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RESEARCH ARTICLE

# FARMERS' PARTICIPATORY EVALUATION OF TEFF (*ERAGROSTIS TEFF (ZUCC.) TROTTER*) PRODUCTIVITY IN RESPONSE TO NITROGEN AND PHOSPHOROUS FERTILIZERS AT EDO, WOLAITA ZONE, SOUTH ETHIOPIA

***Gifole Gidago and Fanuel Laekemariam**

Wolaita Sodo University, College of Agriculture, P.O.Box 138, Wolaita Sodo, Ethiopia

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**ABSTRACT**

Teff (Eragrostis tef) is one of the most important traditional staple cereal crop grown in Ethiopia extensively under various climatic and soil conditions. On farm experiments aimed at evaluating productivity of teff in response to NP fertilizers and identifying the most suitable NP rates for production of teff were conducted at farmer's field at Edo Kebele, Duguna Fango Woreda, Wolaita Zone, Southern Ethiopia in the main rainy seasons of 2012 and 2013. Four levels of nitrogen (0, 23, 46, and 69 kg ha$^{-1}$) and phosphorous (0, 10, 20, and 30 kg ha$^{-1}$) were used to evaluate productivity of teff under participatory approach by using Farmers' Research and Extension Group (FRG). Teff variety DZ-Cr-37 was used for the experiment in a factorial Randomized Complete Block Design (RCBD) with three replications. Application of nitrogen (N) and phosphorous (P) fertilizers had very highly influenced total biomass, grain and straw yields of teff but the effect of N and P interaction was not significant on these parameters. Highest net benefit was obtained with application of 23 kg ha$^{-1}$ followed by 46 kg ha$^{-1}$ after which the net benefit declined. Similarly, highest net benefit was obtained from the application of 10 kg P ha$^{-1}$. Farmers' evaluation result also indicated that most of the participating farmers preferred application of 23 kg N ha$^{-1}$ and 10 kg P ha$^{-1}$. Therefore, application of 23 kg N ha$^{-1}$ and 10 kg P ha$^{-1}$ is recommended for production of teff at Edo.



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## INTRODUCTION

Teff (*Eragrostis tef*) is the most important and traditional staple cereal crop in Ethiopia and is grown extensively under various climatic and soil conditions. It is a versatile crop growing in low land, mid and higher agro ecological zones of the country. Although it is adapted to a wide range of environments and diverse agro climatic conditions, it performs well at an altitude of 1800-2100 m a s l, annual rainfall of 750-850 mm, growing season rainfall of 450-550mm and a temperature of 10 $^{o}$C-27 $^{o}$C (Seifu Ketema, 1993). It performs well on clay loam and clay soils, which retain moisture during growing seasons. Teff is well suited on soils with a moderate fertility level and can tolerate a moderate waterlogged condition (National Soil Service, 1994). Teff is the dominant cereal crop providing over two-thirds of the human nutrition in Ethiopia (Lacey and Llewellyn, 2005). Doris (2002) reported that it contains 11% protein and excellent source of essential amino acids, especially lysine, the amino acid that is most often deficient in grain foods.

****Corresponding author: Gifole Gidago,***
*Wolaita Sodo University, College of Agriculture, P.O.Box 138, Wolaita Sodo, Ethiopia*

He further mentioned that teff is also an excellent source of fiber and iron, and has many times the amount of calcium, potassium and other essential minerals found in an equal amount of other grains. The author also noted that teff is nearly gluten-free, and is gaining popularity in the whole food and health industry in the U. S. as an alternative grain for persons with gluten sensitivity. Gilbert (1997) indicated that teff straw from threshed grain is considered to be excellent forage, superior to straws from other cereal species. Teff straw provides an excellent nutritional product in comparison to other animal feed and is also utilized to reinforce mud or plasters used in the construction of buildings. Teff covers the largest cultivated land as compared to cereals, pulses and oils, with average annual production of 1.87 million tones (CSA, 1999).Teff is also major grain crop next to maize in Wolaita Zone, Southern part of Ethiopia which occupies about 23% of the land covered by grain crops (SNNPRS, 2007). Like used in other parts of Ethiopia it is also used as sources of income, food, forage, etc. The average national productivity of teff in Ethiopia is 8 dt ha$^{-1}$ (CSA, 2003) and its productivity at Wolaita Zone is 7 dt ha$^{-1}$ (SNNPRS, 2007; Fanuel *et al.*, 2016). This is low compared to the yield that is attained under research center which is up to 32 dt ha$^{-1}$ (EIAR, 2015).

