6. Verification of Phosphorus for Sorghum (*Sorghum bicolor*) and Tef (*Eragrostis tef*) in the Low Land Areas of North Shewa Zone, Ethiopia

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Abstract

On farm trials on verification of Phosphorus containing fertilizers for major cereals crops was conducted at Kewet, Efratana gedem, Antsokiya gemza and Ensarona wayu districts in 2018/19 main cropping season to verify the need of Phosphorus containing fertilizers for the major cereals crops in the lowland areas of North Shewa. *The experiment consisted of five treatments including: T_1 (0 P_2O_5 $Kgha^{-1}$), T_2 (46 P_2O_5 $Kgha^{-1}$TSP), T3 (19 P_2O_5 $Kgha^{-1}$NPSB), T_4 (38 P_2O_5 $Kgha^{-1}$NPSB) and T_5 (57 P_2O_5 $Kgha^{-1}$NPSB) with recommended rate of Nitrogen (100 $Kgha^{-1}$ urea) NPS and TSP were applied as a straight fertilizer at planting. These treatments were distributed in randomized complete block design with three replications. Analysis over location showed that grain yield was not significantly ($P<0.05$) affected by the application of P fertilizer except on plant height for both sorghum and tef. However, relatively high sorghum grain yield (4837.9 Kg) and tef yield (1415.7 Kg) were, obtained from the application of 57 $Kgha^{-1}$ P_2O_5. Even though the soil analysis result of available Phosphorus was within the low range for the testing sites, application of P fertilizer sources did not significantly affected sorghum and tef grain yield and yield components. The organic carbon and available Phosphorus content of the testing sites was very low so that management of soil organic matter and application of adequate amount of Nitrogen containing external fertilizer sources as well as application of maintenance Phosphorus are indispensable. This result showed that further investment of Phosphorus fertilizer had not more agronomical advantageous. It is better to use at least 19 $Kgha^{-1}$ P_2O_5 for the maintenance of soil P depleted through crop up take, residue removal, animal grazing and other purposes. Special attention needs further considerations of crop type in external sources of P containing fertilizer sources. Otherwise, it is not economical to use P source fertilizer around the study areas.*

Introduction

Chemical fertilizers are believed to be the key components of nutrient sources of major production of agricultural crops. In Ethiopia, increasing crop production and productivity strategy is given a top priority implementation of high input and improved technology utilization (Araya & Sung-Kyu, 2019). Increasing crop yields and closing the yield gap can be accomplished by implementing and advancing a variety of practices and technologies, such as adequate fertilizer use and efficient nutrient management, which can play critical roles in global food security (Stewart, and Roberts, 2012 and, Van der Velde M *et al*., 2014). The production capacity of soil is determined by its chemical and physical properties which help in the full utilization of the essential elements in the soil by plant roots (Ibeawuchi *et al.,* 2007). Hailu, (2014) reported that most Ethiopian soils are deficient in macro and micronutrients.

The government of Ethiopia did several efforts to popularize the implementation of soil test based fertilizer application system through the use of soil fertility information with newly introduced fertilizer formulas such as NPS, NPSB, NPSBZn and NPSCu which contains N, P, S Bo, Zn, and Cu (MOANR, 2016). In addition, to address the newly developed fertilizer utilization information, several stakeholders promoted farmers by importing and distributing chemical fertilizers through cooperatives to improve crop productivity [illegible] loped ation

Lowland areas of North Shewa during the main cropping season of 2018/19 to verify the need of Phosphorus containing fertilizers for sorghum (*Sorghum bicolor* L.) Moench]) and tef and validate the newly released soil fertility status and fertilizer recommendation map of Amhara Region respectively. Geographically, the experimental sites were located at 09° 54' 45" to 10°00'44" N and 39°33'34" to 40° 02'26" E in Kewet; 10°17'20" to 10° 24'22" N and 39°54'26" to 39° 55'23" in Efrata gedem; 10°39'59" to 10° 43'16" N and 39°41' 34" to 39° 47'43" E in Antsokiya, and 09^0 91' to 09^0 94'N and 36^0 61' to 39^0 67'E in Ensarona wayu districts with the altitude range of 1287-1323, 1488-1586, and 1443-1454 m.a.s.l. The study areas are characterized by a unimodal rainfall pattern and receive an average annual rainfall of 760.2 mm in Kewet, 762.5 mm in Efrata gedem, 1005.2 mm in Antsokiya gemza and 926.8 mm in Ensarona wayu districts. The long term annual mean minimum and maximum air temperatures were 14.53 and 29.72 in Kewet, 14.61 and 30.01 in Efratana gedem, 13.85 and 25.07 in Antsokiya gemza and 12.66 and 25.42 in Ensarona wayu. Generally, Vertisols are the dominant soil type across the study areas.

