Indexing soil P to recommend for durum wheat in East Shewa, Oromiya Region

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Abstract: On farm soil test based phosphorous determination research experiment was carried out in three locations of East Showa from 2003-05 cropping seasons. Six levels of P were applied as a treatment (Triple Super Phosphate) and recommended level of nitrogen from urea was applied uniformly to all plots. Application of 15.1 kg P per ha in Ude and 25.1 kg P in Akaki provided the maximum mean grain yields of 3.75 and 1.79 t ha^{-1}, respectively for year (2003). In the 2004 cropping seasons, however, the absence of any application of external P gave the highest (3.38 t ha^{-1}) in Chefe Donsa and the least mean grain yield (1.74 t ha^{-1}) was recorded in Ude by 15.1 kg P . In the year 2005 result revealed that the two treatments from Chefe Donsa and Akaki gave the maximum comparable mean grain yields (4.89 and 4.49 t ha^{-1}) but and the least yield was obtained through the application of soil P only (1.88t) in Ude. For these cropping seasons, a total of twenty seven regression equations were developed and eighteen were selected in order to map the soil P (ppm) versus treatments. Accordingly, an average of 97.0, 96.5 and 96.5 (2003), 86.0, 93.0, and 89.5 (2004) and 92.0, 91.5, and 92.5% (2005) remained in the soil for every application of external P in Akaki, Chefe Donsa and Ude, respectively. In most of the years, on average of over 85% of the applied P remained in the soil. In some locations, non-significant differences were due to this. It seems that our soils are saturated by the application of P years around and becoming the least limiting plant nutrient. Therefore, any phosphorus recommendation for optimum durum wheat production should be on the basis of its soil test P value. This experiment also proved that even if the soil P increases through the application of external P from 6.5ppm onwards, it didn't reflect in the increment rather the decline of mean grain yield. But further research work has to be conducted to determine the limiting plant nutrient, its index in different soil types, environment and in its interaction.

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Introduction

Determining the fertility level of the soil through a soil test is the first step of planning a sound fertilizer program. This step leads to higher yields and improved crop quality through recommended fertilizer applications. Therefore in order to maintain normal plant growth, lime and fertilizers (if the soil reaction is found to be low) and fertilizer (if it is neutral to alkaline reaction) alone must be added in sufficient quantity to meet the crop requirement.

Soil test based fertilizer doses especially those of macro-nutrients are accepted as being more rational, balanced, efficient and profitable as compared to blanket recommendation. Since 1996, Ethiopia imported between 200, 000 and 380, 000 MT of DAP and Urea annually. This costs the country huge amount of money in hard currency. Since 1966, blanket application of 100 kg DAP and 100 kg Urea is used all over the country irrespective of the climate, soil type, crop species or variety, altitude, precipitation, water availability, and evapo-transpiration

Basing fertilizers, especially the macronutrient (those needed in large quantity by the plant), dose on soil testing has never been more important to Ethiopia than it is today in view of large escalation in fertilizer prices. Fertilizer recommendations on soil test basis for economic crop production should be both location and situation specific and can be modified with changes in soil test value as well as input output ratios. Ethiopian farmers practicing unbalanced fertilizer use or those using blanket doses for long time will gain most from soil test based fertilizer applications. Therefore, the objective of this experiment was to investigate a soil test value of P for optimum durum wheat production in three selected Weredas of East Showa.

Literature Review

The biggest challenges facing modern agriculture with respect to P is the establishment and maintenance of appropriate balance between providing sufficient P inputs to sustain production, and minimizing diffuse P transfer and its associated impacts on environmental quality. (**P. Schjonning, et.al, 2004**).

The establishment of P management thresholds in the high and low intensity farming systems will require determination of the appropriate amounts and forms of phosphorous inputs, together with continued development of strategies for efficient P cycling, designed to maintain economically viable levels of production with minimum P transfer(**L.M. Condron, 2004**). Soil test based fertilizer doses especially those of macro nutrients are accepted as being more rational, balanced, efficient and profitable as compared to blank recommendation. Results of 21 research experiments show that the response rates to fertilizer (kg grain/kg nutrients applied) was 12.6 when fertilizer rates were based on soil test in contrast to 7.8 by adopting the blanket recommendations **(Randhawa and Velayuthan, 1982)**. This figure shows that there was an increment if about 5 kg of grain per kg of nutrients.

Ethiopia imported 11648163 MT DAP and 464, 537 MT Urea between 1996 and 2001 (**Sources; CSA 2000)**. This costs the country to spend a large amount of money in foreign exchange from its limited resources. Although Ethiopia started importing nitrogen and phosphorous fertilizers since 1966, blanket application of 100 kg DAP and 100 kg Urea is used all over the country irrespective of the climate, soil type, crop species or variety, altitude, precipitation, water availability, evapotranspiration etc.

