Achievements on Integrated Bread Wheat, Soil and Water Management Research

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Introduction

Eastern Africa Agricultural Productivity Project (EAAPP) is a five year agricultural project financed by the World Bank to promote enhanced research in Ethiopia, Kenya, Tanzania, and Uganda focusing on Dairy, Wheat, Cassava and Rice effective from 2010 and ending in 2015.

EAAPP focused in establishing regional centers of excellence for agricultural research, dissemination, and capacity building as follows: Kenya for dairy, Uganda for cassava, Ethiopia for wheat and Tanzania for rice. The Ethiopian Institute of Agricultural Research (EIAR) took the mandate for technology generation in the four commodities with special emphasis on wheat.

Kulumsa Agricultural Research Center (KARC/ EIAR) was assigned as the wheat regional center of excellence and started its coordination of the wheat research regionally since 2011. With this mandate in mind the technology generation, training, and dissemination component of EAAPP-WRCoE started in the following thematic areas

- germplasm enhancement and variety development (Rain fed wheat);
- development of integrated crop, soil and water management practices;
- regional surveillance, monitoring and development of management options for major wheat pests;
- development of small implements and machinery;
- Socio-economic studies in value chain analysis and development, pre-extension demonstration and validation of improved technologies; and
- development of Technologies for Irrigated Wheat (National-Ethiopia).

The first workshop on development of research activities on integrated crop, soil, and water management practices was held in June 2011 with invited participants from 10 EIAR and regional research centers within the country. More than 20 activities were proposed to be undertaken starting from the summer of 2011. But the implementation of the activities fall short of succeeding due to various factors that included high staff turn over from different research centers. The departure of the first principal investigator also created a gap in the supervision of the works at a national and regional level. Since March 2013 the gap in the coordination work was corrected; and the scope of coordination expanded to include wheat agronomy researchers from the three other member countries.

However, many challenges have been facing us in the process of preparation for reviewing all activities that have been planned and perhaps conducted since 2011 cropping season. Part of the activities that were planned in the first and second cropping seasons were either not conducted at all or poorly conducted or failed. These problems can be explained partly by unreported activities or poorly organized field works until the April 2013 EAAPP-WRCoE annual review. Because of this, an independent research review of agronomy and soil activities was conducted in December 2013 at Kulumsa Agricultural Research Center (WRCoE) for reviewing the on-going and completed activities and preparation of new ones. This review meeting created understanding between researchers of different research centers and up lifted the motivation of researchers to do their work in the forthcoming seasons with great responsibility. Following this review workshop, a write shop was conducted in April 2014 at Adama town with invited researchers from eight research centers. The objectives of the write shop were to organize and analyze data on some completed and on-going activities; produce articles, brochures, and posters on some of the research findings; provide recommendations on some agronomic and soil management practices; and prepare a preliminary document on the 3 years research activities on integrated crop, soil, and water management practices supported by EAAPP. This review of 3 years research achievements is just one of the major outcomes of the workshop. The document contains the findings of research works on Integrated Crop, soil, and Water Management activities at a national level. However, not all of the information generated from the reported activities can be considered as readily available for transfer to users. Some of the activities are ongoing, while some of the completed ones may need further work to improve the results.

Determination of Optimum N and P Fertilizer Rate for Bread Wheat in the Highland Vertisols of Arsi Zone, Oromia Region

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Introduction

The relatively slow growth in mean national yield for bread wheat (*Triticum aestivum* L.*)* from 1.46 t ha^{-1} in 2004/2005 (CSA, 2005) to 2.01 t ha^{-1} (CSA, 2011/2012) is due to several constraining factors, such as poor crop management that include the prevalence of poor weed control, depleted soil fertility and a low level of fertilizer usage are among the most important (Tanner *et al*., 1993; Payne et al 1996). Nitrogen and phosphorus deficiency is often encountered in wheat growing areas of Ethiopia, in which the severity of the problems predominate the frequently water-logged soils-highland Vertisols (Tekalign et al, 1988; Syers et al., 2001). The very high potential of Vertisols for wheat productions have been well recognized by highland farmers since the introduction of Vertisols technologies in the 1990s, like BBM and ridge and furrow seed bed preparation methods. Nonetheless, it has been underutilized due, mainly, to the very low input use of fertilizers and poor pest management strategies. Parallel to this fact, researches in the development of site and crop specific fertilizer recommendations have shown modest progress until now due, possibly, to the limited resources of the country. As a consequence of this, the old bulk recommendations continued to be practiced in many areas. Despite its continued use, the importance of zone or site specific fertilizer recommendations in the country have gained the attention of many researchers and scientists since as early as the 1990s; and the progress of the works done so far indicated that increased applications and rates of N and P increased grain yields with a very strong and significant linear response (Asefa at al., 1997; Shambel et al, 1999; Minale et al, 2004; Amsal et al, 2000; Taye et al, 2002). Notwithstanding the contributions of these authors, the scale of work done so far is very little considering the variability of soils, climate, and cropping systems. Consequently, the demand for site specific fertilizer recommendations has been increasing from time to time. It is also well understood that development of agroecology based or site specific N and P fertilizer recommendations and increased implementations of recommended practices is one of the primary means of increasing wheat yields in Ethiopia. Therefore, a fertilizer trial was conducted in 2012 and 2013 with the objective of developing economic optimum fertilizer recommendation for bread wheat in two districts of the highland Vertisols of Arsi zone.

Methodology

Description and Soils

The experiment was conducted during the 2012 and 2013 main cropping seasons on farmers' fields in the south eastern highlands of Ethiopia, in the districts of Digelu-Tijo, Arsi Robe, and Tiyo. Arsi Robe is located from 8.4N to 8.6N and 40.1E to 40.4E, while Digelu-Tijo and Tiyo are located from 8.01N to 8.15N and 039.15E-039.3E and from 7.77N to 8.03N and 38.94-39.31E, respectively, all in degree decimal. The altitudes of the locations vary from 2200 masl at Kulumsa to about 2500 masl at Arsi Robe and Digelu-Tijo. The Long term average annual rainfall for Arsi Robe is 1040 mm and for Kulumsa (Tiyo district) above 840 mm. For Digelu-Tijo there are no weather station data to describe, but the amount and distributions are similar to the neighboring districts. Therefore, it is estimated that average annual rainfall lie between 800 and 1000 mm. Tepid to cool moist mid-highlands and Tepid to cool humid mid-highlands are the agro-ecological classification for the study areas (Ethio-Italian Development Cooperation, 2002). Even though the long term average annual rainfall for Arsi Robe is higher than the other location, its distributions are uneven. The soils vary from Haplic and Vertic Luvisols to Eutric Vertisols in Tiyo district to Eutric Vertisols in Digelu-Tijo and Arsi Robe (Ethio-Italian Development Coop. 2002). The average organic matter content for all locations is less than 2% and the texture vary from clayey to heavy clayey at Kulumsa (Tiyo) to generally heavy clayey at A. Robe and Digelu-Tijo.. Generally, the study areas are part of the high potential areas for wheat production in the country; and improving the fertilizer use in these areas can bring a considerable impact for increasing productions in the zone and improving the national average wheat grain yields. Selection of trial sites on farmers' fields was done in conjunction with local extension agents.

Treatment and Experimental Design

This experiment was conducted to evaluate the response of recently released bread wheat variety Danda'a to treatments consisting of 20 factorial combinations of five N rates (i.e. 0, 46, 92, 138, 184 kg/ ha) from urea and four P_2O_5 rates (i.e. 0, 46, 92,138 kg/ ha) from triple super phosphate. The treatments were laid out in a complete factorial arrangement using RCBD replicated three times. The gross plot size of the trial was 4 x 5 m (= 20m^2) and net plot size of 3m*3m (9m^2). The trial sites were in Arsi Robe and Digelu-Tijo districts, Arsi zone, Oromia Region. The fields were prepared according to the recommended practices using the traditional oxen-plow system of the ridge and furrow with a 0.7 m wide, inter-furrow spacing. Seeds were sawn according to the customary Vertisols management practices of first broadcasting on the plots and then the ridge and furrows were prepared with well experienced farmers to keep the inter-furrow spacing of 0.7m using a small ridge and furrow maker commonly called BBM (Broad Bed Maker). All P fertilizer and half of the N fertilizer treatments were applied at planting and the remaining N was top-dressed at booting stage. Existing recommendation of seed rate (150kg/ha) and a herbicide called pyroxyslam, one time spray per season for weed control, were used.

Data Collection and Analysis

Data were recorded on grain yield and yield components such as: seedling density, number of tillers per plant, spike length, kernels per spike, thousand kernel weight (TKW), plant height, grain and biomass yield. Information on disease and pest incidences was also collected. Plant and grain samples were collected during the second cropping season from each treatment plots of two experimental sites at Digelu-Tijo district at the start of heading and after harvest, respectively.

Grain Protein, starch, wet gluten, and zeleny values were determined using Near Infrared Reflectance (NIR) at Amhara Region Agricultural Research Institute (ARARI), Bahirdar, Ethiopia. Efficiency values calculated based on known procedures (Cassman and Dobermann, 2002; Fageria and Baligar, 2003, Doyle and Holford, 1993). Straw N contents were determined by micro-

Kjeldahl analysis of straw sub samples (Bremner and Mulvaney, 1982) at KARC soil laboratory from the oven-dried bulk samples.

The method of partial budget analysis recommended by CIMMYT (1988) was used to evaluate the economic profitability of the various treatment options and determine the economic optimum rate. For continuous economic analysis, predicted yield data was generated using the regression model developed for prediction of yield response under alternative fertilizer treatments.

All crop parameters data were subjected to analysis of variance using SAS 9.0 statistical software (SAS, 2002). Data were analyzed for trials combined across locations and seasons. The Duncan Multiple Range Test (DMRT) test (at $P<0.05$) was used to assess differences among treatment means. Statistical Package for Social Sciences, SPSS 20.0 (IBM, 2011) was used to analyze the correlations between yield and yield components and the treatments, and for developing prediction models for grain yields.

Results and Discussion

Grain and biomass yield

The average grain and biological yields (AGY and ABY) at Arsi Robe and Digelu-Tijo districts in the 2012 trial results showed that the main effects of N and P are very highly significant. ($p<0.0001$) with mean grain and biological yields of 2861 and 6940, as compared to the control treatment yields 1606 and 3910 kg/ha, respectively. The highest AGY and ABY at Robe were 4229 and 11145 kg/ha and at Sagure and Tiyo 4658 and 9745 kg/ha, respectively.

The summary of 2013 results for same parameters at Digelu-Tijo and Tiyo districts of Arsi zone showed that the main effects of N and P_2O_5 were very highly significant ($p<0.0001$) with mean grain and biological yields of 4134 and 9831 kg/ha. In contrast to the control treatment results of 2589 and 6554 kg/ha, the highest yields obtained were 5431 and 13299 kg/ha of AGY and ABY, respectively. Similarly, the highest number of spikes per square meter (SPM) and number of seeds per spikes (NSPS) averaged for the 2013 trial sites of the two districts were 512 and 43.5, as compared to the controls results of 367 and 36.6, respectively. SPM, NSPS, and plant height (PH) were also highly significantly affected by increased rates of N at all locations in the two seasons.

The interaction effects of N and P_2O_5 are non-significant for most parameters at all locations. N than P fertilizers significantly controlled yield components that control the AGY such as SPM, NSPS, and TKW. However, P was crucial to increase the yield responses within the ranges of 46-92 kg/ha P_2O_5, as can be seen in figure 2 and 3. Generally, the yield increments in the 2012, 2013, and mean of 2012/2013 vary from 111-146% and 103-142% for the highest treatments results of AGY and ABY, respectively, as contrasted to the control treatment results.

Table 1: The Main effects of fertilizer N and P_2O_5 application rates on selected agronomic parameters of bread wheat grown on the highland Vertisols of Arsi zone in 2012 and 2013 /

Sources of variation	Robe and Digelu-Tijo (in 2012)							Robe and Digelu-Tijo (in 2012 and 2013))						
	PIH (cm)	NSPS	SPM	AGY (Kg/ha)	ABY (Kg/ha)	HI	HLW	PH (cm)	NSPS	SPM	AGY (Kg/ha)	ABY (Kg/ha)	HI	HLW
N (Kg/ha)														
0	84.4	41.5	241	1926	5106	39.5	76.3	75.5	38.4	360	2385	6176	39.7	75.0
46	89.6	47.0	252	2554	6067	40.2	75.5	82.8	40.9	376	2852	7160	40.2	75.4
92	101.4	50.8	266	2960	7103	40.1	75.4	87.8	41.6	423	3370	8327	41.0	74.5
138	98.4	55.3	268	3368	7935	40.0	74.7	92.6	43.4	430	3916	9381	42.2	74.9
184	98.0	54.8	263	3516	8685	39.0	74.6	93.8	45.2	461	4271	10365	41.6	74.4
DMRT	**	***	*	***	***	NS	NS	***	*	***	***	***	NS	NS
P_2O_5 (kg/ha)														
0	88.4	47.1	247	2287	5603	39.9	75.6	82.2	40.6	386	2788	6846	40.6	75.1
46	93.1	49.2	249	3004	7018	40.5	75.07	88.1	42.1	416	3511	8551	41.5	75.0
92	94.6	49.9	260	2973	7303	39.9	75.4	88.3	41.9	432	3653	9087	40.5	74.2
138	101.2	53.0	274	3205	7876	39.1	75.12	88.4	43.3	417	3637	8952	41.5	74.7
DMRT	*	*	*	***	***	NS	NS	***	NS	NS	***	***	NS	NS
N*P	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
REP	NS	NS	***	NS	*	NS	NS	*	NS	NS	NS	NS	NS	NS
N*REP	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
P_2O_5*Rep	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
TRT	NS	**	NS	**	**	NS	NS	**	NS	NS	**	**	NS	NS
LOC	**	**	**	***	***	***	***	***	**	***	***	***	NS	*
LOC*P_2O_5	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
LOC*N	NS	NS	NS	NS	NS	NS	*	*	NS	NS	NS	NS	NS	NS
LOC*TRT	NS	NS	NS	***	**	NS	NS	NS	NS	NS	NS	NS	NS	NS
Control	81.3	40.4	231	1606	3910	40.7	76.4	70.3	36.5	337	1969	5266	38.47	75.02
Mean	94.4	49.8	258	2861	6940	39.8	75.3	86.7	41.96	413	3390	8341	40.98	74.8
CV	19.3	14.2	15.8	20.4	23.2	15.9	4.5	8.96	24.6	28.9	32.9	30.82	14.6	3.94

The relationship between AGY and different rates of N and P can be expressed using the following second degree polynomial equation, with R^2 =0.97 for AGY. The predicted average grain yield is expressed by

$$PAGY = c + aN + bP_2O_5 - dN^2 - e(P_2O_5)^2 + f(N * P_2O_5)$$

Where: PAGY is predicted average grain yield, c is a constant with a value of 2667 kg/ha, a, b, d, e, and f are coefficients with values of 12.84, 12.7, 0.015, 0.07, and 0.019, respectively. The parameters PAGY, N, P_2O_5 are all in kg/ha. Grain yield responses of the test variety to N and P_2O_5 combinations, not included in the treatments, were predicted using the equations developed for AGY and the values applied during economic analysis.

The results obtained so far are also in agreement with the works done on bread and durum wheat (Asefa et al., 1997; Shambel et al, 1999; Minale et al, 2004;).

Table 2: Effects of N and P_2O_5 on selected agronomic parameters averaged over locations. 2013.

Sources of variation	PH (cm)	NSPS	SPM	AGY (kg/ha)	ABY (kg/ha)	HI
N (Kg ha^{-1})						
0	77.4	39.2	408	3025	7450	40.6
46	84.2	39.3	439	3769	9249	40.5
92	86.8	41.0	465	3973	9245	43.8
138	91.2	40.4	497	4755	11069	43.0
184	93.4	43.5	501	5111	12170	42.6
DMRT	***	NS	***	***	***	NS
P_2O_5 (Kg ha^{-1})						
0	83.7	40.6	445	3653	8658	42.1
46	87.5	41.3	463	4206	9993	42.2
92	88.6	41.1	472	4370	10428	41.9
138	87.3	40.3	474	4312	10264	42.9
DMRT	NS	NS	NS	*	*	NS
TRT	***	NS	***	***	***	NS
N*P	NS	NS	NS	NS	NS	NS
REP	NS	NS	NS	NS	NS	NS
N*REP	NS	NS	NS	NS	NS	NS
P_2O_5 * REP	NS	NS	NS	NS	NS	NS
Control	72.8	36.6	367	2589	6554	39.4
Mean	86.8	40.8	463	4134	9831	42.3
CV	7.7	18.0	12.2	22.9	23.3	13.2

Table 3: Effects of N and P_2O_5 on selected agronomic parameters (2012 and 2013) Arsi Robe

Sources of variation	PH (cm)	SPM	NSPS	HI	AGY (kg/ha)	ABY (kg/ha)	HLW
N (kg ha^{-1})							
0	79.7	295.7	39.0	35.9	1591	4397	75.4
46	87.9	298.2	42.9	37.3	2230	5525	74.9
92	91.8	339.9	45.3	37.5	2518	6382	74.6
138	95.4	351.3	48.4	38.0	2883	7174	74.2
184	95.9	361.9	48.8	38.0	3136	7914	74.2
P_2O_5 (kg ha^{-1})							
0	86.7	316.4	42.6	38.5	2093	5266	75.1
46	91.0	325.6	45.2	37.0	2584	6444	74.5
92	90.9	344.0	44.8	37.0	2462	6317	74.7
138	92.1	335.0	46.7	36.7	2734	7014	74.3
DMRT							
N	***	*	***	NS	***	***	NS
P_2O_5	***	NS	NS	NS	***	***	NS
N* P_2O_5	NS	NS	NS	NS	NS	NS	NS
REP	*	NS	NS	NS	NS	NS	NS
N*REP	NS	NS	NS	NS	NS	NS	NS
P_2O_5 * REP	NS	NS	NS	NS	NS	NS	NS
TRT	***	NS	***	NS	***	***	NS
Mean	90	329	44.8	37.3	2469	6264	74.7
Control	76.9	300	36.6	34.9	1370	3598	75.8
CV	7.6	37.8	19.5	17.5	27.0	27.7	3.9

Economic analysis

The detail on cost benefit analysis is presented in table 4. Every shift in investment from the lower selected treatments to higher resulted to more than 100% return. The marginal rate of return (MRR) generally varied from 1.14 to 4.19. The highest MRR was obtained from applications of 92-46 kg/ha N-P_2O_5. Further increases in fertilizer use, particularly of nutrient N, still held positive yield rewards. Sensitivity analysis was made based on data used in the MRR analysis and with treatment results above 100% minimum rate of return, except for the control. The if-analysis was done with the assumption of an average of 30% rises in all variable costs within 3 years, keeping the prices of the produce constant. The analysis showed that the recommended rates still hold positive benefit cost ratios.

