 ha^{-1} with 10cm rows spacing showed significantly higher grain yield by 113.22% and 105.67% respectively compared to 50/50 kg of N/P_2O_5 ha^{-1} with 30cm rows spacing. This might be due to the fact that plants supplied with adequate fertilizers tend to have good rooting ability for absorbing nutrients and water and have good vegetative growth which enhances grain filling compared to plants grown under lower fertilizer rates. This assertion is reflected in positive relationship of grain yield with tiller number. The present study was similar to the findings of Legesse Amsalu (2004) who reported better grain yields with adequate quantities of nitrogen and phosphorus application in tef in his study.

Further, the analysis of the harvest index of tef was significantly ($p<0.001$) affected by 12 treatments of rows spacing and combination of N/P_2O_5 fertilizer

Table 2: Main and interaction effects on tef grain yield in kg ha^{-1} and harvest index (%)

Fertilization	Grain yield (kg ha^{-1})				Harvest Index (%)			
	Row spacing							
N/P_2O_5(kg ha^{-1})	10cm	20cm	30cm	Mean	10cm	20cm	30cm	Mean
50/50	2150^d	1966^e	1766.6^f	1960.86^c	27^d	26^d	24^e	26^c
60/60	3036.7^b	2650^c	$2050d^e$	2588.89^b	32^{ab}	$31b^c$	27^d	31^b
70/70	3633.4^a	2933.4^b	2600^c	3055.56^a	34^a	32^{ab}	30^c	32.3^a
80/80	3766.7^a	3050^b	2633.3^c	3150^a	34^a	33^{ab}	30^c	032.6^a
Mean	3146.7^a	2649.8^b	2262^c		32^a	31^b	28^c	
LSD (5%) RS = 89.6					LSD(5%) RS = 0.79			
LSD (5%) FR = 103.5					LSD (5%) FR = 0.92			
LSD (5%) RS X FR = 80.52					LSD (5%) RS X FR = 0.1.5			
CV% 3.95					CV% 3.09			

***N.B:** Means of the same letter along columns and rows are not significantly different* rates (Table 2). The highest harvest index of34% was recorded from the combination of 80/80 kg of N/P_2O_5 ha^{-1} with 10cm row spacing. The harvest index of 33%, 32%, 32% were recorded from the combination of 80/80 kg of N/P_2O_5 ha^{-1} with 20cm rows spacing, 70/70 kg of N/P_2O_5 ha^{-1} with 20cm rows spacing and 60/60kg of N/P_2O_5 ha^{-1} with 10cm rows spacing respectively, which were statically at par with each other. The lowest harvest index recorded was 24%, from the combination of 50/50kg of N/P_2O_5 ha^{-1} with 30cm rows spacing. Plots treated with 80/80kg of N/P_2O_5/ha with 10cm and 70/70kg of $N/P_2O_5ha^{-1}$ with 10cm row pacing showed the harvest index increment of 41.7% and 41.7% respectively as compared to 50/50 kg of N/P_2O_5/ ha with 30cm. Greater harvest index was reported from 80/80 kg of N/P_2O_5 ha^{-1} with 10cm sow spacing and 70/70kg of N/P_2O_5 ha^{-1} with 10cm row spacing. Tareke Berhe (2010) reported that higher harvest index was obtained by reducing seed rate in tef. This might be because of the row spacing in row sowing method that might have reduced intera-specific competition and helped the crop to utilize growth resources in a better way to improve grain filling.

Economic analysis of experiment showed higher net benefits of ETB 50178 from the application of 80/80kg of N/ P_2O_5 ha^{-1} with 10 cm row spacing, followed by ETB 48017 from the treatment with application of 70/70kg of N/ P_2O_5 ha^{-1} with 10 cm rows spacing compared to the other treatments (Table 3). Therefore, row spacing and fertilizer rates directly affected crop yield and yield component of tef. The results reported by Tareke (2010) suggests that N/ P_2O_5 in similar quantities has the potential to produce higher productivity and net benefits in tef.

In order to assess the benefit : cost ratio associated with different treatments, the partial budget technique of CIMMT (1988) was applied on yield and straw yield. Based on this technique, the highest net return was obtained from 80/80 kg/ ha of N/P_2O_5 treatment with 10cm (Table 3). The partial budget analyzed indicate that at 10cm row spacing with 80/80 kg/ha of N/P_2O_5fertilizer rate resulted in maximum relative net return of ETB 50178 ha^{-1} followed by return of ETB 48017ha^{-1}fromthe treatment of 70/70kg of N/P_2O_5 with 10cm row spacing and the third higher net return was estimated at ETB 38121 ha^{-1} for 10cm row spacing with 60/60 kg/ha of N/ P_2O_5 fertilizer rate (Table 3). Similar higher net return was also reported by Tefera and Ketema (2001) in their research.

Table 3: Partial budget analysis for variable cost on mean yield of grain and straws

Parameters	T_{12}	T_{11}	T_8	T_4	T_9	T_{10}	T_7	T_6	T_5	T_3	T_2	T_1
AGYkgh^{-1}	1767	2050	1966	2150	2633	2600	2650	2933	3050	3037	3633	3767
SY kg ha^{-1}	5433	5500	6233	5583	5667	5900	5617	5867	6150	6233	6983	7350
GR ETB ha^{-1}	27389	31775	30473	33325	40812	40300	41075	45462	47275	47074	56312	58389
SR ETB ha^{-1}	8150	8250	9350	8374.5	8501	8850	8426	8801	9225	9350	10475	11025
TR ETB ha^{-1}	35539	40025	39823	41670	49313	49150	49501	54263	56500	56424	66787	69414
Cost of DAP ETB ha^{-1}	1535	1842	1535	1535	2456	2149	1842	2149	2456	1842	2149	2456
Cost of Urea ETB ha^{-1}	801	961	801	801	1280	1121	961	1121	1280	961	1121	1280
Variable cost ETB ha^{-1}	15500	15500	15500	15500	15500	15500	15500	15500	15500	15500	15500	15500
Total cost ETB ha^{-1}	17836	18303	17836(-)	17836(0)	19236	18770(-)	18303(-)	18770	19236	18303(-)	18770	19236
NB(ETB ha^{-1})	17703	21722	21987	23834	30077	30380	31198	35493	37264	38121	48017	50178
MRR%		861%			445.9%			919.7%	380%		2119%	463.7%

*Where, RS= Row Spacing, *Sale of grain = ETB 15.5 kg-1 and Sale of straw = ETB 1.5 kg-1. *Variable costs = Cost from land preparation to yield and straw yield transportation (ETB 15125) + cost of seed (ETB 375) were equivalent for all treatments. Where, GY kg/ha (in kilo gram/ hectare) = Grain yield, AGY = adjusted grain yield, SY = straw yield, GR Birr/ha= grain revenue in Birr/hectare, SR Birr/ha = straw revenue in Birr/ha, TR Birr/ha = total revenue in Birr/ha, TVct Birr/ha= total variable cost in Birr/ha, NB Birr/ha = net benefit Birr/ha, MRR%= marginal return rate in percentage.*

CONCLUSION

To conclude,the findings of the study suggest that, application of 80/80 kg of N/P_2O_5 ha^{-1} with 10cm rows spacing followed by 70/70 kg of N/P_2O_5 ha^{-1} with 10cm rows spacing by the same amounts of 25kg ha^{-1} of seed rate resulted in better economical return with maximum grain yield production for *kora* variety of tef in the field experiment. The study also suggests that there is potential to conduct future studies under varying amounts of seed rate below 25kg ha^{-1} with the studied N/P_2O_5 fertilizer rate and rows spacing.

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