From soil nutrition point of view it is already known that phosphorus next to nitrogen is one of the major plant nutrients and satisfactory level of both grain and forage production on Vertisols totally depends on its adequate supply (**Mesfin Abebe, 1980**). According to **Asnakew Wolde-ab and Tekalign Mamo** in soil fertility trials carried out since 1966 at Holleta, on red and black soils, both nitrogen and phosphorous significantly affected wheat grain yields. The highest mean grain yields were obtained with the application of 60 kg N and 60 kg P_2O_5 per ha. This is an indication of equivalent need of nitrogen and phosphorous for optimum crop production. Phosphorous fertilizer rates vary considerably depending on crop and soil factors as well as differences in fertilization recommendation philosophies. In general, the fertilizer recommendation at high soil test levels is regarded as an insurance measure with the intention that the recommender wishes to be sure that fertilizer does not become a limiting factor and that crop production is at optimum level. Researcher should, therefore, recommend basing phosphorous fertilizer rate on soil test and other soil factors and maintaining fertilization according to crop removal for effective and efficient use of fertilizers. **Tekalign Mamo and I Haque** employed eight chemical methods for estimating the available P in 32 Ethiopian soils using Phasey beans as a test crop grown in small pots in a greenhouse and soil test values then correlated with plant characteristics. Olsen method gave the highest correlation with the percentage yield and P uptake in all three cuts and also was giving 97 percentage correct predictions. Studies of the fertilizer response of crops by **Desta Beyene** (**1978**) at the EPID/IAR experimental sites in Indibir during the periods 1973-76, analyzing the effects of phosphate fertilizer on the grain yield of maize and on soil phosphate. It includes practical recommendations for nitrogen and phosphate fertilization in the cultivation of maize, triticale, tef and potato. This proposal is, therefore, intended to identify specific soil test based phosphorous fertilizer rate recommendation for durum wheat in East Showa.

Material and Methods

The soil textural class in the experimental area found to range from silty loam to heavy clay and having the soil types Haplic Andosol, Vitric Andosol and Eutric Vertisol. Before planting composite soil samples and after harvest, from plots that receive different levels of P were sampled and analyzed. Therefore, a total of 9 composite soil samples and after harvest 54 soil samples (one sample is made of a composite of 7 augur sub-samples from a given experimental plot) were collected, prepared and analyzed for its P. The experiment was carried out on farmers' field in three locations (Ude, Akaki and Chefe Donsa) of East Showa under their own management conditions. Three farmers were selected from a single location, each farmer serve as a replication and a total of nine farmers were involved in this study. The test crop was durum wheat, *klinto* variety with the recommended seed rate (150kg/ha). The plot size is 10X10m with a total effective plot area of $600m^2$ (20mX30m) and the design for this experiment was

RCBD. There is 1.5 and 1m spacing between block and experimental plot, respectively. TSP with six different levels (0, 5.0, 10.0, 15.1, 20.1 and 25.1 kg P) were used as a treatment in this experiment as a source of P. Statistical software packages such as Microsoft Excel was used to compile, summarize, and make statistical analysis and regression the data for analysis.

Sites Description

Ude: It is located 60 km East of Addis Ababa and its geographical extent ranges from 08^{0}45$'$15$''$ to 08^{0}46$'$45$''$ north latitude and form 38^{0}46$'$45$''$ to 39^{0}01$'$00$''$ east longitude. The soil textural class was Loam and having the haplic andosol, vitric andosol and vertisol. The mean annual rainfall, maximum and monthly temperatures ranges between is 801.3mm, 25.5 ^{0}C, 23.7 in July & 27.7^{0}C in may, respectively. The mean annual minimum temperature is 10.5^{0}C, monthly values ranges between 7.4 in December and 12.1^{0}C in July and August. It has an altitude 1850m a.s.l and hot to warm sub-humid climate.

Akaki: is located 30 km North of Debre Zeit and its geographic location is at 08^{0}53$'$39” north latitude and 38^{0}49$'$13” east longitude. It has a soil dominated by heavy clay and Eutric Vertisol. It has an altitude 2400m a.s.l and hot to warm sub-humid climate.

Chefe Donsa: It is located 35 km east of Debre Zeit and its geographic location is at 08^{0}57$'$15” north latitude and 39^{0}06$'$04” east longitude. Its textural class is Heavy Clay and Soil Types was Eutric Vertisol, Altitude 2450m a.s.l, and is hot to warm sub-humid climate.

