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Verification and Demonstration of Soil Test Based Phosphorus Fertilizer Recommendation Rate on Yield of Teff (Eragrostis Tef (Zucc) Trotter) in Vertisols of Northern Ethiopia

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Abstract
Nitrogen and phosphorus fertilizers are the major limiting factors in most Ethiopia Vertisols. Phosphorus calibration experiments were conducted at wereda Tahtay koraro for phosphorus fertilizer recommendation on Teff for Teff producing area and critical concentration and requirement factor of Phosphorus fertilizer were developed. Using these critical concentrations verified at Medebay-Zana district at farmer's field by the year of 2011. The treatments were blanket recommendation (46 kg N ha^{-1}, 46 kg P_2O_5 ha^{-1}) and soil test based phosphorus fertilizer recommendation. The result of Soil test based phosphorus fertilizer recommendation rate (STBR) on teff shows that higher yield as compared to blanket fertilizer recommendation. The maximum grain yield obtained from Soil test based phosphorus fertilizer recommendation rate (STBR) was 2100 kg ha^{-1} and the minimum is obtained 949 kg ha^{-1}. Generally the grain yield and straw yield showed that 26.42% and 35.26% yield increment over the blanket type application of fertilizer. Due to this result the farmers on the soil test based phosphorus fertilizer recommendation rate (STBR) technology perceived positively.
Keywords: Blanket recommendation, Soil test, Vertisols, Teff, Medebay-Zana

1. Introduction
Ethiopia is one of the sub-Saharan African countries where severe soil nutrient depletion and low agricultural production is observed as well as economic growth Even though the country has potentially rich in land resource (Getahun, 2003). Soil fertility is considered to be the major bottleneck constraint in crop production in Ethiopia which is due to continuous cultivation of the soils without adequate replenishment for many years (FAO, 1999). The major plant nutrients are N and P that added to the soil in the form of Di-Ammonium phosphate (DAP) and urea fertilizer (Henry, 1990).

Agriculture is the driving force of the Ethiopian economy, growth and long-term food security. Agriculture directly supports 80-85% of the population, 43% of gross domestic product (GDP) and over 80% of export value (Bationo *et al*., 1993). According to reports of CSA (2014) smallholder farmers are the backbone of the sector, crop production by area is predominantly cereals (79.38%) followed by pulses (14.04%), oil crops (6.58%) and others (4.34%). Five major cereal crops account for almost all production: maize (25.81%), Teff (17.57%), sorghum (15.22%), wheat (15.60%) and barley (7.59%).

Application of urea and DAP fertilizers has been adapted through extension program in the Ethiopia. The blanket recommendations are, regardless of considering the physical and chemical properties of the soil as well as does not taken to account climatic condition and available nutrient present in the soil (Taye Bekele *et al*., 2000). As indicated by Seyfu (1993). There are different blanket fertilizer recommendations for various soil types of Ethiopia for teff cultivation. N/P recommendation rates by the Ministry of Agriculture were set at 55/30, 30/40, and 40/35 N/P kg ha^{-1} for teff crop on Vertisols, Nitosols, and Cambisols, respectively across the country. However, 100 kg ha^{-1} of DAP and 100 kg ha^{-1} of urea were set by the Ministry of Agriculture and Rural Development later (Kenea *et al*., 2001) and these blanket recommendation leads to Excess or low application of chemical fertilizers, that aggravates stunted growth of plants due to toxicity or deficiency of the essential elements (Abreha and Yesuf, 2008). However, for many years no studies have been conducted on site specific fertilizer recommendation rate.

But since 2004 Tigray Agricultural Research Institute was started calibration studies for cereal crops especially for teff, wheat and barley crop and developed some critical concentrations and requirement factors of phosphorous fertilizer recommendation guide line (TARI, 2010). As indicated by Abreha and Yesuf (2008) the experiment that conducted at Tahtay koraro for phosphorus fertilizer recommendation on teff for teff producing area have already established, That is the critical Value (6 mg kg^{-1}) and requirement factor of Phosphorus (4.76 mg kg^{-1}). Using the above critical concentration and requirement factor experiment was conducted at Medebay-Zana district. Therefore, this study was initiated to evaluate soil test with blanket fertilizer recommendation and to asses farmers' perception up on the soil test recommendation.

2. Materials and methods
2.1. Description of the Study Area
The field experiment was conducted during the 2011 main cropping season under rainfed conditions at farmer's

field in Medebay-Zana District, North West Zone of Tigray Regional State. Medebay-Zana District one of the six districts of the North West Zone, is located 14^0 6' 26'' E and 38^0 27' 19'' N. The District altitude varies between 1700 and 2800 meter above sea level.