Table 4: Economic Analysis based on fertilizer inputs, total variable cost, and net benefit

DAP (kg/ha)	Urea (kg/ha)	Total fert (kg/ha)	Total revenue (birr)	Total variable cost (birr)	MC (birr)	Net benefit (birr)	MB (birr)	MRR (ratio)
0	0	0	17318	7900		9418		
0	100	100	22251	9250	1350	13001	3583	2.65
150	92	241	27504	11353	2103	16151	3150	1.50
100	160	261	28538	11552	199	16986	835	4.19
150	142	291	29659	12028	476	17631	645	1.36
100	211	311	30390	12227	199	18163	532	2.67
150	192	341	31592	12703	476	18890	727	1.53
100	261	361	32019	12902	199	19117	228	1.14
150	242	391	33303	13378	476	19926	808	1.70
250	153	402	33998	13654	277	20343	417	1.51
200	222	422	34588	13854	199	20734	391	1.96
250	203	452	35872	14329	476	21542	808	1.70
250	303	552	38953	15679	1350	23274	1732	1.28

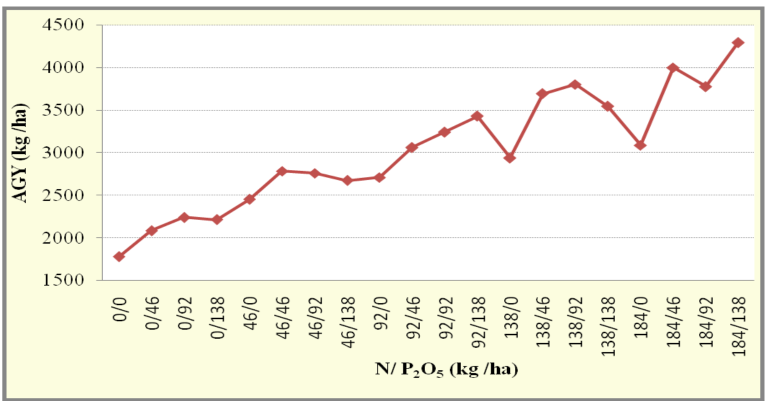

Figure 2: General response curve of bread wheat to fertilizer treatments averaged over locations and years

Conclusions and Recommendations

The recommendation domains are the highland Vertisols areas of Arsi and Bale. The range of Nitrogen fertilizer use in these areas should lie between 92-138 kg/ha in order to obtain very high yields. On the other hand, with substantially higher use of N fertilizer, the range of P fertilizers necessary to be included to obtain the high yield goals should lie between 46 and 92 kg/ha P_2O_5. From analysis of agronomic data the highest yields were obtained through applying the highest treatment of N and P. On the other hand, the results of economic analysis made based on the marginal rate of return showed that the highest MRR was obtained from application of 92-46 kg/ha N- P_2O_5.

Interpretation of agronomic data, national yield goals in the short and long term, and existing farmers' capacity to invest on inputs, and environmental impact from high fertilizer use were factors considered in making the economic optimum recommendations. Considering the various factors affecting decision making three forms of recommendations are made. From my understanding fertilizer recommendations should be flexible. Based on farmers preference of fertilizer use rate and their tendency to gradually adopt higher rates a base recommendation of 92-46 (N- P_2O_5) kg/ha, equivalent to 160 kg/ha Urea + 100 kg/ha DAP is given. This rate was the treatment with highest marginal rate of return (MRR). It would be better to advice poor farmers to start with this base recommendation. With the increasing benefits they experience they can progressively develop to higher levels. Based on the need to attain the long term high yield goals set by planners the 138-69 (N- P_2O_5) kg/ha, equivalent to 240 kg/ha Urea + 150 kg/ha DAP is recommended. However, continued use of DAP can cause P nutrient buildup in the soil. Hence, farmers with history of good P fertilizer use should be advised to use 100 instead of 150 kg/ha DAP. For some lead farmers and for progressive use by poor farmers an intermediate recommendation of 115-46 (N- P_2O_5) kg/ha, equivalent to 210 kg/ha Urea + 100 kg/ha DAP is given. It would be not worthy to compare the recommendations given with the existing one, which is 100 kg/ha DAP + (100-125 kg/ha) Urea.

The economic analysis that included the MRR and sensitivity analysis showed that the improved recommendation would remain to be highly profitable for years to come. The if-analysis was done by varying the total variable costs by 30%, while keeping the prices of the produce constant. Under Ethiopian conditions, however, inflation affects both input and output prices, as a result of which the total revenues could proportionally increase with increasing costs. What is more important is Ethiopian government usually takes some measures to control price rises in fertilizers than the produce. This fact clearly indicates that the validity of the recommendations made can be little affected over the course of time across the recommendation domains. Analysis of Variance for the main effects of fertilizer N and P at different locations and years is presented in table 1, 2,3. The tables of interaction effects for different years and locations are not presented. But the response curve in figure 2 is used to depict the interaction effects of N and P_2O_5 averaged over locations and years.

References

Amsal Tarekegn, DG Tanner and Chanyalew Mandefro, 2000. Agronomic and economic evaluation of the farm N and P response of bread wheat grown on two contrasting soil types in central Ethiopia

Asefa Taa, DG Tanner, Kefyalew Girma and Amanuel Gorfu. 1997. Grain yield of wheat as affected by cropping sequence and fertilizer application in southeastern Ethiopia. African Crop Science Journal 5: 147-159.

Cassman KG, A Doberman and DTWalters. 2002. Agroecosystems, nitrogen use efficiency, and nitrogen management. Ambio 31, 132-140.

CIMMYT. 1988. From Agronomic Data to Farmer Recommendations: An Economics Training Manual. Completely revised edition. Mexico, D.F.

CSA. 2005. Report on Area and Production of Major Crops (Private Peasant Holdings, Mehe Season).Statistical Bulletin. Volume I. May. 2005. Addis Ababa.

CSA. 2011. Report on Area and Production of Major Crops (Private Peasant Holdings, Meher Season). Statistical Bulletin. Volume I. April 2011, Addis Ababa.

Doyle, AD and I.C.R Holford. 1993. The uptake of nitrogen by wheat, its agronomic efficiency and their relationship to soil and fertilizer nitrogen. Aust. J. Agric. Res. 44: 1245-1258.

Ethio-Italian Developemtn Cooperation. 2002. Atlas of Arsi zone. Arsi-Bale Rura Development Project. Arsi zone Planning and Economic Developemnt Office. Regional State of Oromia. GIS sub unit.

Fageria NK. and DG Baligar, 2003. Methodology for evaluation of lowland rice genotypes for nitrogen use efficiency. J. Plant Nutr. 26, 1315–1333.

IBM Corporation. 1989-2011. SPSS Statistical Software. Version 20.

Minale Liben, Alemayehu Assefa, Tilahun Tadesse and Abreham Mariye. 2004. Response of Bread Wheat to Nitrogen and Phosphorous Fertilizers at Different Agroecologies of Northwestern Ethiopia..*In*: Proceedings of the 12th Regional Wheat Workshop for Eastern, Central and Southern Africa. Nakuru, Kenya.

SAS Institute .2002. The Statistical Analysis Software System for Windows. Version 9.00. TS Level 00M0. SAS Institute Inc., Cary NC. USA

Shambel Maru, kefyalew Girma, Workiye Tilahun, Amanuel Gorfu and Mekonnen Kasaye.1999. On-farm N and P fertilizer trial in Bread wheat on vertisols in South eastern Ethiopia. Agronomy and Crop Physiology progress report. Kulumsa Agricultural Research Center. EIAR. Ethiopia.

Syers JK, ET Craswell, and P Nyamudeza. 2001. Research Needs and Opportunities for Farming Vertisols Sustainably. *In*: Syers JK, FW Penning and P Nyamudeza (eds). 2001. The Sustainable Management of Vertisols. CABI Publishing. New York. USA.

Taye Bekele, Yesuf Assen, Sahlemedhin Sertsu, Amanuel Gorfu, Mohammed Hassena.D.G.Tanner and Tesfaye Tessemma.2002. Optimizing Fertilizer Use in Ethiopia.Correlation of Soil Analysis with Fertilizer Response in Hetosa Wereda, Arsi Zone. EARO/SG-2000 Collaborative Research.

Tekalign Mamo, I Haque and GS. Kamara. 1988. Phosphorus Status of Some EthiopianHighland Vertisols. *In:* Proceeding of Management of Vertisols in the Sub-Saharan Africa. International Livestock Center for Africa. Addis Ababa. Ethiopia.

Determination of Optimum N and P Fertilizer Rate for Bread Wheat in Alamata District, Tigray Region

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Introduction

The national yield bread wheat in Ethiopia is 2.45 t/ha; however, in Tigray Region, it is about 1.82 t/ha. The low mean yields are mainly attributed to a large number of integrated factors that include poor crop, soil, and water management; poor pest control; and low availability and dissemination of improved varieties and seeds. Low availability of nitrogen and phosphorus has been reported to be a major constraint to Wheat production in Ethiopia (Amanuel et at., 1991, Tekalign et at., 1988; Minale et al., 2006). An inadequate supply of N and P fertilizer greatly reduces yields and profit. Alamata area is one of the high potential areas in Tigray region for wheat production, and the introduction of high yielding bread Wheat genotype accompanied with improved production technology packages like optimum NP fertilizations could markedly increase the production and productivity of wheat. But none of the introduced bread wheat varieties were evaluated for their response to N and P in the study areas. Therefore, the present study was initiated with the objective of determining the optimum nitrogen and Phosphorus fertilizer rate to improve the production and productivity of wheat in the studied areas.

Materials and Methods

This study was conducted in southern part of Tigray at Ofla and Endamehoni Woredas in 2013. The experimental design was RCBD, replicated three times; with five levels of N (0, 46, 69, 92, 138, kg/ha) and four levels of P_2O_5 (0, 46, 69, 92) with a factorial combination. The gross and net plot size was 5 m x 4 m and 4 m x 3 m. Variety used was Mekelle 3. All P_2O_5 and half of the N was applied at planting, whereas the remaining N was applied at the start of heading (during the time of peak demand). The fertilizer sources for N and P were Urea and TSP. Seed rate of 150 kg/ha, row method of planting, and the recommended practices of land preparation and herbicides were used. Whenever necessary disease and soil-born pest control methods was implemented. Data was analyzed using SAS 9.0 statistical package (SAS 9.0, 2002).

Results and Discussion

The results of ANOVA is presented in Tables 1 and 2. The main and interaction effects of N and P_2O_5 on the grain and biomass yields of bread wheat were highly significant. The highest grain yields (3.81 t/ha and 4.7 t/ha) at Ofla and Mekan were obtained from combination of 69/46 and 69/69 kg/ha N- P_2O_5, in contrast to the yields of 1.52 and 2.03 t/ha from the control treatment, respectively. Highest biomass yields, 10.75 and 13.72 Mt/ha, for Ofla and Mekan were obtained from application of 138/69 and 138/ 46 kg/ha N- P_2O_5, respectively (Table 2). Looking at the yield data of the two locations, the tested crop was more responsive to fertilizer rates at Mekan than at Ofla. By looking at the graph shown in Figure 1, yields generally decline after the 69/46 and 69/69 kg/ha (N-P_2O_5) treatment levels for Ofla and Mekan areas, respectively.

Table 1: Main effect of N & P2O5 on GY of Bread Wheat (2013)

Treatment	Grain yield (t/ha)		Biomass yield (t/ha)	
	Ofla	Mekan	Ofla	Mekan
Nitrogen rate (kg/ha)				
0	1.84c	2.93e	5.50d	9.44d
46	2.97b	3.39d	7.23c	10.7c
69	3.28a	4.07a	8.24ab	11.8b
92	3.27a	3.69c	8.15b	12.11ab
138	3.306b	3.97b	8.48a	12.38a
LSD	0.14	0.10	0.32	0.395
P2O5 (kg/ha)				
0	2.54c	3.47c	6.83d	10.98c
46	2.76b	3.65ab	7.31c	11.65a
69	3.06a	3.74a	8.55a	11.16bc
92	3.17a	3.59b	7.7a	11.36ab
LSD	0.13	0.09	0.28	0.35
CV	5.93	6.68	4.02	4.23

Table 2 interaction effect of N and P2O5 o on grain yield and Biomass of bread wheat (2013)

N (kg/ha)	P_2O_5 (kg/ha)	Grain yield (t/ha)		Biomass yield (t/ha)	
		Ofla	Mekan	Ofla	Mekan
0	0	1.525k	2.032k	4.30g	6.34g
0	46	1.580k	3.14j	4.65g	10.14f
0	69	1.980 j	3.364i	6.65f	10.35f
0	92	2.26 ij	3.63efgh	6.4f	10.88ef
46	0	2.430hi	3.597fgh	7.15f	11.45de
46	46	2.895fg	3.497ghi	7.6ef	10.42f
46	69	3.020ef	3.49hi	6.4f	10.45f
46	92	3.540ab	3.637efgh	9.35bcd	10.51f
69	0	2.961fg	3.902bc	6.35f	12.55bc
69	46	3.810a	4.0b	10.5ab	12.17cd
69	69	3.080ef	4.743a	9.0cd	11.71d
69	92	3.250cde	3.643degh	7.1f	10.79ef
92	0	3.120def	3.73cdef	8.75cde	13.10ab
92	46	2.955fg	3.86bcd	6.8f	11.81cd
92	69	3.645ab	3.97b	9.95abc	11.43de
92	92	3.380bcd	3.361fgh	7.0f	12.08cd
138	0	2.690gh	3.623fgh	7.6f	11.46de
138	46	2.57 h	3.85bcde	7.0f	13.72a
138	69	3.560ab	3.72cdefg	10.75a	11.8cd
138	92	3.425bc	3.67defgh	8.55de	12.54bc
LSD		0.28	0.27	0.65	0.79

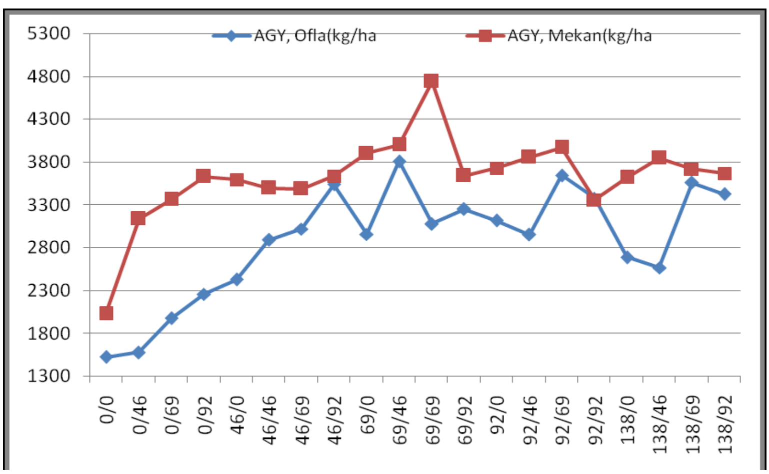

Figure 1: Curves showing grain yield response patterns to fertilizer N and P at two locations

Conclusions

The tested crop was more responsive to fertilizer rate increments at Mekan than at Ofla. One simple explanation could be Mekan area is more productive than the other is. Nevertheless, the management of trial site at Ofla was relatively poor and the topography of the site was sufficient to cause nutrient flows between blocks and/ or plots. Therefore, the difference in the responses between the two sites cannot definitely be attributed to the differences in the production potentials between the sites. Yield declines after the 69/46 kg/ha and 69/69 kg/ha N-P_2O_5 treatment levels are generally observed. This may not necessarily imply that the treatments with the highest grain and biomass yields are the threshold levels for the studied areas. Therefore, it is possible to assume that better yields could be obtained under well-controlled field management non-experimental factors. Nonetheless, the results obtained so far are good.

References

Amanuel Gorfu, Asefa Taa, DG Tanner and W Mwangi. 1991. On farm research to Derive Fertilizer Recommendations for Small-Scale Bread Wheat Production: Methodological Issues and Technical Results. Research Report No. 14. IAR, Addis Ababa, Ethiopia. 37pp.

Amsal Tarekegne, DG Tanner and Chanyalew Mandefro. 1997. Effect of cropping sequence and nutrient application on crop parameters during the first three seasons of a wheat based long-term trial in central Ethiopia. pp. 685-694. *In:* Adipala, E, JS Tenywa and MW Ogenga-Latigo (eds.). Proceedings of African Crop Science Conference 13 - 17 January 1997.) Vol. 3 Uganda, Kampala.

CSA. 2014. Report on Area and Production of Major Crops (Private Peasant Holdings, Meher Season). Statistical Bulletin. Volume I. April 2014, Addis Ababa.

Minale Liben, Alemayehu Assefa, Tilahun Tadesse and Abreham Mariye. 2006. Response of Bread Wheat to Nitrogen and Phosphorous Fertilizers at Different Agroecologies of Northwestern Ethiopia. pp 41-45. *In:* Kinyua, MGJ. JO Kamwaga, A Owuoche, C Ndiema, PN Njau, DK Friesen and D Ouya (eds). Proceedings of the 12th Regional Wheat Workshop for Eastern, Central, and Southern Africa. Nakuru, Kenya, 22–26 November 2004. Mexico, D.F.; CIMMYT and KARI.

Tekalign Mamo, I Haque and GS Kamara. 1988. Phosphorus Status of Some Ethiopian Highland Vertisols. In Proceeding of Management of Vertisols in the Sub-Saharan Africa. International Livestock Center for Africa. Addis Ababa. Ethiopia.

Effects of N and P Fertilizers on Yield and Utilization of Nutrient on Bread Wheat on Sandy Soils of Hawzen District, Tigray Region

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Introduction

Crop response to nitrogen fertilizer is influenced by factors such as nitrogen fertilizer management, soil type, crop sequence and supply of residual and mineralized nitrogen (Lory et al, 1995). A good supply of nitrogen to the plant stimulates root growth and development as well as uptake of other nutrients (FAO, 2000; Brady and Weil, 2002). Wheat total uptake of N increased with increasing N application (Damene. 2003). Nitrogen rate significantly influenced grain yield, protein content, N uptake efficiency, N biomass production efficiency, N utilization efficiency, N use efficiency for grain, and N use efficiency for protein yield of wheat (Haile et al, 2012). Phosphorus is the second most essential element of crop production and it is deficient in most soils around the world to achieve maximum yields. Adequate phosphorus enhances many aspects of plant physiology like fundamental process of photosynthesis, flowering, seed formation, and maturation (Brady and Weil, 2002, Salisbury and Ross, 1992). Fertilizer P application significantly and positively influenced grain yield and number of tiller of wheat (Damene. 2003). A report of (Mengel and Kirkby, 1996) had also indicated cereal crops requires about 20 kg P/ha for normal production. Residual soil available P content increased with increasing rates of applied P up to 20 kg P/ha after sowing (Damene, 2003).