Before starting the experiment, initial composite and after harvesting from each experimental treatment soil samples were collected (to determine soil pH, Av.P, OC, TN, Av.K and soil texture). Soil pH was measured in H_2O (pH-H_2O) using 1:2.5 soil to solution ratio by pH meter as outlined by Van Reeuwijk (1992). Soil organic content which was analyzed as described by Walkley and Black (1934). The modified Kjeldahl procedure was followed for the deter- mination of TN of soils as described by Jackson (1958). Available Phosphorus in soil samples was extracted by Olsen extraction method (Olsen *et al*., 1954). The content of P in the extract was determined using spectrophotometer following the procedure described by Murphy (1968). They were five treatments including: T_1 (0 $Kgha^{-1}$ P_2O_5), T_2 (46 $Kgha^{-1}$ P_2O_5 from TSP**),** T3 (19 $Kgha^{-1}$ P_2O_5 from NPSB), T_4 (38 $Kgha^{-1}$ P_2O_5 from NPSB) and T_5 (57 $Kgha^{-1}$ P_2O_5 from NPSB) with recommended rate of Nitrogen (46 $Kgha^{-1}$ from urea) NPSB and TSP were applied as a straight fertilizer at planting. These treatments were distributed in randomized complete block design with three replications.

The gross plot size for sorghum was $26.25m^2$ and for tef was 25 m^2. The blocks were separated by 1m wide-open spaces; whereas the plots within a block were 0.5 m apart from each other. The seeds of sorghum were sown at the rate of 10 $Kgha^{-1}$ in rows of 75 cm at the spacing of 20 cm between seeds for sorghum after thinning, and for tef seeds were sown with the rate of 30 $Kgha^{-1}$

in broadcast. Among the total number of seven rows of sorghum the middle three rows and 2m by 2m ($4m^2$) for tef were used to evaluate the study variables. Girana-1 sorghum variety Kuncho tef varieties were used as a test were used as test crops. Sorghum seeds were treated with Apron star to protect head smut. Disease and pest controlled was according to the recommended methods.

Data Analysis: The agronomic and yield data were analyzed using the general linear model (GLM) procedures of the SAS statistical software (2002) to evaluate the effect of different sources of P fertilizer. Least Significant Difference (LSD) test at P≤0.05 was used to separate means whenever there were significant differences among different treatments.

Results and Discussion

Selected Soil Chemical Properties of the Experimental Sites: The selected soil chemical and physical properties of the composite samples of the experimental sites indicated in Table 1 and 2. The results revealed that the soil reaction was from neutral to slightly alkaline (Tekalegn, 1991). According to the criteria set by Landon (1991), the organic carbon content of soils ranged from 0.38 to 1.79% which is rated as very low (>85% of testing sites) and the total Nitrogen content was also ranged 0.03 to 0.22% as low (90% of testing sites) to medium. The Olsen extractable available Phosphorus was very variable which was ranged from very low (38%), low (44%) and medium (18%) from the total testing sites (Tekalign, 1991).

Table1. Selected physical and chemical properties of the experimental soil sorghum at Kewet, Efratagedem, Antsokiya and Ensaro Districts, 2018/19

Districts	Sites	pH (1:2.5)	OC (%)	TN (%)	Av.P (ppm)	Cl	Si	S	Textural Class
Kewet	Charie	7.28	1.04	0.09	2.44	52	36	12	Clay
	Medina	7.57	1.04	0.10	1.82	70	16	14	Clay
	Sefeberet	7.66	1.79	0.14	2.22	71	16	13	Clay
Efrata gedem	Yimlo	6.67	0.82	0.03	10.86	36	20	44	Clay loam
	Feredeweha	6.93	0.83	0.09	4.44	48	42	10	clay
Antsokiya gemza	Mekedesa	6.69	1.08	0.22	13.62	37	37	27	Clay
	Atiko	6.69	1.17	0.11	24.00	22	40	38	Loam
	Afso	6.68	1.26	0.10	10.62	34	37	29	Clay loam
Ensarona wayu	Jamma1	6.66	-	0.024	19.02	40	34	26	Clay

Table2. Selected physical and chemical properties of the experimental soil tef at Kewet, Efratagedem, Antsokiya and Ensaro Districts, 2018/19