The study area is characterized by uni-modal rainfall pattern with the main wet season (*kiremt*) extending from July to September. Similarly, the mean maximum and minimum temperatures were 21.28 and 7.56^0C, respectively. Vertisols are the dominant soil types in the area. The area has crop-dominated mixed crop-livestock farming system. The dominant crops growing around the experimental area are wheat (*Triticum aestivum* L.), maize (*Zea mays* L.), barley (*Hordeum vulgare*), teff (*Eragrostis tef*) and some species of legume crops (Abreha and Yesuf, 2008).

2.2. Experimental Procedures and Treatments

The experiment was conducted at farmer's field and consisted of two treatments that is blanket recommendation (46 kg N and 46 kg P_2O_5 ha^{-1}) and soil test result of phosphorus with fixed amount of nitrogen (46 kg N ha^{-1}). A full dose of P was applied at planting time close to seed drilling line, while N fertilizer was applied in split application, half at planting time and the rest three weeks after planting. Source of the fertilizers for N and P were Urea and Triple super phosphate respectively. The plot size was 10 m * 10 m (100 m^2) with 50 rows. The spacing between rows and plots was 20 cm and 1 m, respectively. All recommended cultural practices for the test crop were done as per the recommendation.

2.3. Soil Sampling and Analysis

2.3.1. Soil Sampling

Before planting, surface composite soil samples were collected from the field for site characterization at a depth of 0-20 cm. Auger was used for collecting soil samples. The collected samples were properly labeled, packed and transported to Mekelle soil laboratory. The surface soil samples collected from the experimental field were air dried and grinded and allowed to pass through 2 mm sieve and for further analysis for total nitrogen and organic carbon allowed to pass through 0.5 mm sieve (FAO, 2008).

2.3.2. Soil Analysis

Particle size distribution was determined using the Bouyoucos hydrometer method (Bouyoucos, 1962). The pH of the soil was measured in the supernatant suspension of a 1: 2.5 soil to water ratio using a pH meter (Rhoades, 1982). Electrical conductivity (EC) was measured according to the method described by Jakson (1967). Organic carbon was determined by the Walkely and Black (1934). Total nitrogen was determined using the Kjeldahl method as described by Bremner and Mulvaney (1982). Available P was determined following the Olsen method (Olsen *et al*., 1954) using ascorbic acid as reducing agent. CEC soil was determined by ammonium acetate method (FAO, 2008).

2.4. Data Analysis

The collected data were subjected to statistical analysis. Analysis of variance (ANOVA) was carried out using SAS version 9.1 statistical software program (SAS, 2004). Significant difference between and among treatment means were assessed using the least significant difference (LSD) at 0.05 level of probability (Gomez and Gomez, 1984).

3. Result and discussion

3.1. Soil Characteristics of the Study Area

3.1.1. Chemical Properties of Soils

3.1.1.1. Soil reaction and electrical conductivity

The data in Table 1 in indicates that the soil pH value within the soil showed inconsistently. According to the soil pH rating established by Tekalign (1991), the results of soil analysis in this study showed that the pH of the soil varied from neutral to slightly alkaline in the study area. According to Landon (1991) soils having pH value in the range 5.5 to 7.5 are considered suitable for most agricultural crops. Therefore, the soil pH values recorded for the study area of the present study agree with these findings.

The observed values of electrical conductivity (EC) in the study area were below critical values. In the surface soil horizons, it ranged from 0.012 to 0.042 ds m^{-1} in all composite soils. Generally, the EC values measured throughout the composite soil samples of the soils in the study area indicated that the concentration of soluble salts above the levels at which growth and productivity of most agricultural crops are affected due to soil salinity (US Salinity Laboratory Staff, 1954; Landon, 1991).

3.1.1.2. Organic carbon and total nitrogen

The data in Table 1 in indicated that the organic carbon values within the composite soil samples showed that no significant difference. The observed trend could be due to the intensive cultivation, removal of total crop residue and the animal manure used for fire. Soil organic matter (SOM) content is generally low in cultivated soils when compared to soils under grazing and forest lands (Eylachew, 1999). According to the soil organic carbon rating established by Tekalign (1991), the results of soil analysis in this study showed that the OC of the soil varied from low to medium in the study area. Therefore, according to Landon (1991) and Tekalign (1991) the SOC values recorded for composite surface soil samples of the experimental fields of the study area were rated under low to medium rate.

As organic carbon contents of the experimental fields, the contents of the total N (TN) also decreased consistently with depth. The observed trend might be because of low organic substrate content and low activity of microorganism at the upper soil layers. According to the TN rating established by Landon (1991), the results of soil analysis in this study showed that the TN of the study area was under low to medium rating. The low total N contents indicate that the soils of the study area are deficient in N to support proper growth and development of crops for expressing their genetic yield potential which suggest that the soils require fertilization with external N inputs and gradual build of its OC levels to ensure sustainable productivity.