Nitrogen and phosphorous are considered as the most deficient in soils of Ethiopia including Hawzen (Asnakew et al, 1991; Bereket and Yirgalem, 2012). Indicating nitrogen and phosphorus can be the most yield limiting factors of cereals including wheat production in Ethiopia. Soil fertility status also varies within adjacent farms or plots mainly due to preceding individual farmer's soil management practice. Though information on the effects of nitrogen and phosphorous on wheat productivity in Ethiopia is available, a comprehensive work is scanty in sandy and degraded soil like the case of Hawzen. Therefore, a fertilizer trial was conducted to develop the economically optimum fertilizer N and P management option for wheat production in Hawzen district.

Materials and Methods

The study area

: on-farm field experiments were conducted in 2013 growing season at Hawzen district, Tigray region. The study area is one of the major wheat growing areas in region. The trial was conducted in two nearby farmers' fields (located at 39° 27' 2'' E and 13° 15' 16'' N, altitude of 2263 meter above sea level for field 1 and at 39° 27' 30'' E and 13° 59' 9'' N, altitude of 2275 meter above sea level for field 2 to evaluate the response of bread wheat to nitrogen and phosphorous fertilization. Hawzen district is located in tepid to cool sub moist mountains plateau agro ecological zone (MoA, 2000). Soils in Hawzen district are one of the most degraded soils in the Tigray region which are believed to be very poor in soil organic matter. Wheat is grown during the main season from June to September. The wheat growing season of 2013 had relatively enough rainfall compared to the long term average. Annual mean maximum temperature is 24^{o}C and mean minimum is 7.7 ^{O}C. The rainfall data for the district was summarized from the nearest district data of Hawzen Office of Agriculture and Rural Development (Hawzen Office of Agriculture and Rural Development, 2013). Temperature and potential evapo-transpiration data were estimated using the LocClim 1.0 software (FAO, 2002).

The treatments were five levels of N (0, 46, 69, 92 and 138 N kg/ha) and four levels of P (0, 46, 69 and 92 P_2O_5 kg/ha). The treatments were replicated three times in a Randomized Complete Block design in a plot size of 3 m by 4 m. Nitrogen and phosphorus were applied in the form of urea and TSP, respectively. Phosphorous and half of the nitrogen rates were incorporated into the soil at planting. Half of the nitrogen rates were applied during tillering.

The initial experimental fields' soils were analyzed for texture, organic carbon, total nitrogen, CEC, available P, exchangeable Ca and Mg, and pH (table 1). Soil samples after harvest were also analyzed for total nitrogen and available phosphorus. The methods used for physicochemical analysis were pH (Jackson, 1967), organic carbon (modified Walkley and Black method (Jackson, 1967), texture using hydrometer method procedure of Bouyoucos (Day, 1965), available phosphorous (Olsen, 1954), total nitrogen using Kjeldehal method (Bremer and Mulvancy, 1982) and CEC and exchangeable Ca and Mg using Neutral ammonium acetate method(Black et al, 1965). Grain and straw samples were analyzed for nitrogen and phosphorous.

The bread wheat variety used in this experiment was Picaflor (*kekaba*) planted on 10 July 2013 for field 1 and 11 July 2013 for field 2. Harvesting was conducted on 30 October for field 1 and 23 October for field 2. Data was taken on number of plant height and spike length at maturity. Above ground biomass from sample quadrants were sun dried before weighing. The spikes were threshed and cleaned and grain yield was weighed. The straw yield was calculated by subtracting grain yield from the above ground biomass. Grain and straw yields were adjusted to 12.5 % moisture content. Nutrient recovery and uptake, agronomic and physiological nutrient use efficiency were calculated from established formulas and facts (Syers. et al., 2008).

Results and Discussions

Soil before Planting

The chemical and physical properties of the soils of the experimental fields are indicated in table 1. The soil textural classes for both experimental fields are sandy loam. From the results of the soil, analysis it can be depicted both nitrogen and phosphorous may be yield limiting for wheat production in the area. Experimental field 2 was relatively low in its soil fertility than experimental field 1 especially in its phosphorous availability, CEC, and texture.

Table1. Surface (0-20 cm) soil properties of experimental fields in on-farm experiments in Hawzen district Tigray Ethiopia in 2013

	Field 1	Field 2
pH_{water}(1:2.5)	6.83	5.94
Organic carbon (%)	0.67	0.61
P-Olsen (mg kg^{-1})	9.48	4.45
Total-N (%)	0.098	0.102
CEC (meq/100 g soil)	20.4	14.16
Exchangeable Ca (cmol(+)/kg soil)	1.2	.4
Exchangeable Mg (cmol(+)/kg soil)	4.8	.2
Clay (%)	14	4
Silt (%)	17	
Sand (%)	69	9

Yield components

The number of effective tillers per plants of wheat significantly increased due to the main effect of nitrogen and phosphorus fertilizers application in experimental field 1 (Table 2). Number of effective tillers per plant showed a significant increase in field 2 due to phosphorus application but not nitrogen fertilization. These results are supported by the findings of Damene, 2003). A significant decrease in thousands seed weight of wheat was observed due to nitrogen application (Reason: why N and not P). The current result is supported by the findings of Gooding and Davis (2007) and Damene, (2003). However, the trend was not observed due to phosphorous application and thousands seed weight of wheat was not significantly affected by phosphorus application. Not all the measured yield components were affected significantly by the interaction effect of nitrogen and phosphorus fertilization (Table 2).

Grain and straw yields

Grain yield of wheat significantly increased due to the main effect of nitrogen fertilization in both the experimental fields (Table 3). Highest grain yields were obtained at the highest nitrogen rate of 138 kg N/ha in both fields but was not statistically different from the rate of 69 kg N/ha in field 1 and 46 kg N/ha in field 2. Straw yield of wheat significantly increased due to nitrogen in field 1. The highest yield was recorded at the highest nitrogen rate though it was not statistically significant with the nitrogen rate of 69 kg N/ha. Straw yield was not affected significantly due to main effect of nitrogen in field 2, indicating that nitrogen is more yield limiting factor in field 1 than field 2 as both grain and straw yields of wheat responded to nitrogen application while only grain yield of wheat responded to nitrogen in field 2. Grain and straw yields of wheat were significantly increased due to the main effect of phosphorous in field 2 (Table 3). Highest grain yield was obtained at a rate of 69 kg P_2O_5/ha though it was not statistically different from the preceding lower rate (46 kg P_2O_5/ha). Highest straw yield was obtained at the highest phosphorous rate (92 kg P_2O_5/ha) though it was not statistically different from the preceding lower rate (69 kg P_2O_5/ha). Grain and straw yields of wheat were not significantly affected by the main effect of phosphorous in field 1. Though it was not statistically significant, 8% in grain and 11% in straw yields increase were observed in field 1 at the lowest phosphorous rate (46 kg P_2O_5/ha). The result indicated us phosphorus is yield limiting factor of wheat in field 2 but not in field 1. This is supported by the soil analysis result prior to planting where the available soil phosphorus content in field 2 is very low while the available soil phosphorous in field 1 is low in its class but near the range of sufficiency of phosphorous in soil (> 10 mg/kg) (table 1). Average grain and straw yields of wheat were better in field 1 than field 2 indicating a better soil fertility status of Field 1 than Field 2 (Table 1).

Table 2 Effect of N and P fertilizers on some agronomic parameters of bread wheat in two farmers' field in Hawzen district of Tigray Ethiopia in 2013

Treatment	**Field 1**				**Field 2**			
	NETPP	PH (cm)	HL (cm)	TSW (gm)	NETPP	PH (cm)	HL (cm)	TSW (gm)
N rate (kg/ha)								
0	2.10	67.37	6.18	40.03	3.32	68.67	6.12	32.39
46	3.10	75.98	6.97	38.87	3.53	69.85	6.67	31.35
69	3.24	76.97	7.30	38.14	2.60	70.58	7.08	28.53
92	3.14	79.12	7.13	37.87	3.70	71.92	6.77	30.12
138	3.91	79.82	7.50	34.73	3.78	70.32	6.97	29.05
LSD	0.64	4.28	0.377	3.5	NS	2.038	0.34	1.88
P-value	<0.001	<0.001	<0.001	0.05	NS	0.042	<0.001	<0.001
P rate (kg P_2O_5/ha)								
0	2.63	73.07	7.00	38.43	2.34	60.84	5.77	31.36
46	3.09	74.96	6.60	38.32	3.57	73.04	7.07	29.94
69	3.48	77.49	7.25	37.74	3.96	74.56	6.92	30.45
92	3.21	77.88	7.20	37.19	3.68	72.64	7.12	29.40
LSD	0.57	3.8	0.337	3.13	0.78	1.823	0.305	NS
P-value	0.038	0.05	0.002	NS	<0.001	<0.001	<0.001	NS
N*P interaction	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	25	6.8	6.5	11	31	3.1	7.5	7.5

Nutrient uptakes and recoveries

The total nitrogen and phosphorus uptakes of wheat increased with an increasing rate of nitrogen and phosphorus, respectively in field 1(Figure 2). In field 2 a trend of increase in nitrogen and phosphorus uptakes were observed till a rate of 69 kg N/ha and 69 kg P_2O_5/ha, respectively. However, a trend of decrease in both nutrients uptake was observed in the higher application rates of each nutrient.

Highest recovery fraction of nitrogen was obtained at a rate of 69 kg N/ha in both the experimental fields (Figure 3). Nitrogen recovery was higher in field 1 than field 2. Indicating nitrogen is yield-limiting factor of wheat in field 1. This is supported by yield response of wheat (Table 3). Highest recovery fraction of phosphorous was obtained at the highest rate of phosphorous (92 kg P_2O_5/ha) in field 1 and at a rate of 46 kg P_2O_5/ha in field 2. Highest recovery fraction at the highest phosphorous application rate field 1 is an indication that phosphorous is not yield limiting factor of wheat. Phosphorous recovery was higher in field 2 than field 1. Indicating phosphorus is yield-limiting factor of wheat in field 2. These are consistent with the soil phosphorus and the yield response of wheat to phosphorous application (Tables 1 and 3).

Table 3 Effect of N and P fertilizers on grain and straw yields of bread wheat in two farmers' field in Hawzen District of Tigray Ethiopia in 2013

Treatment	Grain yield (kg/ha)		Straw yield (kg/ha)	
	Field 1	Field 2	Field 1	Field 2
N rate (kg/ha)				
0	2496	2309	5715	5239
46	3656	2662	6623	5499
69	4131	2447	7244	6243
92	4398	2663	7592	5804
138	4443	2914	7897	6256
LSD	577	408	966	NS
P-value	<0.001	0.048	<0.001	NS
P rate (kg P_2O_5/ha)				
0	3551	1922	6357	4044
46	3837	2647	7056	5918
69	3988	2997	7044	6444
92	3922	2828	7285	6827
LSD	NS	402	NS	837
P-value	NS	<0.001	NS	<0.001
N*P interaction	NS	NS	NS	NS
CV (%)	18.2	19	16.7	19.5

Grain protein content due to nitrogen fertilization

Grain protein contents of wheat were highest at a rate of 138 kg N/ha (11.9 %) and 69 kg N/ha (13.36%) at application rates for field 1 46 kg N/ha and field 2, respectively indicating the required amount of nitrogen fertilizer to attain the highest protein content was less in field 2 than field 1 (Figures 1 and 2).The result is consistent with the trend of nitrogen uptake (Figure 2). A report by (Iqtidar et al, 2006) also indicated nitrogen fertilization increased protein content of wheat and the highest grain protein content (13.09%) was obtained at N rate of 120 kg N/ha. The lowest grain protein contents were recorded at nitrogen application rate of 46 kg N/ha (6.2%) and the control (9.5%) for field 1 and field 2, respectively. These showed the increases in yield of wheat (table 3) due to nitrogen fertilization at a rate of 46 kg N/ha were attained decreasing the protein content in field 1 and increasing the protein content in field 2. These could be due to dilution effect because field 1 was more responsive to nitrogen fertilization than field 2 and the percentage change in increase of wheat grain yield from the control was higher in field 1 than field 2 (Table 3).

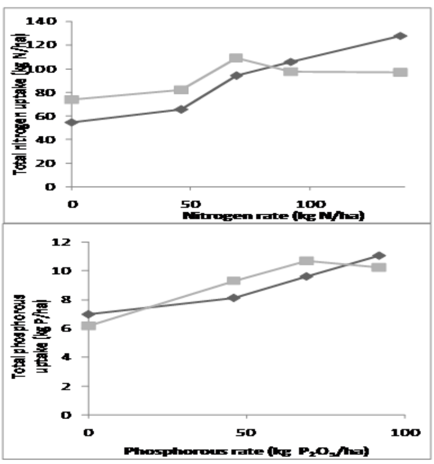

Figure 1. Nitrogen and phosphorous uptake as influenced by nitrogen and phosphorus application for field1 (a line and a triangles) and for field2 (a line and squares).

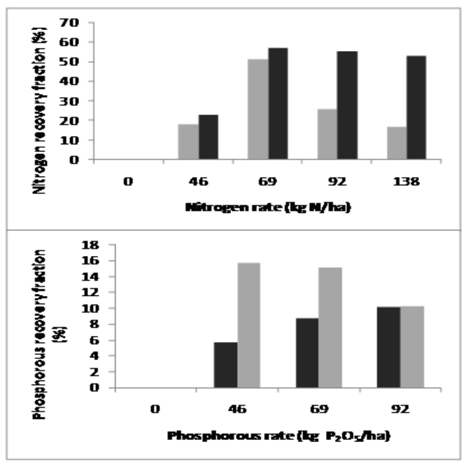

Figure 2. Nitrogen and phosphorous recovery for field1 (black bars) and for field2 (grey bars).

Partial budget analysis

An increase in output will always raise profit as long as the marginal rate of return is higher than the minimum rate of return i.e. 100% (CIMMYT, 1988).

Data in table 4 shows that the marginal rate of return at the nitrogen application rates of 46, 69 and 92 kg N/ha were greater than 100% in field 1 showing that it is economical to apply up to 92 kg N/ha. Nevertheless, field 2 does not exhibit a consistent result although it shows an economically feasible application rate at 92 kg N/ha. Wheat straw yield is also important as of grain yield to the smallholder farmers because wheat straw is an integral livestock feed. Considering straw in the partial analysis would improve the economic return of nitrogen fertilization in both fields.

Since the marginal rate of return in field 1 due to phosphorus application is less than 100%, application of phosphate application is not economical (table 5). This is in line with the initial soil P as it has relatively enough phosphorus. However, in field 2, it is economically profitable to apply up to 69 kg P_2O_5/ha. Considering straw yield in the partial analysis would also improve the economic return of phosphorus fertilization in field 2.

Conclusions

Wheat responded to both nitrogen and phosphorus in the less fertile soil while responded only to nitrogen in the relatively fertile soil. There were no interaction effects of the two nutrients to affect wheat productivity and nutrient utilization. The current soil fertility difference may not be due to the inherent soil fertility status because the experimental fields are near to each other and the parent material could also possibly be similar. Previous management by the farmers may have influenced the soil fertility status. Indicating our approach to soil fertility management should consider the past management history and should also be site specific based on soil fertility assessment.

References

Asnakew W. M Tarekegn. B Mengesha. and A Tefera. 1991. Soil fertility management studies and wheat in Ethiopia. pp 112-144. *In:* Hailu Gebremariam. DG.Tanner and Mengistu Huluka. (eds.). Wheat Research in Ethiopia. A Historical Perspective.IAR, CIMMYT, Addis Ababa, Ethiopia.

Brady NC and RR Weil. 2002. The Nature and Properties of Soils (13 th ed.) Pearson Education Ltd., USA

Bremner JM and CS Mulvaney. 1982. Total nitrogen. *In:* Page, AL, RH Miller and DR Keeney. (eds). Methods of Soil Analysis, Part 2. Argon.Mongr. 9. 2ed. ASA and SSSA, Madison, WI.

CIMMYT. 1998. From Agronomic data to farmers recommendations: An economic training manual. Completely revised edition, Mexico, D.F.

Damene. D. D.2003. Yield response of bread wheat (*Triticum aestivum* L.) to applied levels of N and P fertilizers on Nitosol of Dawro Zone, South Western Ethiopia, a thesis (M.Sc.), The School of Graduate Studies, Alemaya University, Ethiopia.

DZARC (Debreziet Agricultural Research Center). 1989. Annual Research Report of 1989.DZARC, Debre-Zeit, Ethiopia. PP. 64- 69.

Salisbury FN and CW Ross. 1992. Plant Physiology. 4th ed. Wads Worth Publishing Company, Belmant, California.1992.

FAO (Food and Agricultural Organization). 2002. Web LocClim, Local Climate Monthly Estimator. http://www.fao.org/sd/locclim/srv/locclim.home (February, 2014).

FAO (Food and Agricultural Organization). 2000. Fertilizers and their use 4th ed. International fertilizer industry association, FAO, Rome, Italy. 2000.

Gooding MJ and WP Davies. 1997. Wheat Production and Utilization, Systems, Quality, and Environment. CAB International, USA.

Haile D D Nigussie and A Ayana. 2012. Nitrogen use efficiency of bread wheat: Effects of nitrogen rate and time of application. Journal of Soil Science and Plant Nutrition, 2012, 12 (3), 389-409.

Hawzen Office of Agriculture and Rural Development, 2013. Unpublished metrological data, Hawzen, Tigray, Ethiopia.

Hussain M I and SH Shah. 2002. Growth, yield and quality response of three wheat (*Triticum aestivum L.*) varieties to different levels of N, P and K. Int. J.of Agri. and Bio., 4(3), 362-364.

Iqtidar H, AK Muhammad and AK Ejaz.. 2006. Bread wheat varieties as influenced by different nitrogen levels. J Zhejiang Univ Sci. 7(1), 70-78.