Depletion of nutrients as a result of erosion, crop mining, lack of optimum fertilizer rates, etc., are some of the problems contributing to the low productivity of crop. Fanuel and Gifole (2012) reported that N and P are low in Wolaita area in their study at Wolaita Zone. Wondewosen (2009) also reported similar result in his study at Wolaita Zone. In addition, Fanuel *et al.* (2016) demonstrated that in Wolaita area there was a continuous cultivation without fallowing and complete crop residue removal that consequently resulted for the appearance of multiple nutrient deficiencies (N, P, K, S, B and Cu). Therefore, one of the solutions to alleviate the problem could be application of NP fertilizers from external sources based up on recommendation for the crop. Application of fertilizers in a recommended amount is essential for high yield and quality of grains. The use of fertilizers is considered to be one of the most important factors to increase crop yield per unit area basis (Khan *et al*., 2003). Several studies at different locations on response of teff to NP fertilizers have shown that both the straw and grain yield of the crop have been increased due to the applied fertilizers. Reports from Debre Zeit Agriculture Research Center indicated that 40 kg N $ha^{-1}$ is generally optimum for better yield of teff. Another study by Abdena *et al*. (2006) at Wollega Zones indicated that application of N fertilizer on teff gave significant response and was economically feasible at 15 kg N $ha^{-1}$.

The report of Abay *et al*. (2011) also indicated that application of P at 10 to 30 kg/ha is recommended for teff production at a seeding rate of 25 kg/ha in Hossana area. However, little experimental information is available in Wolaita Zone especially in the study area. Furthermore, field visits and discussion with farmers in the study area also indicated that there is no information on the rates of NP fertilizers except that they are using nationally recommend rate for teff production although there is variation on use of it among farmers in the study area (Edo Kebele, Duguna Fango Woreda). Besides, the lower seeding rate of teff (10 kg/ha) recommended for the study area by Fanuel *et al*. (2012) through farmers' participatory research also demands further calibration of NP rate. Therefore, this research was initiated with the objectives to evaluate productivity of teff in response to NP fertilizers and to identify the most suitable NP rates for production of teff in the study area.

## MATERIALS AND METHODS

### Description of the Study Area

The field trial was conducted at farmer's field *at Edo Kebele, Duguna Fango Woreda, Wolaita Zone of Southern Ethiop*ia in the main rainy seasons of 2012 and 2013. In the site, there is established Farmers' Research and Extension Group (FRG) consisting of 16 farmers. The experiments was conducted on two selected farmer' field. The research site is found in the altitude ranging between 1300-2200 m.a.s.l, with the minimum and maximum average annual temperature $16^{0}$C and $26^{0}$C, respectively; and the average annual rainfall of 950 mm.

### Treatments and Experimental Design

Four levels of nitrogen (0, 23, 46, and 69 kg $ha^{-1}$) and phosphorous (0, 10, 20, and 30 kg $ha^{-1}$) were used to evaluate productivity of teff under participatory approach by using FRG. Teff variety DZ-Cr-37 was used for the experiment in a factorial Randomized Complete Block Design (RCBD) with three replications. Size of each plot was $9m^2$ (3m x 3m). The spacing between plots and blocks were 0.75m, respectively. Triple superphosphate (TSP) was used as source of phosphorous (P) and all doses were applied at sowing time. Urea was used as source of nitrogen (N) and was applied by split application (half at planting and the remaining half was applied at mid tillering stage). All cultural practices such as weeding, hoeing, etc. were kept uniform for all treatments.

### Data Collection

### Agronomic Data

Growth parameters, yield components, biological yield, grain yield and straw yield data were collected.

### Soil Data

Soil samples from depth of 0-30 cm were taken from the experimental field before sowing the crop for analysis of soil texture, pH, available P, total N, OC (Organic Carbon) and cation exchange capacity (CEC) following standard laboratory procedures as outlined by Sahlemedhin and Taye (2000).