3.1.1.3. Available Phosphorus

The result presents at Table 1 for available phosphorus content indicates that the values within the composite soils of the experimental sites were inconsistent. The observed trend may be ascribed to the low SOC content, removal of total crop residue, severe soil erosion and the insignificance application of animal manure. According the soil atlas of Tigray regional state indicates that the low available phosphorus content in the region could be due to low amount of organic materials applied to the soil and complete removal of biomass from the field (Tekalign *et al*., 2014). According to Tisdale *et al*., (2002) soil P sufficiency rating, the available P content of the composite soil samples in the study area were rated under medium (8.96 mg kg^{-1}).

3.1.1.4. Cation exchange capacity (CEC)

As indicated in Table 1 CEC did not show any clear pattern of variability among the composite samples of the experimental sites. The parent material and type of clay might have been very important in contributing to the CEC values. This is in line with the findings of Landon (1991) who reported very high CEC on Vertisols and that varied with soil depth. According to the rating suggested by Hazelton and Murphy (2007) the CEC values of the composite soil samples in the study area were rated under medium (16.37 Cmol (+) kg^{-1}).

Table1. Soil characteristics of experimental sites

Location	EC (ds m^{-1})	pH (1:2.5)	OC (%)	TN (%)	Avail. P (mg kg^{-1})	CEC (Cmol (+) kg^{-1})	Particle size distribution (%)			Textural class
							Sand	Silt	Clay	
Composite-1	0.024	7.41	1.24	0.13	10.41b	13.18	38	27	35	Clay loam
Composite-2	0.017	6.93	1.12	0.12	6.42b	14.92	15	37	48	Clay
Composite-3	0.012	6.69	1.03	0.05	9.83b	17.75	18	30	52	Clay
Composite-4	0.025	7.53	1.07	0.08	4.87b	15.60	33	29	38	Clay Loam
Composite-5	0.042	7.48	1.84	0.15	13.27a	20.43	13	38	49	Clay
Mean	0.024	7.26	1.26	0.106	8.96	16.37				
LSD	0.019	1.12	1.28	0.13	5.63	6.86				
CV (%)	10.44	7.46	26.56	19.34	17.41	14.25				
α = 0.05	ns	ns	ns	ns	*	ns				

EC= Electrical Conductivity; OM=Organic Matter; TN=Total Nitrogen; Avail. P= Available Phosphorus; CEC=Cation Exchange Capacity

3.2. Yield and yield components of Teff as influenced by STBPR

The result of the trial conducted at Medebay-Zana shows that Teff grain yield was highly increased with application of 46 kg/ha N and site specific fertilizer recommendation, which gave 297 kg/ha yield advantage over the blanket type fertilizer recommendation. As indicated by (Haftamu *et al.,* 2000) with extra use of NP the Teff grain yield was no variation or not economical. In contrast the fertilizer cost is increasing and the economic return is not comparable with the cost of fertilizer that incur to the household income but, the use of 46 kg ha^{-1} N and site specific fertilizer application increased Teff grain yield from 1540 kg ha^{-1} to 2100 kg ha^{-1} with grain yield increment. The optimum N which is 46 kg N ha^{-1} and site specific fertilizer recommendation rate was influenced Teff grain yield and the mean maximum grain yield was 1421 kg ha^{-1} with a 26.42% grain yield advantage over the blanket type fertilizer recommendation rate.