Lory JA. GW Randall and MP Russelle. 1995. A classification system for Factors affecting crop response to nitrogen fertilization. Agron. J. 87: 869-76

Jackson ML. 1967. Soil Chemical Analysis.Prentice Hall of India Pvt. Ltd., New Delhi.

Mengel. K and EA Kirkby. 1996. Principles of Plant Nutrition, Panimo Publishing Corporation, New Delhi, India.

Minale L, A Alemayehu, T Tilahun and M Abreham. 2006. Response of Bread Wheat to Nitrogen and Phosphorous Fertilizers at Different Agroecologies of Northwestern Ethiopia. *In:* Kinyua MG, J Kamwaga. JO Owuoche A C Ndiema. PN Njau. DK Friesen. D Ouya. (eds). Proceedings of the 12th Regional Wheat Workshop for Eastern, Central, and Southern Africa. Nakuru, Kenya, 22–26 November 2004.Mexico, D.F.; CIMMYT and KARI.

MoA (Ministry of Agriculture) 2000. Anonymous. Agro Ecological Zonation of Ethiopia. Ministry of Agriculture, Addis Ababa, Ethiopia.

Olsen SR, CV Cole, FS Watanabe and LA Dean. 1954. Estimation of available phosphorus in soil by extraction with sodium bicarbonate. USDA Circular 939:1-19. Gov. Printing Office Washington D.C.

Day PR. 1995. Particle fractionation and particle-size analysis. *In:* CA Black. DD Evans. JL White. LE Ensminger. FE Clark (eds). Method of Soil Analysis, Part 2. ASA, Inc. Madison, Wis, USA.

Shapiro. 2009. Monsanto's plan and prospects for wheat improvement through breeding and biotechnology. I*n:* Reynolds M and D Eaton (eds) Book of Abstract. Complementary strategies to raise wheat yield potential. Workshop held at CIMMYT, E. Baton, Mexico, DF., CIMMYT.

Syers JK, AE Johnston and D Curtin. 2008. Efficiency of Soil and Fertilizer Phosphorus Use: Reconciling changing concepts of soil phosphorus behavior with agronomic information. FAO Fertilizer and Plant Nutrition Bulletin 18. Food and Agricultural Organization of the United Nations. Rome

Response of Bread Wheat to N and P Fertilizer in Wonberema and Debre Elias Districts of Amhara Region

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Introduction

Amahra Region is one of the wheat producing regions in Ethiopia. The total wheat area and production in the Amhara Region in 2011 were reported as 498,748.68 ha (27% of the countries coverage) and 824,861.9 tons, respectively, with the productivity of 1.6 t/ha (CSA, 2011). In spite of its high importance in the region, the average wheat productivity of Amhara region is very low even less than the national average yield attributed mainly to lack of disease resistant varieties, poor crop management strategy (seeding rate, spacing, and fertilizer rate and planting method) which is characterized by low input agriculture. Despite the many research recommendations made in the region, they are limited in number; and the available technologies have not been adopted well. Most of the agronomic recommendations are now out dated and are not applicable and feasible at the existing farmers' condition, where the environmental and social situations are dramatically changed. Therefore, a trial was conducted by Adet Agricultural Research Center to develop improved fertilizer N and P management for Debre Elias and Wonberema districts.

Materials and Methods

Experimental design and treatments

The field experiment was conducted for two years 2012/13 and 2013/14 on farmers' fields at Debre Elias and Womberma, three sites for each. Treatments consisting of three levels of N (92,184,276 kg/ha) and three levels of P_2O_5 (30, 60,90kg/ha) including 138/46 kg/ha N/ P_2O_5 were laid out in factorial arrangement with RCBD, replicated three times. All P_2O_5 and half of the N was applied at planting whereas the remaining N was applied at tillering. The gross and net plot size used was 5 m x 4 m and 4 m x 3 m, respectively. The improved bread wheat variety (Tayi) was used in the trial with broadcast method of planting.

Data collection and analysis: All yield and yield component data were collected and subjected to analysis of variance using SAS 9.0 statistical software (SAS Institute, 2002). Data were analyzed for trials combined across site and seasons. The method of partial budget analysis recommended by CIMMYT (1988) was used to evaluate the economic profitability of the various treatment options and determine the economic optimum rate.

Results and Discussion

The response of grain yield for N was highly significant ($P<0.01$) at both locations while the response to phosphorus was statistically significant ($P<0.01$) at Debre Elias only (Table 1). The overall combined analysis showed that it was highly influenced by application of different levels of N and P_2O_5 (Table 4). The interaction of N and P was not significant to affect grain yield in both locations and their combination (Table 1). In contrast, Minale et al.(1998) revealed that N, P and site by N interactions significantly affected all of the crop parameters except the number of spikes m^{-1} . An increasing trend of grain yield with an application of increased N and P_2O_5 amount was obtained (table 1, 2, 3). The top N amount 276 N kg/ha gave the highest yield at the highest P_2O_5 level, 90 kg/ha; otherwise gave even lower yield than 184 N kg/ha with higher P levels (60 and 90 kg/ha P_2O_5).

Result of the economic analysis indicated that application of more N and P_2O_5 gave better net benefit over the lower N and P_2O_5 amount applied (Table 5). Using dominance analysis dominated treatments were removed from further analysis, and only two treatments had marginal rate of return (MRR) less than 100% among the none dominated ones.

Table 1: Over all ANOVA result for Wonberema and Debre Elias (2012-2013 combined)

Source of variation	Wonberema				Debre Elias				Mean of two locations			
	PH	TN	BY	GY	PH	TN	BY	GY	PH	TN	BY	GY
Nitrogen(N)	**	ns	**	**	**	**	**	**	**	ns	**	**
Phosphorus(P)	*	ns	ns	ns	**	**	**	**	**	ns	**	**
Year	**	**	*	**	**	*	**	**	**	**	*	**
Location	-	-	-	-	-	-	-	-	**	**	**	ns
N x P	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
N x P x location	-	-	-	-	-	-	-	-	ns	ns	ns	ns

Table 2: Effect of N and P on the yield and yield components at womberema- (2012-2013)

Treatment	Plant height (cm)	Tiller (number/m^2)	Fresh biomass (kg/ha)	Grain yield (ke/ha)_
Nitrogen (kg/ha)				
92	95.4B	5.0	5925.9B	3162.57 B
184	101.3A	5.3	8761.1A	4566.82 A
276	101.9A	5.1	9713.0A	4979.06 A
P	<.0001	0.61	<.0001	<.0001
Phosphorus (P_2O_5) kg/ha				
30	97.4B	5.0	7564.8	3877.57
60	100.5A	5.3	8296.3	4399.30
90	100.8A	5.1	8538.9	4431.58
P0.05&0.01	0.0349	0.7630	0.2133	0.2496
Nitrogen x Phosphorus				
92/30	91.7C	4.7	4777.8	2666.71 C
92/60	96.5BC	5.3	6305.6BC	3343.03 BC
92/90	98.1AB	4.9	6694.4BC	3478.26 BC
184/30	99.7AB	5.2	8361.1AB	4212.59 AB
184/60	103.0A	5.5	9027.8A	4773.01 AB
184/90	101.3AB	5.3	8894.4A	4714.99 AB
276/30	100.7AB	5.1	9555.6A	4753.67 AB
276/60	102.1AB	5.1	9555.6A	5082.16 A
276/90	103.0A	5.0	10027.8A	5101.50 A
C- 138/46	96.6	4.7	7167	4000.00
Mean	99.6	5.1	8133.3	4236.10
CV	5.3	28.2	25.7	32.0
P 0.01&0.05	0.0003	0.9599	<.0001	0.0011

Table 3: Effect of N and P on the yield and yield components at Debre Elias (2012-2013)

Treatment	Plant height (cm)	Tiller (number/m^2)	Fresh biomass (kg/ha)	Grain yield (kg/ha)
Nitrogen (kg/ha)				
92	88.9B	3.4A	5138.9B	3014.54 B
184	93.1A	2.5B	6805.6B	4077.36 A
276	93.9A	2.5B	7625.0A	4405.84 A
P	<.0001	0.0023	<.0001	0.0002
Phosphorus (P_2O_5) kg/ha				
30	89.2C	3.3A	5472.2B	3188.45
60	92.1B	2.6B	6416.7B	3787.41
90	94.6A	2.4B	7680.6A	4521.74
p	<.0001	0.0050	0.0002	0.0005
Nitrogen x Phosphorus				
92/30	86.0D	4.0A	3958.3D	2550.68 D
92/60	88.1D	2.9BC	5333.3DC	2956.52 CD
92/90	92.7AB	3.2AB	6125.0BC	3536.28CD
184/30	90.1BC	3.0BC	5791.7C	3536.28 BCD
184/60	93.4AB	2.7BC	6833.3BC	4000.00 BC
184/90	95.7A	2.0C	7791.7BC	4695.65 BA
276/30	91.6ABC	3.0BC	6666.7BC	3478.26 BCD
276/60	94.8A	2.4BC	7083.3BC	4405.84 AB
276/90	95.5A	2.1C	9125.0A	5333.29 A
C- 138/46	89.8	3.6	4125	2782.61
Mean	92.0	2.8	6523.1	3832.49
CV	3.5	27.3	22.3	24.5
P(0.01&0.05)	<.0001	0.0030	<.0001	0.0001

Table 4: Effect of N and P on the yield and yield components, combined over years and locations

Treatment	Plant height (cm)	Tiller (no/m^2)	Fresh biomass (kg/ha)	Grain yield (kg/ha)
Nitrogen (kg/ha)				
92	92.8B	4.3	5611.1C	3103.44 B
184	98.0A	4.2	7978.9B	4371.06 A
276	98.7B	4.0	8877.8A	4749.77 A
	<.0001	0.3685	<.0001	<.0001
Phosphorus (P_2O_5) kg/ha				
30	94.1B	4.3	6727.8B	3601.95 B
60	97.2A	4.2	7544.4A	4154.57 A
90	98.3A	4.0	8195.6A	4467.62 A
p	<.0001	0.3380	0.0007	0.0019
Nitrogen x Phosphorus				
92/30	89.4C	4.4	4450.0D	2620.24 A
92/60	93.1BC	4.4	5916.7DC	3188.45 ED
92/90	95.9AB	4.2	6466.7C	3501.50 EDC
184/30	95.9AB	4.3	7333.3BC	3941.98 EDC
184/60	99.2A	4.4	8150.0BA	4463.72 BA
184/90	99.1A	4.0	8453.3BA	4707.20 BA
276/30	97.0AB	4.3	8400.0BA	4243.48 BAC
276/60	99.2A	4.0	8566.7BA	4811.55 BA
276/90	100.0A	3.8	9666.7A	5194.16 A
C- 138/46	93.8	4.3	5950.0	3513.04
Mean	96.5	4.2	7489.2	4074.71
CV	4.7	29.3	25.0	29.8
P(0.01&0.05)	<.0001	0.9908	<.0001	<.0001

Table 5: Amount of input , total variable cost, gross and net benefit analysis table

Trt#	N level	P_2O_5	GY (kg/ha)	Adjusted GY (kg/ha	DAP (kg/ha	Urea (kg/ha)	TVC	Gross benefit (birr/ha)	Net benefit (birr/ha)
1	92	30	2620.24	2358.216	65.2	174.5	3534.2	16507.5	12973.3
2	92	60	3188.45	2869.605	130.4	149.0	4056.4	20087.2	16030.8
3	92	90	3501.5	3151.35	195.7	123.4	4578.6	22059.5	17480.9
4	184	30	3941.98	3547.782	65.2	374.5	6546.2	24834.5	18288.3
5	184	60	4463.72	4017.348	130.4	349.0	7068.4	28121.4	21053.1
6	184	90	4707.2	4236.48	195.7	323.4	7590.6	29655.4	22064.8
7	276	30	4243.48	3819.132	65.2	574.5	9558.2	26733.9	17175.7
8	276	60	4811.55	4330.395	130.4	549.0	10080.4	30312.8	20232.4
9	276	90	5194.16	4674.744	195.7	523.4	10602.6	32723.2	22120.6
Control	138	46	3513.04	3161.736	100.0	260.9	5318.7	22132.2	16813.5

Cost of Urea =15.06 birr/kg, DAP=13.90 birr/kg, Cost of wheat grain = 7 birr/kg

Table 6: Analysis of marginal rate of return (MRR %)

N level (kg/ha)	P_2O_5 (kg/ha)	TVC	Net Benefit (birr/ha)	MRR	MRR %	Rank
92	30	3534.2	12973.3			
92	60	4056.4	16030.8	5.855	585.517	
92	90	4578.6	17480.9	2.777	277.679	
184	30	6546.2	18288.3	0.410	41.035	
184	60	7068.4	21053.1	5.295	529.454	3rd
184	90	7590.6	22064.8	1.937	193.747	2nd
276	60	10080.4	20232.4	-0.736	-73.596	
276	90	10602.6	22120.6	3.616	361.600	1st

Conclusion and Recommendation

Generally, N significantly affected both grain and biomass yields at both locations, but Phosphorus significantly affected the yields only in Debre Elias. The highest yields (> 5.0 t/ha) were obtained from applications of 276/ 90 and 276/ 60 kg/ha N-P_2O_5. The results are clearly indicative of the fact that bread wheat is more responsive to N than P. Therefore, for those farmers with the good capacity to invest or with access to credit the 276 kg/ha N and 90 kg/ha P_2O_5 is recommended. Resource poor farmers can alternatively use 184 kg/ha N and 90 kg/ha P_2O_5 (320 kg/ha Urea and 200 kg/ha DAP), followed by 184 kg/ha N and 60 kg/ha P_2O_5 (375 kg/ha Urea + 130 kg/ha DAP) in both locations (Table 5). The study also revealed that application of more N would be profitable only with higher levels of P. The control treatment, which is 138/46 N/ P_2O_5 kg/ha (260 kg/ha Urea + 100 kg/ha DAP), which was the previous recommendation was proven to be less productive and not economical.

References

Asnakew W. 1989. The response of bread wheat to rate and time of nitrogen application,

CSA. 2011. Report on Area and Production of Major Crops (Private Peasant Holdings, Meher Season). Statistical Bulletin. Volume I. April 2011, Addis Ababa.

CIMMYT. 1988. From Agronomic Data to Farmer Recommendations: An Economics Training Manual. Completely revised edition. Mexico, D.F.

Minale Liben, Alemayehu Assefa, DG Tanner and Tilahun Tadesse. 1998. The Response of Bread Wheat to Nand P Application Under Improved Drainage on Bichena Vertisols in North-Western Ethiopia.

On-farm Participatory Evaluation of Bread Wheat Productivity under Different NP Levels, Precursor Crops, and Vertisols Types in the Highlands of Central Ethiopia

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Introduction

Field observations conducted in November 2006 by the author of this report showed that bread wheat covered about 65% of the total cropped areas in the Vertisol of Enewarie and Deneba. Different fertilizer rate studies were conducted to improve the agronomic and economic productivity of bread wheat on Vertisols of Deneba and Enewarie areas. Based on the works of ADD/NFIU (1991) on 2.5 ha field trial sites, 0.5 ha intermediate trial sites and dispersed simple fertilizer trials on farmers' fields, application of 60/13 kg/ha of N/P fertilizer was recommended. The Amharic version of Crop Production and Protection Manual (Amhara National Regional State Bureau of Agriculture, 1992 E.C) specifically recommended the application of 87/20 kg ha^{-1} of N/P. Thus the recommendations made since 1991 to 2000 did not take into account the effects of soil fertility variations caused by precursor crops and soil types within Vertisols. The most common precursor crops for wheat (lentil, chick pea, grass pea and tef) occupy about 35% of the total cultivated area. Moreover, simple random field observations by the author of this paper in 2006 growing season indicated that farmers' fertilizer application rate for wheat production ranged from 63/14 to 161/29 kg ha^{-1} of N/P as measured from 28 farmers in Deneba and Enewarie areas. This showed that farmers' application rates were by far higher than the recommended rate. Therefore, an on-farm NP fertilizers rate study was conducted in 2006-2007 to determine agronomic and economic yield response of bread wheat on the black soils of Deneba and Enewarie areas. Taking into account the agronomic and economic yield response of bread wheat to applied NP fertilizers, application of 151/40 and 192/60 kg/ha of N/P in Deneba-Enewarie areas were recommended for participatory evaluation by including the previous recommendation of 87/20 kg/ha of N/P and the latest farmers' application rate. Other adjustments in the recommendations to be made in the participatory evaluation were to include dominant precursor crops, Vertisols types, and appropriate sowing dates. Because, the recommended sowing date (early sowing while the soil is moist and friable) in general and wheat precursor in one site out of four highly depressed productivity in the on-farm NP fertilizer experiment conducted in 2006-2007. Early sown wheat, even if it is provided with BBM, faces waterlogging problem. Farmers believe that the sowing date and productivity of bread wheat vary according to the soil type and moisture condition of the soil. Using manually made BBM, farmers plant wheat relatively earlier (13 to 24 July) when the soil becomes saturated on relatively light Vertisols called bushel; or they plant late (25 July to 6 August) on relatively heavy Vertisols called mererie. Therefore, a participatory evaluation of the agronomic and economic performance the newly recommended rates as compared to the old blanket recommendation and farmers' highest rate in use was conducted in 2012 and 2013 under different management practices in the highlands of North Shewa.

Objective: the objective of the field trial was to demonstrate to farmers through participatory evaluation of the agronomic and economic performance of 151/40 and 192/60 kg ha^{-1} of N/P rates as compared to the old blanket recommendation and to the farmers' highest rate of fertilizer application under different precursor crops, late sowing dates, and Vertisols types in Enewarie and Deneba areas of the highlands of North Shewa.

Materials and Methods

Description of the Study Areas: a total of 32 sites in two years (representing mererie and bushella Vertisols as rated by farmers, precursor crops of lentil and tef) were selected with the participation of farmers and development agents in two locations, Deneba and Enewarie. The two locations are part of the Vertisol areas within geographical coordinates of 9°47'N - 9°53'N and 38°54'E - 39°13'E. The altitude of these areas range from 2600-2750 m asl. Bassed on lab analyses result of soil samples from mererie and bushella Vertisols, the clay contents of both Vertisols types was greater than 60%.

Design of Treatments

According to field observations made in 2012, some farmers applied the highest rate of 256/80 kg ha^{-1} of N/P fertilizer in Deneba and Enewarie areas. Therefore, this rate was taken as one of N/P fertilizer treatment levels for the participatory evaluation. The two N/P fertilizer treatment levels were 151/40 and 192/60 kg ha^{-1} that were selected from 155 N/P levels generated by response equations of the on-farm experiment conducted in 2006-2007. The last N/P fertilizer treatment level (87/20 kg/ha of N/P) was the old blanket recommendation released before 2000. A total of six fertilizer levels were tested on each of 32 sites, of which each of the two precursor crop by two soil type treatment combinations are represented by eight sites. There was no replication at each site. Plot size was $100m^2$, of which only $4.8m^2$ was harvested for yield estimation.