District	Sites	pH (1:2.5)	OC (%)	TN (%)	Av.P (ppm)	Cl	Si	S	Textural Class
Kewet	Charie	6.79	0.38	0.02	5.34	64	26	10	Clay
	Medina	7.57	0.82	0.08	1.86	70	16	14	Clay
Efrata gedem	Yimlo	6.67	0.82	0.06	9.66	36	20	44	Clay loam
	Feredeweha	7.24	0.97	0.11	3.72	48	42	10	Clay
Antsokia gemza	Mekedesa	6.71	1.15	0.07	13.62	46	42	12	Clay
	Atiko	6.52	1.27	0.10	28.32	42	28	30	Clay
	Afso	6.40	1.26	0.10	10.62	22	40	38	Loam

Application of P fertilizer (Table 3) affected the mean sorghum plant height significantly. Averaged across all study districts, P fertilization increased the mean plant height from 195.9 cm recorded from the plot without P fertilizers to 204.0 cm with the application of 57 $Kgha^{-1}$ P_2O_5. In general, plant height increased almost consistently with increasing the rates of P fertilizers but there is no significant effect among 19, 46 and 57 $Kgha^{-1}$ P_2O_5. This result is in line with the report of Wakene *et al.*, (2014) who stated that plant height of barely increased with increasing rates of P_2O_5 from 0 to 69 $Kgha^{-1}$.

Table 3. Mean response of Sorghum plant height for application of Phosphorus fertilizer over all Districts, 2018/19

Treatment	Plant height (cm)				Mean
	Kewet	Efrata gedem	Antsokiya gemza	Ensarona wayu	
1. 0 P_2O_5 $Kgha^{-1}$	202.2^{c}	175.0^{bc}	204.1	202.1^{b}	195.9^{cd}
2. 46 P_2O_5 $Kgha^{-1}$ TSP	196.0^{bc}	167.9^{c}	203.1	197.0^{b}	191.3^{d}
3. 19 P_2O_5 $Kgha^{-1}$ NPSB	204.7^{ab}	178.6^{abc}	202.3	204.5^{ab}	197.3^{bc}
4. 38 P_2O_5 $Kgha^{-1}$ NPSB	210.5^{a}	183.7^{ab}	208.5	204.1^{ab}	201.9^{ab}
5. 57 P_2O_5 $Kgha^{-1}$ NPSB	206.5^{ab}	186.9^{a}	212.6	211.3^{a}	204.0^{a}
CV (%)	4.21	5.48	4.22	3.37	5.71
LSD (0.05)	8.29	11.86	ns	8.33	5.77

Application of P had an impact on the height of tef plants, with the exception of Antsokiya gemza and Ensarona wayu districts. P fertilizer did not all have the same effect on plant height other districts (Table 4). The longest mean plant height (126.6 cm) was recorded from 19 $Kgha^{-1}$ P_2O_5 at Ensarona wayu district whereas the shortest mean plant height (109.5) was recorded from 57 $Kgha^{-1}$ P_2O_5 at Antsokiya gemza district. Moreover, Table 4 shows that the application of P fertilizer did not affect plant height in the other districts.

Table 4. Mean response of tef plant height for application of P fertilizer over all sites of study Districts, 2018/19

Treatment	Plant height (cm)				Mean
	Kewet	Efrata gedem	Antsokiya gemza	Ensarona wayu	
1. 0 P_2O_5 $Kgha^{-1}$	128.7	122.7	121.7^{a}	121.4^{ab}	122.2
2. 46 P_2O_5 $Kgha^{-1}$ TSP	132.1	122.9	119.0^{a}	116.6^{c}	120.7
3. 19 P_2O_5 $Kgha^{-1}$ NPSB	131.2	126.4	119.0^{a}	126.4^{a}	123.3
4. 38 P_2O_5 $Kgha^{-1}$ NPSB	134.9	124.6	111.4^{b}	119.5^{bc}	119.7
5. 57 P_2O_5 $Kgha^{-1}$ NPSB	131.9	125.7	109.5^{b}	123.9^{ab}	120.4
CV (%)	3.88	4.36	5.20	4.58	9.65
LSD (0.05)	ns	ns	4.89	6.75	ns

Similarly, tef panicle length was highly significantly affected by the application of Phosphorus at Antsokiya gemza and Ensarona wayu districts only. The effect of Phosphorus on panicle length was not consistent (Table 4). The longest mean panicle length (48.5 cm) was recorded from 19 $Kgha^{-1}$ P_2O_5 at Ensarona wayu district whereas the shortest mean panicle length (40.0 cm) was recorded from 38 $Kgha^{-1}$ P_2O_5. But there was no significant variation in panicle length in the other districts due to the application of Phosphorus (Table 5).