### Farmers Participation in stand evaluation

After giving the awareness creation in depth to the selected farmers on importance of their involvement in the research, they were grouped into three and each group was assigned to one replication for stand evaluation at crop physiological maturity stage. Farmers' used their own criteria viz. lodging intensity, expected grain and straw yield. Each group had a secretary and after a number of round way trips on assigned replication coupled with a hot discussion, they came up with common ranking preferences. Finally, each group presented its preference to other participants. The preference of each group, total summary and average preference rank of FRG farmers is indicated on table 5. To summarize all rankings, tally method was used in which the first, second, third and fourth ranking had weighted value of four, three, two and one points, respectively.

### Economic Analysis

Economic analysis was done using partial budget analysis method. Both grain and straw yields were taken into consideration. In addition, the balance between USD and Ethiopian Birr (ETB) at the harvesting time which was 1 USD= 19.0131 ETB also considered. The field price of 1 deci ton (dt) of grain yield of teff that the farmer receives was 1500 Ethiopian Birr (ETB) or 78.8929 USD and that of 1dt straw yield was 30 Ethiopian Birr (ETB) which was equivalent to 1.5778 USD. N was applied as urea and its price was 11 ETB $kg^{-1}$ or 0.5785 USD. P was applied as TSP. Since TSP is not available in the market, the applied P was converted into Diammonium Phosphate (DAP) equivalents and its price was 12 ETB $kg^{-1}$ or 0.6311 USD. The gross benefit was calculated as grain yield in deci ton (dt) × field price that farmer receives from sale of crop + straw yield in deci ton (dt) × field price that farmer receives from sale of straw. Finally, net benefit was calculated by subtracting total variable cost from gross benefit.

### Data Analysis

The data collected were analyzed using the general linear model of Statistical Analysis System software (SAS) and means were compared using LSD at probability level of 5%.

## RESULTS AND DISCUSSION

### Selected Physico-chemical Properties of Experimental Soils

The result of soil analysis indicated that the experimental soil was sandy loam in its texture (Table 1). The pH of soil was 7.1 (Table 1) which is favourable for maximum availability of P according to Havlin *et al.* (1999). The available P content experimental soil which was 1.41 mgkg$^{-1}$ (Table 1), could be classified as low according to Pushparajah (1997) who classified the range of available P <11, 11-20, 20-30 and > 30 mgkg$^{-1}$ as low, medium, high and very high respectively. The low contents of P might be due to the uptake or utilization P by crops or due to continuous cropping with low or no application of P containing fertilizers. The low P contents of the study site might also be attributed to the lower contents of organic matter of the sites.

**Table 1. Selected physico-chemical properties of experimental soils before treatment application at Edo, in 2012 and 2013**

| Texture | pH ($H_2O$) | Available P (mgkg$^{-1}$) | Total N (%) | OC (%) | CEC (cmol (+) kg$^{-1}$) |
|---|---|---|---|---|---|
| Sandy loam | 7.1 | 1.41 | 0.15 | 0.53 | 27 |

**Table 2. Plant height (cm), Panicle length (cm) and Total number of productive tillers per plant (No.) as affected by NP application at Edo, in 2012 and 2013**

| | Plant height | Panicle length | No. of productive tillers per plant |
|---|---|---|---|
| Nitrogen | | | |
| 0 | 84.03b | 30.17b | 2.61b |
| 23 | 88.32a | 31.96a | 2.96a |
| 46 | 90.69a | 32.12a | 3.16a |
| 69 | 88.37a | 31.61a | 3.04a |
| LSD (5%) | 3.18 | 1.29 | 0.32 |
| Phosphorous | | | |
| 0 | 85.63 | 31.79 | 2.90 |
| 10 | 89.35 | 31. 73 | 2.81 |
| 20 | 87.99 | 30.92 | 3.22 |
| 30 | 88.45 | 31.43 | 2.85 |
| LSD (5%) | NS | NS | NS |
| Seasons | | | |
| 2012 | 89.37a | 32.74a | 2.53b |
| 2013 | 86.34b | 30.20b | 3.36a |
| LSD (5%) | 2.25 | 0.91 | 0.23 |
| CV | 6.28 | 7.08 | 18.92 |

Values followed by the same letter (s) within a column are not significantly different at P≤0.05.
NS-not significant.