Management practices: bread wheat variety “Menzie” at the seed rate of 175 kg/ha was broadcasted in July 16-26 and 22–31, 2012 and 2013 on bushella Vertisols and mererie Vertisols, respectively. At sowing, broad beds with bed width of 80cm and furrows with width of 40cm and a depth of 15cm) were shaped manually after the furrow was made by oxen drawn plow. The sources of fertilizer levels were urea and DAP. DAP was applied all at sowing, and half of Urea at tillering stage, soon after weeding and the other half at the start of booting. Weeds were controlled by chemical spray and one hand weeding. Training and field days were conducted for farmers and farmers’ research group members about the participatory evaluation trial and management practices of wheat production on Vertisols. In addition, a one day result presentation workshop was held at Deneba and Enewarie in Aug 2013 to create awareness and reach a conclusive consensus in selecting final recommendable rate specific to Vertisols types and precursor crops for improving agronomic and economic productivity of bread wheat.

Data analyses

ANOVA and trend analyses using stepwise regression procedures were done using SAS statistical package (SAS. Version 9.0, 2002). General Linear Model was used to analyze the data by assigning precursor crops, Vertisol types and NP fertilizer levels in the respective main plots, sub-plots and sub-sub-plots. Thus there were eight replications. NP levels were used to fit response curve for the corresponding mean grain and straw yield from precursor crop by

Vertisol levels combination. Probability level of 5% was used for entering and retaining each term in stepwise regression analysis. Thus, for economic analyses, eight equations were generated from observed means so as to generate at least 21 NP fertilizer levels for each of corresponding grain and straw yields from precursor crop by Vertisols types combination. Economic analysis using procedures (CIMMYT, 1988) was done on 21 NP levels with corresponding grain and straw yields data generated from the fitted response curves. Input and output farm gate prices of May to June 2012 were used in the economic analyses. Thus urea, DAP, sun dried wheat grain and straw had a respective price of 12.076, 14.909, 7.65 and 1.57 Birr kg^{-1} at Deneba and Enewarie areas.

Results and Discussion

Appropriate selection of sowing dates and precursor crops in 2012 and 2013 participatory evaluation experiment highly improved productivity of N/P levels when compared to their productivity in 2006 and 2007 on-farm experiment in which yield was depressed by early sowing dates and wheat precursor (Table 2). The experience gained in 2006 and 2007 experiment with regard to sowing dates, precursor crops and Vertisol types that were supported by farmers' knowledge and the results of on-farm sowing date experiment in 2007-2008 (Unpublished data of the author) helped improve productivity by about 32-51% for grain yield, and 21-28% for straw yield (Table 2). It was also documented elsewhere in the highlands of central Ethiopia that the use of farmers' knowledge improved bread wheat productivity and helped select site specific fertilizer recommendations (Molla, 2013).

Results of analysis of variance by assigning precursor crops, Vertisols types and NP fertilizer in the respective main plots, sub-plots and sub-sub-plots are presented in Table 3. Only main effects of precursor crops, NP levels, and interaction effects of Vertisols type by precursor crops significantly ($p<0.05$) affected grain and straw yield response of bread wheat. Vertisols types highly affected yield response of bread wheat on lentil precursor than on tef precursor (Table 4). Lentil precursor on mererie Vertisols gave about 57% more grain yield of bread wheat over that of lentil precursor on bushella Vertisols. Differential effect of Vertisol types on bread wheat grain yield productivity following tef precursor was small that mererie Vertisols gave about 10% more grain yield over bushella Vertisols. Moreover, grain yield productivity of bread wheat was higher by about 24% on lentil than on tef precursor on mererie Vertisols, but productivity of lentil precursor was lower by about 13% than tef on bushella Vertisols. The trend was also similar for straw yield productivity on mererie Vertisols while the productivity gap was negligible on bushella Vertisols, straw yield of bread wheat on lentil precursor being about 2% lower than that of tef precursor. This shows that grain and straw yield productivity of bread wheat on mererie Vertisol was higher on lentil precursor than tef precursor, but tef precursor was higher yielding than lentil precursor on bushella Vertisols. Higher positive effect of tef precursor on bread wheat productivity on bushella Vertisols is difficult to explain but might be attributed to soil compaction practice of farmers' during tef sowing that might form firm structure to improve drainage in bushella Vertisols. Research results elsewhere also showed that even though tef is a cereal crop, it improves productivity of cereal crops when it is used as a precursor crop. For instance, a two rotation cycle experiment comprising tef-maize, climbing type haricot bean-maize, and soybean inoculated with rhizobium-maize gave the respective maize grain yield of 8.2, 8.6 and 7.8 t/ha at Bako, western Ethiopia (Zerihun *et al*, 2013). This shows that grain yield of maize following a cereal crop, tef, was comparable to those of legume precursors; such effects of tef should draw the attention of research so as to explain its attributes.

Mean separation showed that each preceding lower NP level was significantly ($p<0.05$) lower yielding than the immediate succeeding higher level (yields are presented in Table 2). This was also true for straw yield. Even though analysis of variance was not able to detect interaction effects of NP levels with Vertisols types and precursor crops, regression analyses showed that grain yield response of bread wheat to applied NP levels on lentil precursor of mererie Vertisols was highly significantly ($p<0.01$) quadratic while all other responses were significantly ($p<0.05$) linear (Fig. 1). Application of 107 kg/ha NP on lentil precursor of mererie Vertisols gave bread wheat grain yield of 3915 kg/ha that was higher than grain yield of 3768 kg/ha obtained from the application of 336 kg/ha NP on lentil precursor of bushella Vertisols. This clearly shows how farmers' knowledge was important in identifying Vertisol types that significantly affected yield response pattern of bread wheat to applied NP levels (Molla, 2013). Bread wheat straw yield response to applied NP fertilizer on tef precursor of mererie Vertisols was significantly ($p<0.05$)

cubic while all other NP by precursor crop by Vertisol types combination effects were significantly ($p<0.05$) linear. This trend could also be explained by soil analysis results presented in Table 1 and N to P ratios of NP rates presented in Table 5. Mererie Vertisols had relatively lower values of organic carbon and total nitrogen than bushella Vertisols and hence was more responsive to lower NP rates having higher ratio of N; decreasing N ratio with increasing NP rates. Relatively lower content of available P and K in bushella Vertisols was more responsive to application of higher NP rates for the reason that these higher NP rates had higher ratio of P. In other words, P ratio in NP rates increased with increasing NP rates (Table 5). Ratio of N to P affects productivity (Tahir *et al*, 2004).

Economic analyses showed that higher NP rates were more profitable on bushella Vertisols than on mererie Vertisols (Table 6). The highest NP rate, 336 kg/ha, gave marginal rate of return (MRR) values less than 50% on mererie Vertisols while it gave about 91-102% MRR on bushella Vertisols. NP rates of 191 and 252 kg/ha gave the respective MRR values ranging from 64.1 to 123.6%, and 44.3 to 77.9%; the highest values being on lentil precursor of mererie Vertisols for both NP rates. Other NP rates such as 210.1 and 273 selected from the curve fit of the observed yield data were more profitable by giving the respective MRR values ranging from 79.7-134.1% and 54.2-102.2%. Sensitivity analysis at 15% price increment of fertilizer also showed that these two NP rates have more than 50% MRR in all precursor crops by Vertisols types combinations except that 34% MRR was obtained for application of 273 kg/ha NP on tef precursor of mererie Vertisols. During the first year result presentation workshop in 2012, farmers commented that economic analysis should also be done by taking only grain yield to see the extent of profitability. Thus, when grain yield was considered as the only output for economic analysis, all NP rates, other than application of 191 and 210.1 kg/ha of NP, gave MRR values less than 50% in all precursor crops by Vertisols type combinations. Even MRR values of application of 191 and 210.1 kg/ha of NP were higher than 50% only on lentil precursor of mererie Vertisols. Unless straw yield is included in the economic analysis for other precursor crop by Vertisols types combinations, MRR values even for application of 191 and 210.1 kg/ha NP go down to as low as 14.7% and 30.6%, respectively, with no sensitivity analysis. Until management practices are developed to improve nutrient use efficiency for improving productivity and profitability of lower

NP rates, economic analysis based on grain yield data, excluding straw yield, could be a convincing approach so as to curtail farmers' run for higher NP rates; farmers also have reservation on monetary value of straw.

Table 1: Yield of bread wheat as affected by interaction of precursor crops and Vertisols types in 2012-2013 at Deneba-Enewarie areas

Precursor crops	Grain yield (kg/ha)			Straw yield (kg/ha)		
	Vertisol type		Difference	Vertisols type		Difference
	Mererie	Bushella		Mererie	Bushella	
Lentil	4848.87	3093.56	1755.31	7325.09	5053.69	2271.40
Tef	3920.63	3558.56	362.07	5444.38	5163.16	281.22
Difference	928.25	-465.0		1880.71	-109.47	

Table 2: Productivity of NP levels in 2006-2007 on-farm experiment and 2012-1013 on-farm participatory evaluation experiment

NP levels (kg/ha)	Predicted yield (kg/ha) in 2006-2007*		Observed yield (kg/ha) in 2012-2013#	
	Grain yield	Straw yield	Grain yield	Straw yield
107	2013	3286	3040	4193
191	2703	4393	3684	5396
252	3182	5294	4204	6412
336	Not tested	Not tested	4494	6986

Table 3: Analysis of variances summary for grain and straw yield responses of bread wheat to precursor crops, Vertisol types and NP fertilizer levels in Deneba and Enewarie areas, 2012-2013

Source of variation		Values for grain yield			Values for straw yield		
	DF	Mean square	F-value	Pr >F	Mean square	F-value	Pr >F
Precursor crop (P)	1	1716804.50	0.66	0.4299	25098612.50	4.31	0.0567
Rep(P)	14	2597928.44			5821110.70		
Vertisol type (V)	1	35866215.13	17.47	0.0009	52127155.13	12.10	0.0037
P*V	1	15529164.50	7.57	0.0156	31686770.28	7.35	0.0169
V*Rep(P)	14	2052667.79			4309679.10		
NP	3	13054901.6	117.02	<0.0001	48152936.60	89.04	<0.0001
P*NP	3	86247.94	0.77	0.5122	875368.50	1.62	0.1912
V*NP	3	76939.15	0.69	0.5609	502691.50	0.93	0.4302
P*V*NP	3	131476.15	1.18	0.3229	499230.90	0.92	0.4334
Error	84	111557.30			540821.10		

Table 4: Yield of bread wheat as affected by interaction of precursor crops and Vertisols at Deneba Enewarie areas types in 2012-2013

Precursor crops	Grain yield (kg/ha)			Straw yield (kg/ha)		
	Vertisol type		Difference	Vertisols type		Difference
	Mererie	Bushella		Mererie	Bushella	
Lentil	4848.87	3093.56	1755.31	7325.09	5053.69	2271.40
Tef	3920.63	3558.56	362.07	5444.38	5163.16	281.22
Difference	928.25	-465.0		1880.71	-109.47	

Table 5: Four tested NP levels and 17 NP levels generated by equations for economic analyses

NP levels (kg/ha)	Urea (kg/ha)	DAP (kg/ha)	N to P ratio		NP levels (kg/ha)	Urea (kg/ha)	DAP (kg/ha)	N to P ratio
107	150	100	4.35:1		210.1	275	220	3.78:1
115.9	162.5	108.3	4.35:1		219.7	287.5	230	3.78:1
124.8	175	116.7	4.35:1		252	300	300	3.20:1
133.8	187.5	125	4.35:1		262.5	312.5	312.5	3.20:1
142.7	200	133.3	4.35:1		273	325	325	3.20:1
151.6	212.5	141.7	4.35:1		283.5	337.5	337.5	3.20:1
160.5	225	150	4.35:1		294	350	350	3.20:1
169.4	237.5	158.3	4.35:1		304.5	362.5	362.5	3.20:1
191	250	200	3.78:1		315	375	375	3.20:1
200.6	262.5	210	3.78:1		325.5	387.5	387.5	3.20:1
					336	400	400	3.20:1

Table 6: Predicted grain and straw yields (10% downward adjusted), marginal rate of return (MRR) and sensitivity analyses results of four NP levels selected out of 21

NP rate (kg/ha)	Urea/DAP (kg/ha)	GY (kg/ha)	SY (kg/ha)	Fertilizer cost (birr/ha)	Net income (birr/ha)	MRR (%)	MRR (%) at 15% fertilizer price increment	MRR (%) for GY only
Effect of NP fertilizer applied on lentil precursor of mererie Vertisols								
107	150/100	3523	5132	3302.30	31707.30	-	-	-
191	250/200	4270	6204	6000.80	36403.28	123.6	94.4	67.6
210	275/220	4407	6447	6600.88	37231.31	134.1	103.5	70.3
252	300/300	4663	6982	8095.50	38540.82	77.9	54.7	23.7
273	325/325	4770	7250	8770.13	39101.72	78.9	55.6	16.6
336	400/400	5001	8053	10794.00	40103.82	28.5	11.7	Dominated
Effect of NP fertilizer applied on lentil precursor of bushella Vertisols								
107	150/100	2162	3116	3302.30	18128.80	-	-	-
191	250/200	2619	4167	6000.80	20573.50	71.2	48.8	16.3
210	275/220	2722	4406	6600.88	21142.89	94.9	69.4	32.4
252	300/300	2950	4930	8095.50	22213.75	65.8	44.1	12.6
273	325/325	3064	5193	8770.13	22824.92	90.6	65.7	29.5
336	400/400	3407	5981	10794.00	24658.45	90.6	65.7	29.5
Effect of NP fertilizer applied on tef precursor of mererie Vertisols								
107	150/100	2914	3767	3302.30	24904.78	-	-	-
191	250/200	3365	4835	6000.80	27330.93	64.1	42.7	14.7
210	275/220	3467	5028	6600.88	27817.83	79.7	56.2	30.6
252	300/300	3692	5368	8095.50	28577.16	44.3	25.4	11.1
273	325/325	3805	5491	8770.13	28956.24	54.2	34.0	27.8
336	400/400	4143	5630	10794.00	29737.08	26.6	10.1	27.8
Effect of NP fertilizer applied on tef precursor of bushella Vertisols								
107	150/100	2501	3328	3302.30	21057.45	-	-	-
191	250/200	3016	4296	6000.80	23814.32	81.5	57.8	31.0
210	275/220	3133	4516	6600.88	24454.69	106.7	79.7	49.2
252	300/300	3389	4998	8095.50	25681.25	75.9	52.9	26.9
273	325/325	3518	5240	8770.13	26370.48	102.2	75.8	45.9
336	400/400	3904	5966	10794.00	28438.14	102.2	75.8	45.9

References

ADD/NFIU (Agricultural Development Department/National Fertilizer and Inputs Unit). 1991. Results of fertilizer trials conducted on major cereal crops by ADD/NFIU (1986-1989). Joint Working Paper No. 34. Food and Agriculture Organization, Addis Ababa, Ethiopia

Amhara National Regional State Bureau of Agriculture. 1992.. Crop production and protection manual (Amharic Version). 98pp

Asamenew G, SC Jutzi, A Tedla and J McIntire. 1988. Economic Evaluation of Improved Vertisol Drainage for Food Crop Production in the Ethiopian Highlands. In Management of Vertisols in sub-Saharan Africa. Proceedings of a Conference Held at ILCA, Addis Ababa, Ethiopia, 31 August -4 September. ILCA, Addis Ababa, pp: 263-283

Asamenew G, H Beyene, W Negatu and G Ayele. 1993. A survey of the farming systems of Vertisol areas of the Ethiopian highlands. Pp: 29-49. *In:* Mamo T, A Astatke KL Srivastava and A Dibabe (eds.) *Improved management of Vertisols for sustainable crop-livestock production in the Ethiopian highlands: Synthesis report 1986-92*. Technical Committee of the Joint Vertisol Project, Addis Ababa, Ethiopia.

Badaruddin M and DW Meyer. 1994. Grain legume effects on soil nitrogen, grain yield and nitrogen nutrition of wheat. *Crop Sci.* 34: 1304-1309

CIMMYT (International Maize and Wheat Improvement Center). 1988. From agronomic data to farmer recommendations: An economic workbook, Mexico, D.F.: CIMMYT. 59pp

Ghobadi ME M Ghobadi and A Zebarjadi. 2011. The response of winter wheat to flooding. *World Academy of Science, Engineering and Technology* 78: 440-442

Karlen DL, DG Varvel, DG Bullock, RM Cruse. 1994. Crop rotation for the 21st century. *Adv. Agron.* 53: 1–45

Malik R 2010. Soil quality benefits of break crops and/ or crop rotations-a review. Nineteenth World Congress of Soil Science, Soil Solutions for a Changing World, 1–6 August 2010, Brisbane, Australia. Published on DVD, p95-98

Molla A. 2013. Farmers' Knowledge Helps Develop Site Specific Fertilizer Rate Recommendations, Central Highlands of Ethiopia. World Applied Sciences Journal 22(4): 555-563.

Rahimizadeh M, A Kashani, A Zare-Feizabadi, A Koocheki and M Nassiri-Mahallati. 2010. Nitrogen use efficiency of wheat as affected by preceding crop, application rate of nitrogen and crop residues. Australian J. Crop Sci. 4(5): 363-368

Ryan J, S Garabet, K Harmsen and A Rashid. 1996. A soil and plant analysis manual adapted for the West Asia and North Africa region. ICARDA, Aleppo, Syria. 140pp

Setter TL and I Waters, 2003. Review of Prospects for Germplasm Improvement for Waterlogging Tolerance in Wheat, Barley and Oats. *Plant and Soil* 253: 1–34.

Tahir M, MA Ali, S Iqbal and M Yamin. 2004. Evaluation of the effect of use of NP fertilizer in different ratios on the yield of wheat (*Triticum aestivum*) crop. *Pak. J. Life Soc. Sci.* 2(2): 145-147

Tanner D G, A Gorfu and K. Zewdie, 1991. Wheat Agronomy Research in Ethiopia. In Wheat Research in Ethiopia: A historical Perspective, Addis Ababa, IAR/CIMMYT, pp: 95-135.