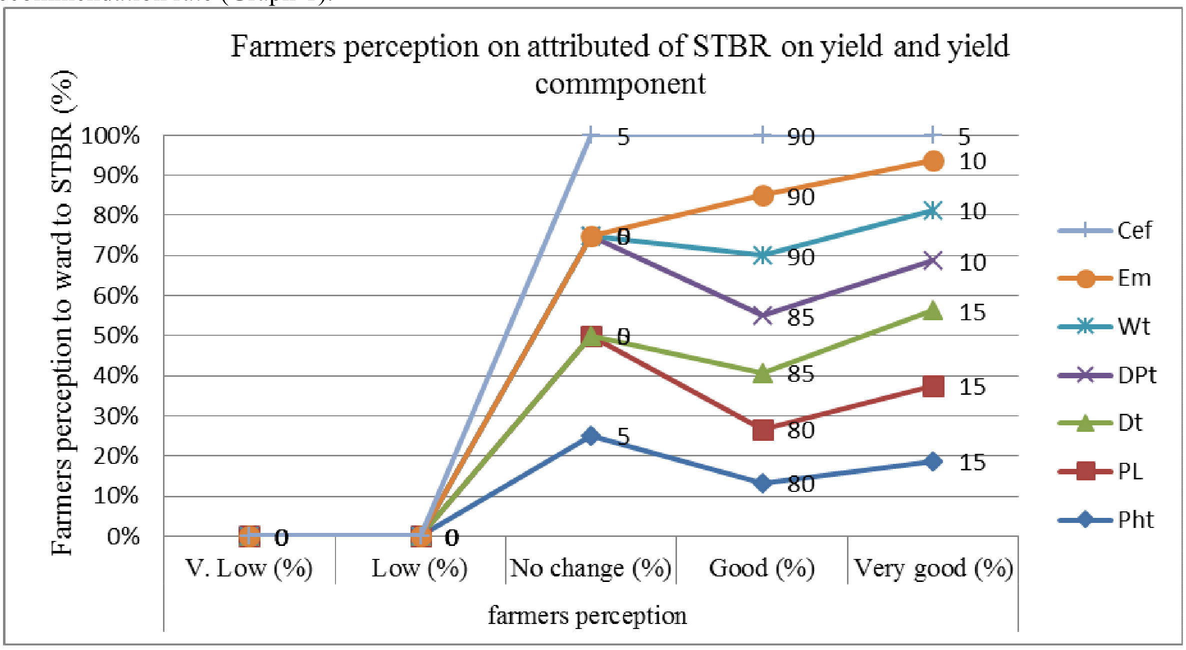
The result of the trial conducted at Medebay-Zana shows that Teff straw yield was highly increased with application of 46 kg ha^{-1} N and site specific fertilizer recommendation, which gave 1959 kg ha^{-1} straw yield advantage over the blanket type fertilizer recommendation. As indicated by (Haftamu, 2000) with extra use of NP the straw yield was no change. On the other hand the fertilizer cost is increasing and the economic return is not comparable with the cost of fertilizer that incur to the household income but, the use of 46 kg ha^{-1} N and soil test based P increased teff straw yield from 6075 kg ha^{-1} to 8658 kg ha^{-1}. The optimum N which is 46 kg N ha^{-1} and site specific fertilizer recommendation rate was influenced teff straw yield and the mean maximum straw yield was 7515 kg ha^{-1} with a 35.26% straw yield advantage over the blanket type fertilizer recommendation rate.

Table 2: Descriptive statistics of soil test based "P" fertilizer recommendation (STBR) on grain and straw yield

Attributes	Grain yield (kg ha^{-1})		Average	Straw yield (kg ha^{-1})		Average	% increment
	minimum	maximum		minimum	maximum		26.42% and 35.26% yield increment over the blanket type for grain and straw yield respectively
With technology	949	2100	1421	6075	8658	7515	
w/out technology	632	1540	1124	4567	6823	5556	

3.3. Farmer's perception to wards to STBPR

Most farmers perceived positively on the soil test based phosphorus fertilizer recommendation rate (STBPR) with respect to Plant height, Panicle length, Drought tolerance, Disease and pest tolerance, early maturing and cost effectiveness (gained grain vs. fertilizer). In the verification and demonstration of the STBPR no one had bad or low attitude on the technology and they gave their suggestions from there was no change when they compared from the blanket type fertilizer recommendation rate and those counts 5% of the farmers that involved in the verification and demonstration work, on the other hand more than 80% of have good and very good attitude toward the soil test based phosphorous fertilizer recommendation rate than blanket fertilizer recommendation rate (Graph-1).



Graph-1: Farmers perception on attributed of STBR on yield and yield component

Cef= Cost effectiveness; Em= Early maturing; Wt=Weed tolerance; DPT= Disease and pest tolerance; Dt= Drought tolerance; PL= Panicle length; Pht= Plant height

4. Conclusion

The optimum N which is 46 kg N ha^{-1} and site specific fertilizer recommendation rate was influenced teff grain and straw yield and the mean maximum grain yield was 1421 kg ha^{-1} with a 26.42% grain yield advantage over the blanket type fertilizer recommendation rate and 7515 kg ha^{-1} with a 35.26% straw yield advantage over the blanket type fertilizer recommendation rate. Due to this result the farmers on the soil test based phosphorus fertilizer recommendation rate (STBR) perceived positively, therefore,

- ❖ Further effort should be made to disseminate the Soil test based phosphorus fertilizer recommendation rate (STBR).
- ❖ Soil laboratories should be functional and expanded throughout the region so that farmers will get access to test their soil.
- ❖ Research institute and BoARD should work and harmonize on the transfer of the technology to farmers or end users.

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