The total N content of the experimental soils which was 0.15% (Table 1) is in the low range based on the classification made by Landon (1991). The organic carbon contents of the experimental soils was 0.53% (Table 1), which could be classified as very low according to the classification made by Herrera (2005), who classified OC content of < 0.6% as very low, 0.6-1.16% as low, 1.16-1.74% as moderate and > 1.74% as high. The results of OC and N contents could be due to continuous cultivation, lack of incorporation of organic materials, etc. Similar results were also reported by Wakene *et al.* (2001). According to Landon (1991) CEC ranges of 5-15, 15-25 and 25-40 cmol (+) kg$^{-1}$ are rated as low, medium and high, respectively. The CEC of experimental which was 27 cmol (+) kg$^{-1}$ (Table 1) is in the high range and is suitable for crop production.

### Response of teff to NP fertilizers

**Growth Parameters and Yield and Yield Components:** Combined data analysis of the two seasons revealed that there was a very high significant (p<0.001) effect of N application on plant height of teff (Appendix Table 1). The tallest (90.69cm) and the shortest (84.03cm) plant height were recorded from 46 kg N ha$^{-1}$ and control, respectively (Table 2). Application of 46 kg N ha$^{-1}$ significantly increased the plant height by 8% over the control. Statistically non significant differences among P rates on plant height were recorded. However, the highest plant height (89.35 cm) was obtained from plot that received 10 kg P ha$^{-1}$. Besides, N and P interaction was not significant on plant height. However, Assefa *et al.* (2016) reported a highly significant effect of NP on plant height. Non significant response of plant height to the application of NP was also reported by Dejene *et al.* (2010). Seasons had highly significantly affected plant height of teff (p<0.01) (Appendix Table 1). The higher plant height (89.37 cm) was obtained from the first season whereas the lower plant height (86.34 cm) was obtained from the second season (Table 2).

Data regarding panicle length revealed that applied N resulted in significant variation (p<0.05) on panicle length of teff (Appendix Table 1). The longest panicle length (32.12 cm) and the shortest (30.17cm) panicle length were recorded from 46 kg N ha$^{-1}$ and control, respectively (Table 2). However, applied P and its interaction with N did not significantly affect panicle length (Appendix Table 1). Contrary to this, Assefa *et al.* (2016) reported a highly significant response of panicle length to NP application on teff. Similarly, a highly significant response of panicle length to the application of NP was also reported by Dejene *et al.* (2010). On the other hand, seasons had a very highly significant effect on plant height of teff (p<0.001) (Appendix Table 1). The longer panicle length (32.74 cm) was obtained at the first season while the shorter one (30.20 cm) was obtained at the second season (Table 2).

Combined statistical analysis indicated that N application had highly significantly affected (p<0.01) total number of productive tillers per plant (Appendix Table 1) and its highest value (3.16) was obtained from the application of N at the rate 46 kg N ha$^{-1}$ whereas its lowest value (2.61) was obtained from the control (Table 2). P application was not significantly influenced ($p<0.05$) total number of productive tillers per plant (Appendix Table 1) although its value was highest (3.22) at 20 kg P ha$^{-1}$ and lowest (2.81) at 10 kg P (Table 2). Similarly, number of productive tillers per plant had no a significant response to NP interaction (Appendix Table 1). Non significant response of productive tillers per plant was also reported by Assefa *et al.* (2016). However, seasons had a very highly significant effect on total number of productive tillers per plant ($p<0.001$) (Appendix Table 1). The lower (2.53) and the higher (3.36) number of total productive tillers per plant were obtained from the first and the second seasons, respectively as can be seen from Table 2.