Zerihun A, T Abera, T Dedefo and K Fred. 2013. Maize yield response to crop rotation, farmyard manure and inorganic fertilizer application in western Ethiopia. *Afr. J. Agric. Res.* 8(46): 5889-5895

Effect of Sulfur and Nitrogen Fertilizers on Yield and Quality of Durum Wheat on Vertisols of Central Shewa

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Introduction

Grain protein can be used to indicate if current nitrogen fertilizer or rotation practices are providing adequate nitrogen to the crop to meet the requirements arising from the water supply the crop had access to. Profits may also suffer not only due to lost yield, but due to potentially downgrading to a lower classification.

Sulfur deficiency may depress protein formation and prevent nitrate being converted into protein. This may result in low protein grain with high total nitrogen content; and thus making flour of poor bread-making quality (Amsal et al, 2000). Sulfur is also involved in the formation of chlorophyll and in the activation of enzymes (FAO, 2006). Sulfur responses are widespread on the central parts of Ethiopia where Vertisols are dominant, more so on the Chefe Donsa and Debre Birhan areas, and in areas where waterlogging is prominent (Abiy Astatke *et al.*, 2003). Hence, this study was conducted with the objective to quantify the effects of nitrogen and sulfur fertilization on grain yield and protein composition and quality of durum wheat.

Materials and Method

The study was conducted during the 2012/13 main cropping season under rainfed conditions at two districts of East Shewa Zone of Oromia Regional State at one and two farmers' field at Ada and Chefe Donsa Districts, respectively. The experiment comprised of 9 treatments with three levels of N and three levels of S, laid out in Split plot design with four replications. The main plots consisted of three levels of N (60, 90 and 120 kg/ha) and sub-plot with three levels of S (0, 18, 36 kg/ha). The gross plot size was 4 m X 4 m (**16** m^2), and the spacing between main plots and sub plots was 1 m and 0.5 m, respectively. Phosphorus fertilizer was applied to all plots as non-experimental variable at the rate of 10 kg P/ha. Improved durum wheat variety known as *Yerer* was used as a test crop and broadcasted at the rate of 175 kg/ha. The full dose of P fertilizer and half dose of N treatment fertilizer were applied as basal application at planting time and the remaining half N was side dressed at the mid tillering stage.

During the different growth stages of the crop, the necessary cultural and recommended agronomic management practices were all carried out. Accordingly; weeding was done manually three times during the period of the crop. The crop data collected include plant height measured from 10 randomly taken plants per plot at physiological maturity; and grain yield was determined from the net harvested plot area after harvesting and threshing. Similarly, the straw yield was recorded as the difference between the air dry weight of the total above ground biomass measured before threshing and the grain yield. On the other hand, the total above ground biomass was calculated as the sum of the grain yield and the straw biomass recorded on air dry basis. Grain quality parameter (Gluten, moisture content, crude protein and vitreousness) was conducted at Sinana Agricultural Research Center laboratory using Mininfra Smart NIT Analyzer. Soil sample were collected before and after harvest but because of lab renovation activity for laboratory accreditation process, it became difficult to conduct the analysis. Sample grain for quality from Chefe Donsa site were lost due to delays in the laboratory analysis.

The yield and yield component data were subjected to analysis of variance (ANOVA) appropriate to randomized complete block design using SAS software program (SAS Institute, 2000). The analysis results of the grain samples were interpreted using descriptive statistics. When significant differences were observed, comparisons of means were performed using the least significant difference (LSD).

Results

Nitrogen and sulfur fertilizer sources were evaluated under durum wheat at Chefe Donsa and Ada condition in main cropping season. Wheat yields became low, whenever there is a general decline in the fertility status of the soils. These might be true for the Chefe Donsa Vertisols, where the response of durum wheat for nitrogen was significant for plant height, straw and grain yield with the use of 60, 90 and 120 kg/ha nitrogen rates. The highest durum wheat grain and straw yield recorded, 1570 and 3409 kg/ha, respectively, was with the highest plant height, 70cm (Table 1). In agreement with this result, Amsal *et al.* (2000) reported a positive and linear response of plant height to N fertilizer application in the central highlands of Ethiopia.

Table1. Main effects of N and S fertilization on wheat plant height, grain yield and straw yield for Chefe donsa

N rate (kg/ha)	Plant height (cm)	Grain yield (kg/ha)	Straw yield (kg/ha)
Effect of N			
60	60.00c	1044.3b	2872.7b
90	64.50b	1276.3ab	3307.2ab
120	70.08a	1570.8a	3408.7a
LSD (0.05)	2.5	302.33	454.09
S level (kg/ha)	Effect of S		
0	64.33a	1161.9a	2963.6b
18	65.16a	1354.3a	3437.7a
36	65.08a	1375.6a	3187.3ab
CV %	4.49	27.21	16.56
LSD (0.05)	Ns	ns	454.09

**Means within a column sharing common letter(s) are not significantly different at P < 0.05; ns = Non significant; CV values of the respective parameters are common for both main effects*

The response of durum wheat to sulfur application up to 36 kg/ha did not show significant grain yield difference (Table 1), despite the general truth S deficiency resembles that of N. S deficiency symptoms start with the appearance of pale yellow or light-green leaves, unlike N deficiency (FAO, 2006). The durum wheat response for N varies from place to place depending on the fertility status of the soils. Table 2 shows no significant grain and straw yield difference for the application of both grain and straw yields at Ada. However, the overall grain and straw yields obtained at Ada were higher than durum wheat yield at Chefe Donsa. Similar to the case of Ada'a another location at Chefe Donsa showed no significant grain and straw yields difference for the interaction effect of N and S fertilizer applications (Table 3). The overall durum wheat yield obtained from Ada was much higher than the yields obtained from Chefe Donsa.

Table 2. Main effects of N and S on plant height, grain yield and straw yield for Ada 'a

N rate (kg/ha)	Plant height (cm)	Grain yield (kg/ha)	Straw yield (kg/ha)
Effect of N			
60	76.67b	2770.3a	3875.5a
90	79.91a	2811.7a	3605.0a
120	79.83a	2770.3a	3802.0a
LSD (0.05)	2.3	Ns	Ns
S level (kg/ha)	Effect of S		
0	79.08a	2797.8a	3743.9a
18	78.75a	2748.2a	3710.1a
36	78.58a	3004.8a	3828.5a
CV %	3.4	14.88	11.95
LSD (0.05)	Ns	Ns	Ns

**Means within a column sharing common letter(s) are not significantly different at P < 0.05; ns = Non significant; CV values of the respective parameters are common for both main effects*

Probably, this can happen due to the variation in the soil fertility status of the two locations. Therefore, it is necessary to obtain and compare the soil analysis result for the two locations.

Table 3. Interaction effect of N and S fertilization on wheat grain yield at Chefe Donsa (Endale)

N level (kg/ha)	S level (kg/ha)	Grain yield (kg/ha)
60	0	1544.37
60	18	1825.00
60	36	2023.75
90	0	2587.50
90	18	2325.62
90	36	2517.18
120	0	2520.93
120	18	2470.93
120	36	2060.62
CV %		12.57
LSD (0.05)		238.15

Despite the poor fertilizer response (for both N and S) this study managed to determine the grain quality parameter of durum wheat obtained from Ada district. The grain quality result for durum wheat showed no significant variation for gluten, moisture, protein, and virtuousness analysis (Table 4). Also most of the quality parameters conducted fall under normal condition. However the lower moisture content observed may be due to delayed analysis of the samples.

Table 4. Effect of N and S fertilization on selected quality parameters Ada'a

N level (kg/ha)	S level (kg/ha)	Grain quality parameters (%)			
		Gluten	Moisture	Protein	Virtuousness
60	0	26.8	11.8	12.1	94.8
60	18	26.1	11.5	11.7	95.58
60	36	27.2	11.5	12.4	94.14
90	0	26.2	11.5	11.8	92.3
90	18	25.1	11.6	11.5	95.22
90	36	26.0	11.3	11.8	89.92
120	0	26.0	11.7	11.9	92.36
120	18	27.1	11.5	12.4	91.1
120	36	27.5	11.4	12.3	93.48

References

Abiye Astatke, Tekalign Mamo, D Peden and M Diedhiou. 2003. Participatory On-farm conservation tillage trial in Ethiopian highland vertisols: The impact of potassium application on crop yield. Experimental Agriculture 40:369-379.

Amsal Tarekegn, DG Tanner and Chanyalew Mandefro, 2000. Agronomic and economic evaluation of the farm N and P response of bread wheat grown on two contrasting soil types in central Ethiopia.

Benton Jones J. 2002. Agronomic Handbook: Management of Crops, Soils and Their Fertility Hardcover – October 29, 2002

Efrem Bechere, Hirut Kebede and Getachew Belay, 2000. Durum Wheat in Ethiopia: An Old Crop in an Ancient Land. IBCR, Addis Ababa, Ethiopia.

FAO (Food and Agriculture Organization). 2006. Plant nutrition for food security: A guide for integrated nutrient management. FAO, Fertilizer and Plant Nutrition Bulletin 16. FAO, Rome

Determining Economic Fertilizer Rates for Bread Wheat in the Southeastern Highlands of Ethiopia

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Introduction

Increased use of fertilizers, particularly of N, has been recommended as a primary means of increasing wheat grain yields in Ethiopia (Amanuel *et al.*, 1991; Tanner et al, 1993; Asefa at al, 1997; Shambel et al, 1999; Minale et al, 1999; Amsal et al, 2000; Taye B. et al, 2002; Minale et al, 2004), focusing on economically optimal rates of N and P derived from on-farm trials using the previously recommended wheat cultivars. Varietal differences in response to applied N, including differences in N uptake, N use efficiency and apparent N recovery has also been documented by Tilahun *et al.* (1996),

However, many of the published and unpublished reports lacked considerations of varietal, locations, and seed rates interactions with fertilizer rates. Crop yield responses are influenced by both genetic and environmental factors and the interaction between them (Tisdale et al, 2002). Differences in tillering potential, seed size, and other agronomic characteristics exist among bread wheat genotypes released so far in Ethiopia. Variations in the environmental and management factors and their interactions control the degree of expressions of the genetic potential of different varieties. Contrary to this fact, however, most researches done so far in Ethiopia to improve productions gave focus on the effect of a single factor rather than their interactions; as a result of which, the additional benefits to have been gained through the use of optimum combinations of the different management factors have been missed. Generally, information on varietal differences on the responses of bread wheat to differences in seed rates and nutritional levels under different environmental conditions would be very useful in the planning of our seed system and struggle for increased productions and productivity of wheat in the country. With this background, a trial was conducted under different environments of Ethiopia with the objective of determining the effect of different combinations of seed and fertilizer rates on the yield and yield components of different bread wheat cultivars. The outputs of this research will contribute a lot to improve the development of a complete bread wheat productions package for a number of locations based on agro-ecologies.

Materials and Methods

Location description

The experiment was conducted during the 2013 main cropping seasons on farmers' fields and on research stations of Arsi zone, in the districts of Digelu-Tijo, Kofele, and Tiyo. The soils vary from Haplic Luvisols in Tiyo District to Eutric Vertisols and Humic Nitosols in Digelu-Tijo and Kofele districts, respectively. The agroecologies of the study areas vary from Tepid to cool moist mid highlands to tepid to cool humid mid highlands (Ethio-Italian Development Cooperation, 2002)

Split-split plot design replicated three times was used. In order to account for the interaction effects of various factors three recently released bread wheat varieties; namely, Hidase, Shorima, and Degleu were used as the main plot factor and combined in a factorial arrangement with three fertilizer rates: recommended NP (RNP), 1.5RNP, and 2RNP; and four seed rates (100, 150, 200 and 250kg/ha for Vertisols areas and 75, 125, 175, 225 kg/ha for the non-Vertisols). Fertilizer rates and seed rates were used as the sub-plot, and sub-sub plot factors, respectively. In another experiment Shorima, and Degleu were combined with three fertilizer and four seed rates. The number of varieties in this experiment was reduced from three to two in order to reduce the field sizes by one third due to the difficulties in obtaining the required land sizes under farmers' fields. The trial that consisted of three varieties was conducted on research sub-stations located on the three districts and the second trial that consisted of two varieties was conducted on four sites under farmers' fields, making seven sites. All P_2O_5 and half of the N was applied at planting and the remaining N before booting stage. The gross and net plot size were 5 m x 4 m and 3 m x 3 m, respectively.

Data Collection and Analysis

Data on grain yield and yield components such as seedling density, number of tillers per plant, spike length, number of kernels per spike, thousand kernel weight (TKW), plant height, grain, and biomass yields were collected at the recommended time. Information on disease and pest incidences and lodging was also collected. Harvesting was done by hand using sickles. Hundred-culm weight (100cw) were collected from four to five points within a plot and slashed from close to the ground surface and the dry matter yield of aboveground biomass was determined. Grain yield was determined from 9 m^2 net plot by hand threshing of the harvested samples. Yield adjustments were made based on 12.5% moisture content. Above ground biomass yields were determined based on data of hundred culm weight and the harvest index (HI) calculated as the ratio of grain yield to above ground biomass yield expressed as a percentage. TKW was determined by weighing 1000 grains and adjusted under 11% moisture content. The number of grains/spike was determined by hand counting of the grains from 5 spike samples and averaging them. Plant samples were collected for analysis of straw N absorption and grain quality analysis was done to determine how grain quality and N absorption efficiency are affected by fertilization. However, the complete report is included in a paper presented for publication.

To determine the effect of location and varietal differences on the yield, linear regression model from SPSS 20 software (IBM, 1989-2011) was used by taking Digelu-Tijo and Digelu as reference location and variety, respectively. Yield and yield component data were subjected to analysis of variance using SAS 9.0 statistical software (SAS, 2002). The Duncan Multiple Range Test (DMRT) test ($P<0.05$) was used to assess differences among treatment means.

Results and Discussion

Grain and biomass yield responses

Grain yields and yield components of the test crops under different fertilizer and seed rate combinations are presented in tables 1, 2, 3. The average grain and biological yields (AGY and ABY) of Hidase variety at Kofele are highly significantly and significantly affected by the treatments with mean grain and biomass yields of 5.65 and 16.0 t/ha. In contrast to the control treatment (Recommended NP and 125 kg/ha seed rate) grain yield of 5.4 mt/ha, the highest and lowest AGY obtained were 6.71 and 4.8 mt/ha, with treatments of 1.5 RNP/ 225 kg/ha and RNP/ 75 kg/ha fertilizer and seed rate, respectively. Similarly, the highest and lowest ABY obtained were 20.1 and 12.6 Mt/ha with corresponding treatments of 1.5 RNP/ 225 kg/ha seed rate and RNP/ 75 seed rate kg/ha, respectively, against the control treatment of yield of 13.6 mt/ha. Similarly, the grain and biomass yields of Digelu variety was significantly affected by the treatments with mean AGY and ABY of 4.95 and 15.6 Mt/ha. SHORIMA Variety was not significantly affected by the treatments at < 0.05 significant level.

Location and varietal effects

Hidase performed better than at Kulumsa, with the highest AGY obtained being 7.67 mt/ha and yield increments of 964 and 1553 kg/ha, as compared to Kofele and Sagure area (Digelu-Tijo district), respectively. Digelu performed much better at Kofele district, with the highest economical yields obtained being 5.9 mt/ha and yield increments of 705 and 815 as compared to Kulumsa and Digelu Tijo (Sagure), respectively. Shorima super performed at Kofele and Kulumsa (Tiyo) with the highest AGY of 6.54 and 6.51 mt/ha, respectively, as compared to 4.2 mt/ha recorded at Digelu-Tijo.

The differences in the varietal responses at each location are illustrated in table 2. Hidase and Shorima super performed at Kofele with AGY of 6.7 and 6.5 Mt/ha, as compared to 6.0 Mt/ha recorded by Digelu. In the other two locations the highest yield was recorded by Hidase, with 6.1 and 7.67 Mt/ha at Digelu-Tijo and Kulumsa, respectively. Using SPSS 20 linear regression model and setting Digelu-Tijo district (Sagure area) and Digelu variety as the demy variables the effect of location on the varietal responses was analyzed. The average responses of the three varieties at Kulumsa (Tiyo district) and Kofele was found to be 1344 and 1119 kg/ha higher as compared to Digelu-Tijo. Same analysis on the general varietal differences averaged over locations showed that HIDASE and SHORIMA super performed as compared to DIGELU with mean extra yields of 1420 and 656 kg/ha, respectively.

Seed and fertilizer rate effects on AGY and ABY

The main effects of both seed and fertilizer rate were either very highly or highly significant. SPM and NSPS were positively affected by seed rate and fertilizer rate increments, respectively. The differential responses in grain yields of each variety to different seed and fertilizer rates under different locations is presented in two way ANOVA table (table 2). At Kulumsa (Tiyo district), Hidase responded positively to either increased seed (up to 175 kg/ha) under RNP or increased fertilizer rate. The same variety at Kofele responded positively to decreased seed rate at the RNP, but to increased seed rate (up to 175 kg/ha) at higher fertilizer rates. When the fertilizer rate was at 2 RNP, the recommended seed rate (125 kg/ha) gave high yields of 6.6 Mt/ha. With the fertilizer rate was 1.5 RNP, a seed rate of 225 kg/ha gave 6.7 Mt/ha, against 5.4 Mt/ha yield obtained from recommended seed and fertilizer rates. The response at Digelu-Tijo was to increased fertilizer rates.

DIGELU responded best at the recommended fertilizer (RNP, control FR) and recommended seed rate (125 kg/ha) at Kofele. It responded better at RNP and increased seed rate (175 kg/ha) at Kulumsa, and to increased fertilizer rate at Digelu-Tijo, with yield increments of 941 and 1231kg/ha, respectively, as compared to the yields obtained at the recommended rates. SHORIMA responded positively to increased seed rate at the RNP at Kulumsa; although, the highest yield (6.5mt/ha) obtained was at 2 RNP and 125 kg/ha seed rate, compared to 5.4 Mt/ha at the RNP and recommended seed rate. At Kofele, the same variety responded more positively to increased seed rate than fertilizer rate. At Digelu-Tijo, it generally responded positively to both increased fertilizer and seed rate.

Table 1: Analysis of variance of the main and interaction effects of SR, FR, Variety, and location on the yield and yield components (three-variety trial result).