Results and Discussion

Agronomic Result

In **Akaki**, except in the 2003 cropping season the treatments were not showed any significance difference on the mean grain yields. Accordingly, the highest (2.66 ha^{-1}) and the lowest mean grain yield (2.13 and 1.74 t ha^{-1}) was obtained by the application of the blanket recommendation, highest and the control, respectively. During 2004, however, two treatments, the absence of any application and with 15.1kg ha^{-1} P, gave the highest mean grain yield of 2.91 t each. The treatments have shown a significant difference in the mean straw yield but not in grain yield for the last cropping season The control group performs better than even with few P-fertilizer levels both in the mean grain yield at 5.0 and 20.1 kg P. Significant differences for the straw yield would result the maximum and minimum yields of 5.60 and 3.82 t of straw by 25.1 and the control, respectively (Table 1).

Table 1. Grain and straw yield of durum wheat as affected by the application of P-fertilizer at Akaki in three consecutive years.

Treatment	2003		2004		2005	
	Grain Yield (t ha^{-1})	Straw Yield (t ha^{-1})	Grain Yield (t ha^{-1})	Straw Yield (t ha^{-1})	Grain Yield (t ha^{-1})	Straw Yield (t ha^{-1})
0	2.13ab	2.98	**2.91**	3.23	4.49	4.82c
11.5	2.17ab	2.92	2.85	**3.28**	4.45	4.65bc
23.0	**2.44a**	3.18	2.89	3.24	**4.66**	5.03ab
34.5	2.22ab	2.92	**2.91**	3.23	4.61	4.14c
46.0	**2.66a**	3.69	2.89	3.24	4.32	4.48bc
57.5	1.79b	2.87	2.86	3.27	4.64	**5.60a**
CV (%)	14.89	17.16	8.18	8.22	14.91	10.97

Mean	**2.24**	**3.09**	**2.88**	**3.25**	**4.53**	**4.79**
LSD 5%)	606.7	NS	NS	NS	NS	918.3

Means within a column followed by different letters are significantly different as judged by LSD at P ≤ 0.05.

Unlike to Akaki, significant yield differences were observed in the mean grain yield of durum wheat for every application of the treatment in **Chefe Donsa**. Accordingly, the highest (2.77 t) and the lowest (2.09 and 2.19 t) was recorded by 11.5, 57.5 and 0 kg P_2O_5 (2003). Also similar trends were followed in 2004. The highest and the least mean grain yield of 3.38 and 2.34 t was obtained with the absence of any application of P sources and by the treatment with the additional 15.1 kg of P over the soil. In 2005, 25.1kg P gave the highest mean grain (4.89 t) and followed by 15.1, 20.1, 5.0, 10.0, and control, respectively with 4.07, 3.94, 3.80, 3.58 and 3.52 t. Even though a non-significant difference was observed for the Straw yield, the maximum Straw yield (6.53tha^{-1}) was obtained with heavy application of P and the lowest (3.96 t) for with out any application of it. And the soil in this location indicates its responsiveness to P-fertilization to some extent (Table 2).

Table 2 Grain and straw yield of durum wheat as affected by the application of P-fertilizer at Chefe Donsa

Treatment	**2003**		**2004**		**2005**	
	Grain Yield ($t\ ha^{-1}$)	Straw Yield ($t\ ha^{-1}$)	Grain Yield ($t\ ha^{-1}$)	Straw Yield ($t\ ha^{-1}$)	Grain Yield ($t\ ha^{-1}$)	Straw Yield ($t\ ha^{-1}$)
0	2.19c	4.64	**3.38a**	**4.22**	3.50b	4.96
11.5	**2.77a**	5.87	3.05a	3.97	3.80b	5.13
23.0	2.57abc	4.44	3.08a	4.12	3.58b	5.01
34.5	2.24bc	5.74	2.34b	3.26	**4.07b**	**6.11**
46.0	2.75ab	5.42	3.10a	3.69	3.94b	5.40
57.5	2.09c	4.83	3.09a	3.70	**4.89a**	**6.53**
CV (%)	11.70	19.10	11.56	16.69	10.92	17.63
Mean	**2.44**	**5.16**	**3.01**	**3.83**	**3.96**	**5.52**
LSD 5%)	518.8	NS	633	NS	788.6	NS

Means within a column followed by different letters are significantly different as judged by LSD at P ≤ 0.05