## Grain yield

Application of N had very highly significantly ($p<0.0001$) affected grain yield of teff (Appendix Table 2). N application at all rates resulted in significantly higher grain yield over the control. The grain yield increased with increasing levels of N. The highest grain yields (10.86 dt ha$^{-1}$) was obtained from the application of 69 kg N ha$^{-1}$ whereas the lowest grain yields (8.55 dt ha$^{-1}$) was obtained from the control. However except the control, all rates of N application were statistically at par with each other (Table 3). Data regarding P application also showed very highly significant ($p<0.0001$) influence on grain yield of teff (Appendix Table 2). Similar to N fertilizer application, all rates of P application were also resulted in significantly higher grain yield over the control. The highest grain yield of teff (11.10 dt ha$^{-1}$) was obtained from 10 kg P ha$^{-1}$ whereas the lowest (7.87 dt ha$^{-1}$) was obtained from the control. 10, 20 and 30 kg P ha$^{-1}$ rates of application were however statistically at par with each other (Table 3). The highest grain yield obtained in this study is higher than the average national productivity which is 8 dt ha$^{-1}$ (CSA, 2003) and its productivity at Wolaita Zone which is 7 dt ha$^{-1}$ (SNNPRS, 2007; Fanuel *et al.*, 2016). However, the highest grain yield obtained here is lower than the value which was obtained from the research center which is about 32 dt ha$^{-1}$ (EIAR, 2015). Many factors such as climate, soil, etc., might have attributed to the lower grain yield obtained in this study.
Contrary to the effect of N on the grain yield, no significant response was recorded from the interaction of N and P fertilizers (Appendix Table 2). Similar results were also reported by Abay *et al.* (2011) due to application of P, N and P interaction on grain yield of teff. Contrary to this, a highly significant response of grain yield due to application of NP on teff was reported Assefa *et al.* (2016). The effects of seasons were very highly significant on grain yield of teff ($p<0.001$) (Appendix Table 2). The higher (11.97 dt ha$^{-1}$) and the lower (8.40 dt ha$^{-1}$) grain yields were obtained from the first and the second seasons, respectively (Table 3)

## Total biomass and straw yield

The results of the experiment conducted in the study area indicated that levels of N had a very highly significant ($p<0.0001$) effects on total biomass and straw yields of teff (Appendix Table 2). All rates of applied N produced a significantly higher total biomass and straw yields of teff compared to the control (Table 3). The highest total biomass (43.16 dt ha$^{-1}$) and straw yield (32.40 dt ha$^{-1}$) were obtained from 46 kg N ha$^{-1}$, whereas the lowest total biomass (30.01 dt ha$^{-1}$) and straw yield (21.45 dt ha$^{-1}$) were obtained from the control. The total biomass and straw yield increased with increased levels of N from 0 to 46 kg N ha$^{-1}$ but decreased with further N application. The results of the experiment also indicated that the total biomass and straw yields of teff were very highly significantly ($p<0.0001$) influenced by applied P (Appendix Table 2). Similar to effects of N on total biomass and straw yield, P application at all rates resulted in significantly higher total biomass over the control (Table 3). 30 kg P ha$^{-1}$ application gave the highest total biomass which was 41.35 dt ha$^{-1}$ whereas the control resulted in the lowest total biomass which was quantitatively about 31.49 dt ha$^{-1}$. However, N and P interaction had no a significant effect on total biomass of teff (Appendix Table 2). Compared to the control, all rates of applied P resulted in significantly higher straw yield (Table 3). Both total biomass and straw yield increased with increasing levels of P as it was also observed on response of grain yield to increasing levels of N application. Similar to the interaction effects of N and P on grain yield and total biomass, the interaction of NP was not significant on straw yield (Appendix Table 2). Abay *et al.* (2011) around Hossana also reported similar results on straw yield of teff due to application of P, N and P interaction on teff. However, Assefa *et al.* (2016) reported a highly significant response of straw yield due to application of NP on teff. Total biomass and straw yields of teff were very highly significantly ($p<0.001$) influenced by seasons (Appendix Table 2). The higher total biomass (46.98 dt ha$^{-1}$) and straw yield (35.00 dt ha$^{-1}$) were obtained from the first season whereas the lower total biomass (30.13 dt ha$^{-1}$) and straw yield (21.72 dt ha$^{-1}$) were obtained from the second seasons (Table 3).