Table 5. Mean response of tef Panicle length for application of P fertilizer over all of study Districts, 2018/19 sites

Treatment	Panicle length (cm)				
	Kewet	Efrata gedem	Antsokiya gemza	Ensarona wayu	Mean
1. 0 P_2O_5 $Kgha^{-1}$	50.3	43.9	44.9^{a}	46.2^{ab}	46.1
2. 46 P_2O_5 $Kgha^{-1}$ TSP	49.9	44.9	44.4^{a}	43.4^{c}	45.3
3. 19 P_2O_5 $Kgha^{-1}$ NPSB	49.8	46.3	42.7^{ab}	48.5^{a}	46.3
4. 38 P_2O_5 $Kgha^{-1}$ NPSB	50.7	45.0	40.0^{c}	45.9^{bc}	44.8
5. 57 P_2O_5 $Kgha^{-1}$ NPSB	49.2	44.9	40.8^{bc}	47.6^{ab}	45.1
CV (%)	4.69	5.98	5.44	4.52	9.54
LSD (0.05)	ns	ns	2.24	2.54	ns

Data shown on Table 6 the application of P fertilizer revealed that no significant difference was observed among treatments for yield parameters of Sorghum at all districts except application Phosphorus fertilizer had a positive effect on plant height of sorghum (Table 4). Generally, applications of P fertilizer from different sources did not significantly impact the yield of sorghum.

Table 6. Mean response of Sorghum grain yield for application of Phosphorus over all sites at Kewet, Efratagedem, Antsokiya, and Ensaro Districts, 2018/19

Treatment	Grain yield of sorghum ($Kgha^{-1}$)				
	Kewet	Efrata gedem	Antsokiya gemza	Ensarona wayu	Mean
1. 0 P_2O_5 $Kgha^{-1}$	3848.5	3775.3	4843.9	5832.5	4813.5
2. 46 P_2O_5 $Kgha^{-1}$ TSP	4007.1	3434.4	4779.6	6241.4	4759.8
3. 19 P_2O_5 $Kgha^{-1}$ NPSB	4183.5	3554.2	4856.1	5942.4	4861.1
4. 38 P_2O_5 $Kgha^{-1}$ NPSB	4160.9	3758.4	4786.2	6017.9	4804.7
5. 57 P_2O_5 $Kgha^{-1}$ NPSB	3812.1	3666.0	4788.0	6515.9	4837.9
CV (%)	11.95	14.02	12.12	12.55	12.37
LSD (0.05)	ns	ns	ns	ns	ns

The analysis of variance revealed that application of Phosphorus had no significant effect on sorghum grain yield at all districts (Table 7). Average grain yield responses of tef for each treatment of all trial sites (kebeles) of each district were not significantly affected for application P fertilizer Sources.

Table 7. Mean response of tef grain yield for application of P fertilzer over all sites of Districts, 2018/19

Treatment	Grain yield of tef ($Kgha^{-1}$)				Mean
	Kewet	Efratana gedem	Antsokiya gemza	Ensaro wayu	
1. 0 P_2O_5 $Kgha^{-1}$	1215.8	1629.2	900.28	1829.9	1314.1
2. 100 $Kgha^{-1}$ TSP	1322.9	1640.3	884.72	2028.3	1369.2
3. 50 $Kgha^{-1}$ NPS	1322.9	1583.3	879.17	2104.2	1342.6
4. 100 $Kgha^{-1}$ NPS	1285.4	1609.7	920.83	1988.2	1342.6
5. 150 $Kgha^{-1}$ NPS	1493.8	1655.6	951.39	1988.2	1415.7
CV (%)	16.23	10.29	13.17	17.95	18.94
LSD (0.05)	ns	ns	ns	ns	ns

Conclusion and Recommendation

Generally, applications of Phosphorus did not significantly impact the grain yields of sorghum and tef. Even though, soil analysis result of available Phosphorus were within the range of low for some testing sites, application of Phosphorus did not affect the yield components of both crops. However, the organic carbon, TN and available Phosphorus contents of most testing sites were in the low to very low ranges and need management of soil organic matter and application of adequate amount of Nitrogen containing external fertilizer sources. In addition, though Phosphorus didn't significantly affect yield and yield parameters of both crops, application of the smallest rate (19 $Kgha^{-1}$ P_2O_5) for maintenance purpose is indispensable for the replacement of the removed Phosphorus with the harvested parts of the crops.

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