Significant differences were observed in the mean grain yield for all the three years and straw, too except the last two years at **Ude**. Accordingly, the highest (3.75 t) and the least mean grain yield (2.64 t) were observed by the following treatments (15.1 and 0 kg P, respectively). In 2004, however, the maximum mean grain yield of 2.66 tone was obtained the application of only 5 kg of P, followed in diminishing order by P application rates of control (2.54 t), 25 (2.27t)and 10 (2.22t). Furthermore, the lowest grain yield of 1.74 t was obtained with the application 15 kg of P. However, the trend is different when we look into the straw yield. The highest mean straw yields of 4.97 t, of the lowest grain yield, and 4.57 t were obtained with the 15 and 10 kg P applications, respectively. In 2005, the highest mean grain yield (3.53 t) was obtained with the application of 25.1 kg of P and followed by 10 and then back to 20.1 kg having the yield of 3.28 and 3.11 kg ha^{-1}, respectively (see 3). The least grain yield was obtained by the soil phosphorous only. This showed that the soil in Ude is responsive to any P fertilizations regarding the mean grain yield. Contrarily to the Grain yield, the mean Straw yield showed a non-significant difference for P levels.

Table 3. Grain and straw yield of durum wheat as affected by the application of P-fertilizer at Ude

Treatment	**2003**		**2004**		**2005**	
	Grain Yield ($t\ ha^{-1}$)	Straw Yield ($t\ ha^{-1}$)	Grain Yield ($t\ ha^{-1}$)	Straw Yield ($t\ ha^{-1}$)	Grain Yield ($t\ ha^{-1}$)	Straw Yield ($t\ ha^{-1}$)
0	2.64b	3.82c	2.54ab	4.35	1.88b	4.41
11.5	3.33ab	5.01a	**2.66a**	4.31	2.45b	4.11
23.0	3.36ab	4.75ab	2.22abc	4.57	**3.29a**	5.25
34.5	**3.75a**	4.52abc	1.74c	**4.97**	2.43b	4.78
46.0	3.31ab	4.64abc	2.02bc	4.54	3.11a	5.53
57.5	2.73b	4.00bc	2.27abc	4.00	**3.53a**	**5.67**
CV (%)	16.40	10.52	14.62	12.5	12.41	17.59
Mean	**3.19**	**4.46**	**2.24**	**4.46**	**2.78**	**4.96**
LSD 5%)	951.0	853.2	596.1	NS	628.2	NS

Means within a column followed by different letters are significantly different as judged by LSD at $P \leq 0.05$.

Soil Result

By taking the two variables (Y, the mean grain yield, ***dependant,*** and X, the soil P(ppm), ***independent variable***) a regresstion equations were developed by using the Microsoft Excel spreadsheet and verified by SPSS. Accordingly, 27 regression equations were developed but only 18 were selected for making an index for optimum durum wheat production. Equation 1-6, 6-12 and 12-18 represent the regressions equations for 2003, 2004 and 2005 years, respectively. In all the regressions equations **cd**, **u** and **a** refers to Chefe Donsa, Ude and Akaki, respectively.

$Ycd = 0.102X+4.27,$ $R^2=0.96$ *Equation 1*

$Ycd = 0.112X+5.46,$ $R^2=0.97$ *Equation 2*

$Yu =0.25X+5.83,$ $R^2=0.91$ *Equation 3*

$Yu =0.11X+4.38,$ $R^2=0.87$ *Equation 4*

$Ya= 0.1702X+2.29,$ $R^2=0.97$ *Equation 5*

$Ya= 0.1002X+4.33,$ $R2=0.97$ *Equation 6*

*In **2003**, the highest mean grain yield was obtained as a result of the application of only 5 kg P (5.44/6.75 in P_2O_5 and 4.78 /6.02 in P), 15.1 kg P (8.75 in P), and in 6.2/6.63 in P_2O_5 and 5.33P) in Chefe Donsa, Ude and Akaki, respectively.*

Ycd = 0.11x+4.07,	R^2=0.89	*Equation* ***7***
Ycd = 0.04x+4.16,	R^2=0.97	*Equation* ***8***
Yu = 0.2497x+5.83,	R^2=0.92	*Equation* ***9***
Yu = 0.108x+4.38,	R^2=0.87	*Equation* ***10***
Ya = 0.13x+4.93,	R^2=0.99	*Equation* ***11***
Ya = 0.093x+6.02,	R^2=0.73	*Equation* ***12***