**Table 3. Total biomass (dt ha$^{-1}$), grain yield (dt ha$^{-1}$), straw yield (dt ha$^{-1}$) and thousand seed weight (g) as affected by NP application at Edo, in 2012 and 2013**

| | Total Biomass | Grain Yield | Straw Yield |
|---|---|---|---|
| Nitrogen | | | |
| 0 | 30.01c | 8.55b | 21.45c |
| 23 | 39.15b | 10.56a | 28.59b |
| 46 | 43.16a | 10.77a | 32.40a |
| 69 | 41.92ab | 10.86a | 31.02ab |
| LSD (5%) | 3.27 | 0.91 | 2.73 |
| Phosphorous | | | |
| 0 | 31.49b | 7.87b | 23.58b |
| 10 | 40.68a | 11.10a | 29.60a |
| 20 | 40.70a | 11.02a | 29.67a |
| 30 | 41.35a | 10.77a | 30.59a |
| LSD (5%) | 3.27 | 0.91 | 2.73 |
| Seasons | | | |
| 2012 | 46.98a | 11.97a | 35.00a |
| 2013 | 30.13b | 8.40b | 21.72b |
| LSD (5%) | 2.31 | 0.64 | 1.93 |
| CV | 14.70 | 15.51 | 16.70 |

Values followed by the same letter (s) within a column are not significantly different at $P \leq 0.05$. NS-not significant.

## Partial Budget Analysis

The economic analysis conducted taking both the average value of grain and straw yields (2012 and 2013) into consideration indicated that the highest net benefit was obtained from application of N at the rate 23 kg ha$^{-1}$ followed by 46 kg ha$^{-1}$ after which the net benefit declined (Table 4). Similarly, the highest net benefit was obtained from application of 10 kg P ha$^{-1}$ (Table 5).

## Farmers' Crop Stand Evaluation during the Experiment

Farmers' evaluation result revealed that most of the participating farmers preferred application of 23 kg N ha$^{-1}$ and

10 kg P ha$^{-1}$ (Table 6). The farmers' evaluation during the research indicated that application of N/P at the rates 23/10, 23/0 and 69/30 kg ha$^{-1}$ preferred as 1st, 2nd and 3rd rank, respectively (Table 6).

**Table 4. Partial budget analysis for N treatments in the form of Urea fertilizer at Edo, in 2012 and 2013**

| Parameters (Urea Fertilizer) | 0 | 50 | 100 | 150 |
|---|---|---|---|---|
| Grain Yield (dt/ha) | 8.55 | 10.56 | 10.77 | 10.86 |
| Grain income (@ 1500 birr/dt) | 12825 | 15840 | 16155 | 16290 |
| Straw Yield(dt/ha) | 21.45 | 28.59 | 32.4 | 31.02 |
| Straw income (@30 birr/dt) | 643.5 | 857.7 | 972 | 930.6 |
| Total income (birr) | 13468.5 | 16697.7 | 17127 | 17220.6 |
| Cost of Urea (11birr/kg) | 0 | 550 | 1100 | 1650 |
| Total Variable Cost | 0 | 550 | 1100 | 1650 |
| Net Benefit (Birr/ha) | 13468.5 | 16147.7 | 16027 | 15570.6 |
| Benefit: Cost | | 29.4 | 14.6 | 9.4 |

**Table 5. Partial budget analysis for P treatments in the form of DAP fertilizer at Edo, in 2012 and 2013**

| Parameters (DAP Fertilizer) | 0 | 50 | 100 | 150 |
|---|---|---|---|---|
| Grain Yield (dt/ha) | 7.87 | 11.1 | 11.02 | 10.77 |
| Grain income (@ 1500 birr/dt) | 11805 | 16650 | 16530 | 16155 |
| Straw Yield(dt/ha) | 23.58 | 29.6 | 29.67 | 30.59 |
| Straw income (@30 birr/dt) | 707.4 | 888 | 890.1 | 917.7 |
| Total income (birr) | 12512.4 | 17538 | 17420.1 | 17072.7 |
| Cost of DAP (12birr/kg) | 0 | 600 | 1200 | 1800 |
| Total Variable Cost | 0 | 600 | 1200 | 1800 |
| Net Benefit (Birr/ha) | 12512.4 | 16938 | 16220.1 | 15272.7 |
| Benefit: Cost | | 28.2 | 13.5 | 8.5 |