Source	Main trts	PH	SPM	AGY	ABY	HI	NSPS	TKW	HLW
Variety	Hidase	106	541	5958	16084	37.6	46.9	37.7	74.5
	Digelu	116.5	493	4541	14114	32.5	46.9	33.1	76.1
	Shorima	104.5	573	5227	14436	36.4	45.5	32.6	76.8
		***	***	***	***	***	NS	***	***
	Mean	109	536	5242	14878	36	46	34	76
FR	FR1	107	527	5089	14205	36.0	45.1	34.9	76.1
	FR2	110	536	5242	14870	35.7	46.8	34.4	75.6
	FR3	110	543	5397	15591	34.9	47.5	34.0	75.6
		NS	NS	***	***	NS	*	**	*
	Mean	109	535	5243	14889	36	46	34	76
SR	SR1	107	509	4981	13645	36.8	47.5	34.9	76.0
	SR2	108	529	5293	14675	36.3	46.1	34.8	76.1
	SR3	108	551	5357	15231	35.4	46.0	34.2	75.6
	SR4	112	553	5326	15973	33.6	46.3	33.9	75.4
		NS	***	***	***	***	NS	***	**
	Mean	109	536	5239	14881	36	46	34	76
LOC		***	***	***	***	NS	***	***	***
Rep		NS	*	***	**	NS	***	NS	NS
FR*LOCA		NS	NS	***	NS	NS	NS	***	**
FR*SR		NS	NS	NS	NS	NS	NS	NS	NS
Variety*FR		NS	NS	***	**	NS	NS	NS	NS
SR*LOC		NS	*	***	**	NS	NS	**	NS
Variety*LOC		NS	***	***	***	***	***	***	***
Variety*SR		NS	NS	NS	NS	***	NS	NS	NS
mean		109	536	5242	14884	35.5	46.5	34.5	75.8
CV		11.5	10.8	12.8	17	11.2	15.1	5.4	1.8

Table 2: Two way table of economic yields (FR*SR) per variety arranged location wise

Two way table of economic yields (FR*SR) per variety arranged location wise														
Kulumsa(Tiyo)	SR (kg/ha)	Hidase			Mean GY	Digelu			Mean GY	Shorima			Mean GY
		RNP	1.5RNP	2RNP		RNP	1.5RNP	2RNP		RNP	1.5RNP	2RNP	
	75	5890	7043	7529	6821	4033	4388	4342	4254	5413	5904	5862	5726
	125	7029	7424	7346	7266	4271	4328	4464	4354	5245	5760	6538	5848
	175	7200	7413	7273	7295	5212	4217	4143	4524	5625	6154	5683	5821
	225	6773	7230	7676	7226	4232	4217	4451	4300	5866	5425	5681	5657
	Mean	6723	7278	7456		4437	4288	4350		5537	5811	5941	
Kofele													
	75	4772	5106	4460	4779	5354	4468	3027	4283	5480	4933	5767	5393
	125	5357	5097	6595	5683	5917	4601	5041	5186	6036	6039	5593	5889
	175	5924	5863	5752	5846	5800	4069	5290	5053	6270	5961	6435	6222
	225	5731	6717	6456	6301	5984	5184	4704	5291	6515	6497	6640	6551
	Mean	5446	5696	5816		5764	4581	4516		6075	5858	6109	
Digelu-Tijo													
	75	5059	5020	5730	5270	3883	3910	5044	4279	3220	3937	4023	3727
	125	4753	5056	6123	5311	3810	4060	4427	4099	2820	4207	4155	3727
	175	3904	5585	5744	5078	4501	5102	3984	4529	3422	3830	4300	3851
	225	3977	4846	4737	4520	3769	4189	4790	4249	3393	3691	4319	3801
	Mean	4423	5127	5584		3991	4315	4561		3214	3916	4199	

Similar trial was conducted under two farmers' fields at Digelu-Tijo and on-station at Tiyo (Kulumsa) and Kofele districts using two varieties (Digelu and Hidase). The results of the two-variety trial showed that Hidase variety (Hidase) responded positively to increased fertilizer rate and to increased seed rate up to 175 kg/ha at Digelu-Tijo district. In contrast to the response at the RNP and recommended seed rate (125 kg/ha), an average yield increment of 2374 kg/ha was obtained at 138-92 N-P_2O_5 kg/ha and at seed rate of 175 kg/ha. At Kulumsa the response of Hidase to increased fertilizer rate was positive, but with no response to increased seed rate. The yield increment was 805 kg/ha at 138-92 N-P_2O_5 kg/ha and seed rate of 125 kg/ha. At Kofele, it responded positively to increased seed rate of up to 175 kg/ha, but negatively to increased fertilizer rate above the recommended.

Location effects on the responses of Digelu to increased fertilizer rate was highly significant. At Digelu-Tijo it had shown positive response with yield increments of 1404 kg/ha at 138-92 N-P_2O_5 kg/ha, as compared to the RNP. At Kofele the response to increased fertilizer rate above the RNP was negative. Seed rate of up to 175 kg/ha increased yields at RNP.

Seed and fertilizer rate effects on grain Quality

The effect of seed rate and fertilizer rate on grain quality parameters and leaf N absorption was also studied using samples from two on-farm trials, which contained two varieties. The results showed that both varieties were very highly significantly affected by increased fertilizer rates (at $p < 0.0001$). The protein content of Digelu and Hidase increased from 9.8 and 10.9 at FR1 to 11.0 and 12.52 at FR3, respectively. The wet gluten contents increased from 23.98 and 24.0 to 27.99 and 28.71 for Digelu and Hidase, respectively. Similarly, the values increased with increased fertilizer rates from 27.42 and 30.99 to 31.97 and 37.56, for the respective varieties. Seed rates did not have any significant effect on the grain qualities tested. Varietal effects are very highly significant. Hidase responded better than the other variety for the same treatments. Leaf absorption of N was also significantly affected by fertilizer rates (at $p < 0.05$), with the response of Digelu higher than Hidase. The leaf N content increased from 3.12 to 3.50 and from 2.62 to 3.05 for the two varieties, respectively. The effect of seed rate was not significant on leaf absorption of N at $p < 0.05$ level of significance.

Location Effects

The average responses of the three varieties were highest at Kulumsa (Tiyo district) and Kofele, with mean extra yields of 1344 and 1119 kg/ha, respectively, as compared to the average yields of the varieties at Digelu-Tijo. Therefore, Digelu-Tijo was the lowest potential area, based on the 2013 trial results.

However, our interpretation of results and conclusions should not be entirely based on the results of our data analysis only. Factors other than the treatment factors that could influence the productions per hectare have to be considered. The main factor other than the treatment factors that could influence the location effects in the highland Vertisols is the seedbed preparation method. The ridge and furrow method (mistakenly called BBM), which is in use today is very important to improve waterlogging problems in the Vertisols areas. But when this method is compared to the actual BBM (Broad Bed Maker), the land use efficiency is lower. The former method has a bed width of 70-80 cm, with about 20-25 % of the bed width left for drainage furrows, while the latter method has a bed size of 140-160cm, with about 10-15% of it left for the furrows to be used as drainage. Due to the higher effective bed widths in the BBM method there is very high possibility of improving the land use efficiency and consequently the productions per hectare. The potential of the lands in the other two locations is less affected by the seed bed preparation and planting method. Therefore, the conclusion that Digelu-Tijo area is relatively lower potential is based on the existing practices only. The introduction of the BBM technique can contribute a lot to advance the potential of highland Vertisols for wheat productions. This practice will be considered as a parallel approach to improved seed and fertilizer rate recommendation in the verification and demonstration trial under the highland Vertisols areas in 2015 cropping season.

Location effects on the responses of varieties to SR and FR are also different. In **Kofele** District, varietal responses generally increase to SR than to FR. The RNP is sufficient for Digelu and Shorima, but 1.5 RNP for HIDASE. In **Digelu-Tijo** the responses were more affected by FR than SR. Tiyo District the response of Digelu is nearly constant, except at the RNP and 175 kg/ha, but the yields of the other two varieties generally increase with both SR and FR, although the level of responses are lower as compared to Digelu-Tijo.

References

Amanuel Gorfu, Asefa Taa, DG Tanner and W Mwangi. 1991. On farm research to Derive Fertilizer Recommendations for Small-Scale Bread Wheat Production: Methodological Issues and Technical Results. Research Report No. 14. IAR, Addis Ababa, Ethiopia. 37pp.

Amsal Tarekegn, DG Tanner; Taye Tessema and Chanyallew Mandefro. 2000. Agronomic and economic evaluation of the on-farm N and P response of bread wheat grown on two contrasting soil types in central Ethiopia. In CIMMYT, 2000. The Eleventh Regional Wheat Workshop for Eastern, Central and Southern Africa. Addis Ababa, Ethiopia.

Asefa Taa, Kefyalew Girma and Shambel Maru.1997. On-farm N & P fertilizer trial in Breadwheat on vertisols in South eastern Ethiopia. Agronomy and Crop Physiology progress report. Kulumsa Agricultural Research Center. EIAR. Ethiopia

Ethio-Italian Developemtn Cooperation. 2002. Atlas of Arsi Zone. Arsi-Bale Rural Development Project. Arsi zone Planning and Economic Development Office. Regional State of Oromia. GIS sub unit.

IBM Corporation. 1989-2011. SPSS Statistical Software. Version 20.

Minale Liben, Alemayehu Assefa, DG Tanner and Tilahun Tadesse. 1999. The response of bread wheat to N and P applications under improved drainage on Bichena vertisols in northwestern Ethiopia. pp. 298-308. In: The Tenth Regional Wheat Workshop for Eastern, Central and Southern Africa. Addis Ababa, Ethiopia: CIMMYT.

Minale Liben, Alemayehu Assefa, Tilahun Tadesse and Abreham Mariye. 2004. Response of Bread Wheat to Nitrogen and Phosphorous Fertilizers at Different Agroecologies ofNorthwestern Ethiopia. In Proceedings of the 12th Regional Wheat Workshop forEastern, Central and Southern Africa. Nakuru, Kenya.

Shambel Maru, kefyalew Girma, Workiye Tilahun, Amanuel Gorfu and Mekonnen Kasaye. 1999. On-farm N & P fertilizer trial in Bread wheat on Vertisols in South eastern Ethiopia. Agronomy and Crop Physiology progress report. Kulumsa Agricultural Research Center. EIAR.Ethiopia

Tanner, DG, Amanuel Gorfu and Asefa Taa. 1993. Fertilizer effects on sustainability in the wheat-based smallholder farming systems of southeastern Ethiopia. Field Crops Research33:235-248.

Taye Bekele, Yesuf Assen, Sahlemedhin Sertsu, Amanuel Gorfu, Mohammed Hassena, D. G. Tanner, Tesfaye Tessemma and G. Takele. 2002. Optimizing Fertilizer Use in Ethiopia: Correlation of Soil Analysis with Fertilizer Response in Hetosa Woreda, Arsi zone. Addis Ababa, Sasakawa-Global 2000.

Tilahun Geleto, DG Tanner, Tekalign Mamo and Getinet Gebeyehu. 1996. Response of rainfed bread and durum wheat to source, level and timing of nitrogen fertilizer on two Ethiopian Vertisols: II. N uptake, recovery and efficiency. Fertilizer Research 44:195-204.

Tisdale LT., LW Nelson, JD Beaton and JL Havlin. 2002. Soil fertility and fertilizers. 5 ed. Prentice hall. India. New Delhi.

Effect of Seed Rate on the Yield and Yield Component of Bread Wheat Varieties under Rain fed Condition

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Introduction

A large number of Bread wheat varieties adapted to the heterogeneous environmental conditions of Ethiopia were released by different research centers of Ethiopia since 1974. The varieties differ in their yield potentials and seed weight. These varietal differences and seed weight can determine the optimum plant populations per ha that maximize the yield responses of wheat under a given optimum nutritional conditions. However, the existing recommendations of seed rates did not account these varietal differences; as a result of which the yield responses of a number of varieties could be limited due to the lack of appropriate recommendations for the range of varieties. Therefore, a trial was designed to be conducted for three consecutive years with the objective of evaluating the effects of seed rates on the yield and yield component of different bread wheat varieties under rainfed conditions. However, this report contains the results of first year trial conducted with the aim of evaluating the differences in seed weight and other yield and yield component responses of a number of selected bread wheat varieties under the existing recommended seed and fertilizer rates.

Materials and Methods

Description of the Study Sites

This observation trial was conducted at Kulumsa Agricultural Research Center, in 2012 cropping season. The study area was located at 8.08^{o}N latitude and 39.08^{0}E longitude, and at altitude of 2300 m. The dominant soil type in the center is Vertic Luvisol (Abayeheh et.al, 2006). Analysis of 33 years climate data indicated that the area receives mean annual rainfall of 820 mm, which starts in June and continues to September. The mean minimum and maximum annual temperature are 9.78^{O}C and 23.12^{O}C, respectively.

Experimental set-up and procedure

The experiment consisted of 19 different recently and lately released bread wheat varieties. The treatments were arranged in randomized complete block design with three replications. The seedbed was plowed and harrowed four times using tractor mounted mould-board plough and disk harrow before planting. All experimental plots were planted with 19 different bread wheat varieties. Seeds were drilled by hand at 0.20 m spacing between rows at the optimum planting time in plot sizes of 2 m by 4 m. The spacing between plots and replications was 0.5 m and 1 m, respectively. The recommended phosphorus fertilizers (69 kg P_2O_5 ha^{-1}) was uniformly applied to all plots as basal dose at planting from di-ammonium phosphate (DAP) while recommended nitrogen fertilizer (73 kg N ha^{-1}) was applied in splits, half at planting and the remaining half at tillering from urea. The existing recommended seed rate was used for all varieties. Weeding was carried out by hand.

Data collection and analysis

Tillers per plant, plant height, spike per m^{-2}, spike length, grain and above-ground total biomass yields, seed weight and hectoliter weights were collected at appropriate time. Data on the number of tillers was recorded by counting five representative plant samples from each plot. Height of five plants in each plot at random was measured at physiological maturity from soil surface to the tip of spike, excluding awns. The number of spikes m^{-2} was determined from a 0.5m row sample, randomly chosen from the middle five rows of each plot, immediately prior to harvesting. The length of spikes was determined from five plants in each plot at random at physiological maturity.

Harvesting was done from a net plot area of $4m^2$ (2m*2m) by hand for yield determination. The harvested samples were subjected to air drying, threshed using hands, cleaned and the grain weight recorded. The weighed samples adjusted to 12.5% moisture content and converted into kg ha^{-1} for the purpose of statistical analysis. Harvest index was calculated as percentage ratio of grain yield and biological yield. After threshing, grain samples were randomly taken and thousand kernel and hectoliter weights were determined using seed counter and hectoliter weighing devices, respectively, in plant physiology laboratory of Kulumsa Agricultural Research center.

Analysis of variance was carried out for each of the measured or computed parameters following the method described by Gomez & Gomez (1984). All yield and yield component data were subjected to analysis of variance using PROC GLM of SAS version 9.0 (SAS Institute, 2000) statistical software. The significance of differences among treatment means was compared using Duncan multiple range test.

Results and Discussion

The analysis of variance conducted for this study indicated that variety highly significantly affected all of the variables measured for bread wheat. The result of analysis of variance has been summarized in table 1.

Table 1. ANOVA Table for the yield potentials of bread wheat varieties.

Effects	NTPP (no)	SPM (No)	PH (cm)	SPL (cm)	HI (%)	AGY (kg/ha)	ABY (kg/ha)	HLW (Kg/HL)	TKW (gm)
Rep	0.0002	0.641	<0.0001	0.1952	0.0056	0.0073	0.0031	0.0702	0.0015
Trt	<0.0001	0.0007	<0.0001	0.0003	<0.0001	<0.0001	0.0024	< 0.0001	<0.0001
CV	10.12	10.30	3.50	5.21	5.79	11.16	12.83	1.16	5.78
Mean	6.88	400.05	92.88	7.39	37.43	5220.86	13978.92	77.39	34.99

Tillering capacities

Analysis of variance revealed that bread wheat varieties highly significantly (P < 0.0001) vary in their tillering capacities. *Katar* variety was found to have the highest tillering capacity with a single plant tillered 9 extra plants, followed by *Simba* and *Galama* varieties with8 tillers / plant). *Danda'a* variety was found to *have the lowest tillering capacity with 5 tillers/plants. Shorima, Millennium, Kubsa, Kakaba and Kubsa were found to have lower tillering capacities).*

Plant population per unit area

K6295-4A variety was found to have the highest population, followed by Galama, Katar, Shorima, Kakaba and Abola. Tusie, Danda'a and KBG-01 were found to have sparse population.

Plant height

ET-13A2, Mitike, Katar and K6295-4A were found to be the tallest varieties, with108, 107, 103 and 103cm high, respectively. *KBG-01, Kubsa* and *Simba* were the shortest bread wheat varieties, with recorded heights of 79, 81 and 84 cm long, respectively.

Spike length

Danda'a, Hidase, Galama, Mitike, Hoggana, ET-13A2, Millennium and K6295-4A have long spike lengths, with values measured from 7.5 to 8.2 cm. Pavon-76, Huluka, Simba, KBG-01 and Shorima have shorter spike lengths, with 6.4 to 7.0 cm. The spike lengths of the 19 bread wheat varieties are shown in figure 4.

Harvest index (HI)

Hidase and Mitike varieties were found to have the highest and lowest harvest indexes with 44.8 and 24.97 %, respectively. KBG-01 (42.18 g), Pavon-76 (42.15 g), Danda'a (41.91 g) and Kakaba (41.19 g) recorded statistically similar HI with Hidase variety. The result of ET-13A2 was statistically similar with Mitike variety.

Grain yield

The highest grain yield (7822 kg ha^{-1}) was obtained from Hidase variety, followed by Huluka, Millennium, Abola, Katar, Simba, Shorima, Danda'a, Tusie, Kubsa, Pavon-76 and Galama varieties, with yields varying from 5145 to 6184 kg ha^{-1}. K6295-4A and Mitike resulted in the lowest grain yields of 2983 and 3502 kg ha^{-1}, respectively.

Biomass yield

The highest biomass yield (17437 kg/ha) was also obtained from Hidase variety. However, it gave statistically similar biomass yield with Katar, Huluka, Shorima, Millennium, Abola, ET-13A2, Simba, Galama, Mitike, Tusie, and Kubsa varieties, whose yields varied from 15967 to 14014 kg ha^{-1}. K6295-4A variety gave the lowest biomass yield, 10346 kg ha^{-1}.

Hectoliter weight

Tusie variety gave the highest hectoliter weight, 79.80 kg hl^{-1}, but with statistically similar results of Pavon-76, Galama, Digalu, and Abola varieties, which provided 79.0, 78.9, 78.5 and 78.17 kg hl^{-1}, respectively. Mitike gave the lowest HLW, with 74.40 kg hl^{-1}.