In ***2004****, the soils P in all the three locations have the correlations values ranges from 86.6 to 99.5% with the average values of 92.8, 90.2 and 96.2% for Chefe Donsa, Ude and Akaki, respectively. Ude is found to have the values a bit less than that of Chefe Donsa and Akaki by 2.8 and 6.2% respectively. The reason for this would be the weathering frequency of the soil due to environmental factors especially the fluctuation in temperature. In Akaki and Chefe Donsa, however, the highest ranges were observed and hence the average as well. Accordingly, the P values and levels are found to be in increasing order from Ude, Chefe Donsa and Akaki. This means that of the applied treatments 92.8 for Chefe Donsa, 90.2 for Ude and 96.2% for Akaki remain in the soil system after the plant uptake and loss. Thus, it is a good indication for recommending the amount of P. In order to obtain the maximum mean grain yield at Akaki (2.91 t) we need to have 9.4 or 7.92 ppm (Equations 11 and 12), in Chefe Donsa, the soil P was sufficient to produce the highest yield (Equation 7 and 8) and in Ude 2.66t would be a results of 5.62 and 7.27soil P (Equations 9 and 10)*

Ycd = 0.1068x+4.36,	R^2=0.86	*Equation* ***13***
Ycd = 0.0857X+7.74,	R^2=0.97	*Equation* ***14***
Yu= 0.1302x+6.42,	R^2=0.97	*Equation* ***15***
Yu= 0.1106x+5.60,	R^2=0.88	*Equation* ***16***
Ya= 0.0965x+5.25,	R^2=0.87	*Equation* ***17***
Ya= 0.192x+7.86,	R^2=0.97	*Equation* ***18***

In ***2005****, a bit different observations were found. 94.8, 91.2 and 85.5% correlations were found between the treatments and soil P for Chefe Donsa, Ude and Akaki, respectively having the ranges from 74.32 to 96.53 in Akaki. Except in Akaki, increasing correlations were observed for the rest two locations; Chefe Donsa and Ude. Comparably the highest mean grain yields were obtained with the control (4.49 t) and the highest rates (4.64 t) for Akaki and the Chefe Donsa(4.89 t) but at 11.5 kg* P_2O_5 *all yields by having 6.91, 7.39 and 7.40 ppm (Equations 13-18).*

In Ude, increasing levels of P_2O_5 *by one step (11.5) from the control (0) yields positives effect and continuously decrease and rise. At 11.5 kg* P_2O_5 *yields 7.86 and 6.865 ppm, and thus the highest grain yield was obtained with this level and decreases with increasing application at 92 %. At Akaki, the soil P is already 7.86 and 5.95 ppm for the first and second respectively and didn't respond to P application at 85.4% (74-97%)*

Conclusion

In **2003**, the highest mean grain yield was obtained as a result of the application of only 5 kg P (5.44/6.75 in P_2O_5 and 4.78 /6.02 in P), 15.1 kg P (8.75 in P), and in 6.2/6.63 in P_2O_5 and 5.33P) in Chefe Donsa, Ude and Akaki, respectively.

In **2004**, the soils P in all the three locations have the correlations values ranges from 86.6 to 99.5% with the average values of 92.8, 90.2 and 96.2% for Chefe Donsa, Ude and Akaki, respectively. Ude is found to have the values a bit less than that of Chefe Donsa and Akaki by 2.8 and 6.2% respectively. The reason for this would be the weathering frequency of the soil due to environmental factors especially the fluctuation in temperature. In Akaki and Chefe Donsa, however, the highest ranges were observed and hence the average as well. Thus, it is a good indication for recommending the amount of P. In order to obtain the maximum mean grain yield at Akaki (2.91 t) we need to have 9.4 or 7.92 ppm (Equations 11 and 12), in Chefe Donsa, the soil P was sufficient to produce the highest yield (Equation 7 and 8) and in Ude 2.66t would be a results of 5.62 and 7.27soil P.

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From this we can see that the soils in the experimental area do differ in their ability for supplying soil nutrient especially soil P even in the same location. Therefore, the representative correlation equation was taken from a single location for making a conclusion. And also we can notice that the residual effect of the previously and continuously applied P in the soil do have an impacts on the performance of the current crops. In almost every regression equations, the amount of soil P after applying different levels of P showed a correlation ranges from 74.32 to 96.53% in Akaki (2005) and from 86.6 in Ude to 99.5% Akaki (2004). This means that from the applied of every P rates at least 74% remained in the soil. Thus, it is better to test the soil for its P prior to planting and further application of additional P sources. If the soil P is about or greater than 7.39, 7.86 and 7.92 ppm in Chefe Donsa, Akaki and Ude respectively, the soil will not respond in terms of yield increments rather the speed of accumulation become faster. If the soil P is less than these, we need to supplement till reaches 7.38, 7.89 and 7.92 ppm at Chefe Donsa, Akaki and Ude, respectivly.

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