**Table 6. Summary of farmers' preference during stand evaluation of crop at Edo, in 2012 and 2013**

| Treatment Combination | NP rate (kg/ha ) | Farmers Preference | | | | |
|---|---|---|---|---|---|---|
| | | Group 1 | Group 2 | Group 3 | Total Point | Average Ranking |
| N1p1 | 0/0 | 0 | 0 | 0 | 0 | |
| N1P2 | 0/10 | 0 | 0 | 0 | 0 | |
| N1P3 | 0/20 | 0 | 0 | 0 | 0 | |
| N1P4 | 0/30 | 0 | 0 | 1 | 1 | |
| N2P1 | 23/0 | 2 | 2 | 4 | 8 | 2nd |
| N2P2 | 23/10 | 4 | 4 | 3 | 11 | 1st |
| N2P3 | 23/20 | 0 | 0 | 1 | 1 | |
| N2P4 | 23/30 | 0 | 2 | 0 | 2 | 4rth |
| N3P1 | 46/0 | 0 | 2 | 0 | 2 | 4rth |
| N3P2 | 46/10 | 0 | 0 | 0 | 0 | |
| N3P3 | 46/20 | 0 | 1 | 0 | 1 | |
| N3P4 | 46/30 | 1 | 0 | 1 | 2 | 4rth |
| N4P1 | 69/0 | 0 | 0 | 0 | 0 | |
| N4P2 | 69/10 | 0 | 0 | 0 | 0 | |
| N4P3 | 69/20 | 1 | 0 | 0 | 1 | |
| N4P4 | 69/30 | 1 | 1 | 1 | 3 | 3rd |

Lodging intensity, expected grain and straw yield were the most frequently indicated justifications for selecting treatments in the field. This suggests that FRG approach has some positive effects on extension process due to farmers' better understanding of scientific data. Furthermore participation of farmers is helpful in order to bring more precise information during research output applicability to wider context

### Conclusion and Recommendations

The study revealed that application of chemical fertilizers in optimum amount is very important for production of teff in the study area. Accordingly, in the study area, application of N and P fertilizers very highly influenced total biomass, grain and straw yields of teff although NP interaction did not show significant influence on these parameters. The highest grain yields (10.86 dt ha$^{-1}$) and (11.10 dt ha$^{-1}$) were obtained from the application of 69 kg N ha$^{-1}$ and 10 kg P ha$^{-1}$, respectively. The economic analysis conducted by taking both the grain and straw yields into account revealed that highest net benefit was obtained from application of N and P at the rates of 23 kg ha$^{-1}$ and 10 kg P ha$^{-1}$, respectively. Farmers' crop stand evaluation result also indicated that most of the participating farmers preferred application of 23 kg N ha$^{-1}$ and 10 kg P ha$^{-1}$. Therefore, application of 23 kg N ha$^{-1}$ and 10 kg P ha$^{-1}$ is recommended for production of teff under reduced seed rate (10 kg ha$^{-1}$) at Edo.

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## Appendix Tables

**Appendix Table 1. Mean square values for Plant height (cm), Panicle length (cm) and Number of productive tillers per plant (No.) as affected by NP application at Edo, in 2012 and 2013**

| Mean Square | | | | |
|---|---|---|---|---|
| Source | DF | Plant height | Panicle length | Number of productive tillers per plant |
| Rep | 2 | 0.18 | 12.06 | 0.49 |
| N | 3 | 185.59*** | 19.03* | 1.33** |
| P | 3 | 60.36 | 3.81 | 0.82 |
| N*P | 9 | 21.89 | 8.64 | 0.40 |
| Season | 1 | 220.01** | 155.02*** | 16.37*** |
| Error | 62 | 30.42 | 4.96 | 0.31 |

DF- degree of freedom

*, **, ***- Significant at 0.05, 0.01 and 0.001 probability levels, respectively.

**Appendix Table 2. Mean square values for total biomass (dt ha$^{-1}$), grain yield (dt ha$^{-1}$), straw yield (dt ha$^{-1}$) and thousand seed weight (g) as affected by NP application at Edo, in 2012 and 2013**

| | | Mean Square | | |
|---|---|---|---|---|
| Source | DF | Total biomass | Grain yield | Straw yield |
| Rep | 2 | 16.20 | 1.98 | 8.69 |
| N | 3 | 847.60*** | 28.86*** | 568.80*** |
| P | 3 | 535.40*** | 57.79*** | 248.70*** |
| N*P | 9 | 21.27 | 0.98 | 18.25 |
| Seasons | 1 | 6811.95*** | 306.81*** | 4234.33*** |
| Error | 62 | 32.12 | 2.50 | 22.44 |

DF- degree of freedom
*, **, ***- Significant at 0.05, 0.01 and 0.001 probability levels, respectively.

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