Seed weight

Hidase and Danda'a varieties were found to be the most plumb varieties of bread wheat. They weighed 44.34 and 41.32 mg, respectively. Tusie and Galama were found to be the next plumb varieties, with 38.7 and 37.8 mg, respectively. The lightest variety was ET-13A2, with 26.6 mg. Katar, KBG-01, Digalu, K6295-4A and Mitike were among the next lightest varieties of bread wheat.

Conclusion

Generally, varieties highly vary in a number of plant response characteristics. The response of the recently released varieties is higher than the old ones. But some old varieties, like Katar and Galama, showed superior performance in terms of tillering potential and number of spikes per m^2. Katar, Simba, and Abola were also in the highest levels of the intermediate yielders. On the other hand Danda'a was found to be one of the lowest in tillering potential and intermediate in grain yields. However, some of the results contradict the results of other field trial conducted in 2014 at KARC to evaluate the yield potentials of different varieties in use today. Based on the results of this trial, Danda'a was found to be superior in grain yields, as compared to most of the recently released varieties, with grain yield record of more than 8.5 t/ha. This yield is greater than the yields obtained from Hidase under the same trial. But seasonal variations can partly explain for the differences, as Hidase was badly hit by unusually extreme rainfalls during the early period of physiological maturity. Yet other factors that could have contributed to the differences need be explained.

Details on comparative evaluation on the response characteristics of different varieties can be given. But it is hardly appropriate to make conclusions based on the one location and one year trial results. The performance of any one variety can vary from one soil and climate condition to another, and from one season to another too. Since all varieties tested were under the same location, the very high differences in the response characteristics obtained could be attributed to both genetic and environmental factors.

Another field experiment conducted in 2013 and 2014 on the responses of different bread wheat genotypes to differences in seed and fertilizer rates clearly indicated that expressions of the genetic potentials of different varieties depends on the levels of management of inputs and environmental conditions or locations. The results of 2013 trial is reported in the other section of this publication. The result indicated that the yield potentials of different varieties should be evaluated under different input management and environmental conditions.

Despite such arguments on the limitations of the information that the trial results could provide, the usefulness of the results and report cannot be underestimated. Researchers can use the information as a spring board for inception and development of useful research agenda based on the differences in agronomic characteristics of all varieties released so far by KARC and other research centers.

Determining Optimum Sowing Date for Bread Wheat Production under Irrigated Conditions at Koga, Amhara Region

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Introduction

Koga irrigation scheme was developed to irrigate about 7000 ha land. Given the wide range of slopes and the low degree of using advanced techniques in the area, furrow irrigation is the preferred method and recommended for the distribution of water to the fields (Desta et al., 2013). Bread wheat is one of the grain crops grown by smallholder farmers under irrigation in the areas. However, there are no available agronomic, soil, and water management recommendations in the areas for production of the crop. One of the primary agronomic recommendations required to support the adoption and improved productions of bread wheat under irrigated conditions is determination of appropriate sowing date. Therefore, a trial was conducted at Koga irrigation site to determine optimum planting dates for bread wheat productions in the areas.

Materials and Methods

The experiment was conducted for two years 2012/13 and 2013 at Koga irrigation site. Two bread wheat varieties Tay (medium maturing) and Dinkenesh (short maturing); and seven sowing dates (Mid November, End of November, Mid December, End of December, Early January, Mid-January and Early February) were evaluated .The design was RCBD with three replications with a gross plot size of 4 m x 5m planted in rows of 25 cm apart. The national recommended seed rate of 125 kg/ha and fertilizer rate of 92/46 N/P2O5 was used. All other recommended agronomic practices were implemented. The data collected were plant height, emergency date, maturity date, flowering date leaf area index, biological yield grain yield, disease and insect infestation and climatic data.

Results of 2012/13 cropping season

The one year result showed that there was a significant difference among the seven sowing dates and the two varieties for grain yield. The interaction of sowing dates and variety was not significant to affect grain yield; therefore the main effects of each will be discussed here. In this experiment, early sowing was found to be promising for bread wheat under irrigation. Planting bread wheat in mid-November gave the highest grain yield (4515.3 kg/ha) and planting late in early February gave the lowest yield (8111 kg/ha). The result also showed that variety Tay was high yielder than variety Dinkinesh; but there is an indication that Dinkinesh relatively performed well under late sowing conditions.

Early planting has an advantage over late planting since it will relatively escape from Aphid infestation and yellow rust incidence based on preliminary data recorded in 2012/13. The completed report supported with pest infestation and climate data will/should be presented after the collection and analysis of this year data another time.

References

Desta, G, M Getaneh, and A Tsigie. 2013. Examining advance time of furrow irrigation at Koga irrigation scheme in Ethiopia. *In:* Wolde Mekuria. (ed). 2013. Rainwater management for resilient livelihoods in Ethiopia: Proceedings of the Nile Basin Development Challenge science meeting, Addis Ababa, 9–10 July 2013. NBDC Technical Report 5. Nairobi, Kenya: International Livestock Research Institute. Extracted from http://hdl.handle.net/10568/33929

Integrated Manure and Mineral Fertilizer Applications for Bread wheat Productivity and Soil Chemical Properties in South Tigray, Ethiopia

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Introduction

Integrated organic and inorganic fertilizer management is one of the major areas of agricultural research to develop crop and soil management options that insures the sustainability of increasing productions and safe guard the soil and water environment for the future generations. Integrated nutrient is also a means to improve the efficiency of nutrient and water use by plants and to improve the productions and productivity of crops under any given fertilizer and moisture conditions. Therefore, a trial was conducted with the objective of evaluating the effect of integrated fertilizer application rates on the yield and yield components of bread wheat, and to determine the optimum combination of NP fertilizers rates with FYM for the wheat based farming system in the southern highlands of Tigray.

Material and method

Treatments and Experimental Design

The experiment was conducted during the 2013 cropping seasons at Ofla and EEast Mehone in South Tigray. Four rates of N/ P fertilizers (0/0, 23/23,46/46,69/69 kg/ha N/P2O5) were factorially combined with five rates of FYM (0, 4, 6,8,10 Mt/ha), and were laid out in a randomized complete block design (RCBD), with three replications. The farmyard manure (FYM) used for the experiment was well decomposed under shade and applied all at planting with P fertilizer. Fertilizer N was applied in split with half of the dose applied at planting and the remaining half at the start of heading (during the time of peak demand). Urea and TSP were used as source of chemical N and P fertilizers. The gross plot size was 3m x 2.4m with 1.5 m between replication and 1m between plots. The variety used was Mekelle 3, and was planted with row planting with a seed rate of 150kg/ha. All other recommended practices were implemented. Soil data was taken before and after planting, but the analytical result was not provided at the time of writing this report.

Results and Discussion

The main effects of fertilizer rate and FYM were highly significant. The highest yields, 4.19 Mt/ha and 3.91 Mt/ha were obtained from applications of 46/ 46 kg/ ha N/ P_2O_5 and 6.0 Mt/ha FYM, respectively (table 1). The interaction effects of N/ P_2O_5 and FYM were also highly significant. The highest grain yield (4.53 Mt/ha) was obtained from application of 46/46 kg/ ha N/ P_2O_5 plus 4.0 Mt/ha FYM (table 2). The yield increment from application of 46/ 46 kg/ ha N/ P_2O_5, 4.0 Mt/ha FYM, and 46/46 kg/ ha N/ P_2O_5 plus 4.0 Mt/ha FYM was 377 %, 351%, and 407 %, respectively, as compared to the effect of the control treatment (0/0 N/ P_2O_5 kg/ha and 0.0 Mt/ha).

Application of 4.0 Mt/ ha of FYM alone did give any significant yield difference as compared to the control treatment. Nevertheless, when the 4.0 Mt/ha FYM is combined with the 46/46 kg/ha N/P_2O_5 the yield sharply increased by about 400%. Any combinations above this yielded significantly lower yields, except for the combination 69/69 kg/ha N/P_2O_5 with 6.0 Mt/ha, which yielded 6.69 Mt/ht/ha increment only.

Table 1. Main effect of NP Fertilizer and FYM on Grain Yield of Bread wheat

Fertilizer level N/P2o5 (kg/ha)	Grain yield (t/ha)	FYM (t/ha)	Grain yield (t/ha)
69/69	3.78b	10	3.7b
46/46	4.19a	8	3.91ab
23/23	3.22c	6	4.10a
0/0	2.65d	4	3.14c
		0	2.43d
LSD	0.275		0.306
CV	8.49		

Table 2 interaction of FYM and NP fertilizer on grain yield of bread wheat

Trt No	N/P205 (kg/ha)	FYM (t/ha)	GY (t/ha)	Trt No	N/P205 (kg/ha)	FYM (t/ha)	GY(t/ha)
1	0/0	0	1.112i	11	46/46	0	3.96bcd
2	0/0	4	1.12i	12	46/46	4	4.53ab
3	0/0	6	3. 23efgh	13	46/46	6	4.36abc
4	0/0	8	3.6defg	14	46/46	8	4.05bcd
5	0/0	10	3.8cde	15	46/46	10	3.96bcd
6	23/23	0	1.22i	16	69/69	0	2.88h
7	23/23	4	3.17eh	17	69/69	4	3.88cd
8	23/23	6	4.134abcd	18	69/69	6	4.69a
9	23/23	8	3.19cdef	19	69/69	8	4.17abcd
10	23/23	10	3.77cdefg	20	69/69	10	3.25efgh
CV%			8.49				8.49
LSD			0.615				0.615

.

Soil test Based Phosphorus Fertilizer Recommendations for Bread Wheat in Western Amhara Region

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Introduction

Sound soil test calibration is essential for successful fertilizer program and crop production. It is essential that the results of soil tests could be calibrated or correlated against crop responses from applications of plant nutrients in question, as it is the ultimate measure of a fertilization program. To interpret a soil test we must know the relationship between the amount of a nutrient extracted by a given soil test and the expected crop response for each crop. The process of determining the degree of limitation to crop growth or the probability of getting a growth response to an applied nutrient at a given soil test level is known as soil test calibration and must be determined experimentally in the field. (Dahnke and Olsen, 1990; Douglas Beegle, 2009). Calibrations are specific for each crop type and they may also differ by soil type, climate, and the crop variety (Singh and Agarawal, 2007). Therefore, a trial was conducted at Yilmana Densa and Debre-Elias, Amhara Region to develop soil test based phosphorus recommendation for bread wheat production in the studied areas.

Materials and Methods

This field experiment was conducted at Yilmana Densa and Debre-Elias using Randomized Complete Block (RCBD) with 3 replications. The experiment was conducted in two phases. In the first phase of the experiment (year 1), investigation of the optimum rate of N that was best interact with phosphorus and gave highest yield was obtained. For this experiment, 8 treatments were included in the experiment. The treatments were four levels of nitrogen (N) fertilizer (0, 46, 92 and 138 kg N ha^{-1}) and two levels of phosphorus (P) fertilizer (46 and 92kg P_2O_5 ha^{-1}) combined in factorial arrangement.

In the second phase (2011 and 2012), after the optimum amount of nitrogen rate is known (for bread wheat 138 kg N/ha), a basal dressing of equal amount of nitrogen fertilizer was given to all plots and P rate determination trial was conducted. For phase two experiment, the P rates were 0, 46, 92, 138 and 184 kg P_2O_5 ha^{-1}. The data from the optimum N x P rates combination of phase 1 was included in the calibration study. At each site, the field experiment arranged in randomized complete block design with three replications.

Soil Sampling and Analysis

For phase 1 of the experiment, composite soil samples were collected for laboratory chemical analysis at the depth of 30 cm from each field before planting and soil analysis for total N (Kjeldahl method) and available P (Olsen and Bray-II method).

For phase 2 of the experiment of the 1st Year, composite soil samples were collected for laboratory chemical analysis at the depth of 30 cm from each field before planting. After soil sample collection the P fertilizer rates were applied to each plot. Three weeks after the day of planting, soil samples were collected from each treatment plot by replication for determination of available P for the correlation purpose. The samples collected before and at planting were analyzed using the Olsen and Bray-II methods using the procedure outlined by Sahlemdihin and Taye (2000).

Yield Data Collection, Plant Sampling, and Analysis

Grain yield data were collected from the harvestable plots and adjusted to 12.5% moisture level. Other data collected were grain protein content, biomass yield, plant height, lodging percentage, 1000-grain weight, and hectolitre weight.

Determination of Critical P levels

Cate-Nelson graphical technique (Cate and Nelson, 1965) was used to determine the P critical level. It was determined from the relationship between relative yields (yield x (100/ maximum yield)) and soil test P values of each replication. All the relative yield values against the soil test value of each replication were plotted on one scatter graph. A vertical and horizontal line was superimposed on the scatter diagram to maximize the number of points in the positive quadrants. The vertical line divides the data into two classes (high probability of response and low probability of response).The point where the vertical line intersects the x axis has been termed as the critical level. In the Cate and Nelson graph, points in the upper left quadrants would mean that a low soil test value was associated with a high relative yield; and points in the lower right quadrants are those where a high soil test value was associated with a low yield. If most points are in the lower left or upper right quadrants, it is an indication that the soil test accurately predicts plant performance. Low soil tests have low relative yields and high soil tests have high relative yields

Determination of P Requirement Factor

P requirement factor is the measure of the quantity of P nutrient per hectare required to raise the soil P level measured by selected P availability indices by 1 mg kg^{-1}. This was calculated from the difference between available P values in soil samples of the control plots and the plots that received fertilizer as indicated in Table 1.

Table 1. Table for calculating P requirement factor P measured by Olsen and Bray II methods

Trt (kg P_2O_5/ha)	Olsen and Bray II P (mg kg^{-1})	P level increase over the control (mg kg^{-1})	P requirement factor (Pf)
0	A	-	-
46	B	b-a	46/ (b-a)
92	C	c-a	92/ (c-a)
138	D	d-a	138/ (d-a)
184	E	e-a	184/ (e-a)
Mean	-	[(b-a)+ (c-a) + (d-a) + (e-a)]/4	[(46/(b-a))+ (92/(c-a)) + (138/(d-a)) + (184/(e-a))]/4

Developing the Equation

To develop the equation for calculating the P fertilizer requirement, three parameters: P critical level (P_c), Soil test value of P (P_0) and P requirement factor (P_f) are required. P_c is determined from the Cate-Nelson graph, P_0 is the measurement of soil P by the selected Olsen and Bray-II methods and P_f is calculated according to Table 1. Therefore, P fertilizer requirement (P_r) was calculated by the formula:

$$Pr = (P_c - P_o) * P_f$$

Where P_r = P fertilizer requirement (kg ha^{-1}), P_c = Critical P level by Olsen or Bray=II methods (mg kg^{-1}), P_0 = Soil test value of P of the field (mg kg^{-1}), and P_f = P requirement factor determined by the experiment

Results and Discussion

Phosphorus calibration

This experiment was conducted on Nitosols and in 2011 and 2012 cropping season in Yilmana Densa and Debre Elias. The varieties used was Tayi. Results clearly indicated that the application of phosphorus significantly affected the grain yields of wheat (Table 2). Soil P values analyzed for samples taken three weeks after planting have been significantly affected by different levels of P fertilizer application (Table 2). For assessing the relationship between grain yield response to nutrient rates and soil test P values, relative grain yields in percent[(yield/maximum yield) ×100] were plotted against the corresponding soil test values for all P treatments as shown in Figures 1 for bread wheat.

Table 2. Response of bread wheat grain yield and P values for samples taken 3 weeks after planting on Nitosol to P application

P rate	Grain yield	P value
0	1948.29E	4.7690D
20	2316.24D	7.6638C
40	2509.87B	11.3453B
60	2673.01C	12.4296B
80	2875.87A	16.681A
CV	15.76	18.86
LSD	147.42	1.48
P<0.05	***	***

Table 2. Phosphorous requirement factor for wheat response grown in Nitosols

P rates (kg/ha)	Soil test p value		P increase over the control	Pf
	Range	Mean		
0	0.76-7.43	4.7690D	0	0
20	4.76-11.00	7.6638C	2.89	6.91
40	7.94-18.56	11.3453B	6.58	6.08
60	8.44-17.75	12.4296B	7.66	7.83
80	11.40-25.33	16.681A	11.91	6.72
mean				6.89

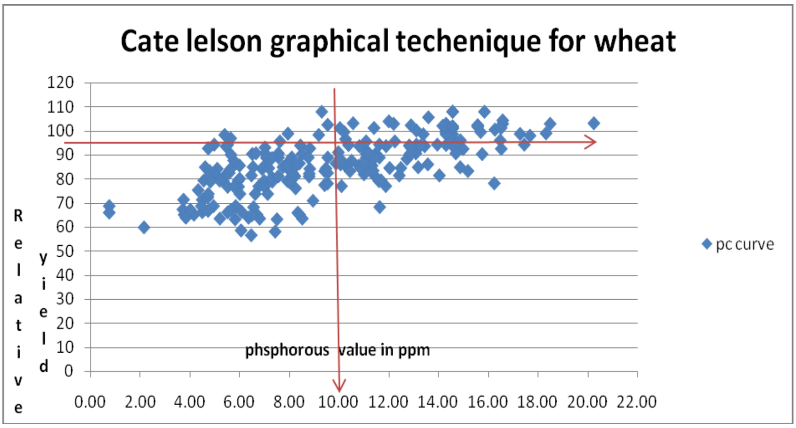

Figure 1. Cate Nelson graphical technique to determine critical phosphorous level.

From this graph, the critical phosphorous level is 10 ppm. From these curves the critical P concentrations at the intersection points were determined based on analytical methods followed. This means that wheat planted on soils having Olsen soil test values greater than 10 ppm would not respond to phosphorus fertilization. On the contrary, if it is lower would respond to P fertilization. For this it is necessary to establish the P-requirement factor, which is a measure of the quantity of P required per ha to raise the soil test level by 1 mg/kg. This value for the studied sites was computed from the difference between available P values in soil samples collected from plots, which received fertilizer and control plots to calculate the total amount of phosphorus fertilizer required to bring the level of available P above the critical level. The calculated P-requirement factors using values from plots that received different levels of P fertilizer, for Olsen-P, are shown in Table 2.

The P-requirement factor using the Olsen method ranged from 6.08 – 7.83 mg/kg soil for plots which received 20-80 kg P/ha. The calculated mean P-requirement factor for the experimental site was 6.89 using Olsen I. The critical P concentration for wheat on Nitisols was about 10 mg/kg as indicated in Figure 1. Therefore, the amount of fertilizer required per hectare can be calculated for the whole site on the basis of soil analysis using Olsen. When the average value for the entire site is considered the mean phosphorus fertilizer required per hectare can also be calculated. The overall result indicates that application of different rates of phosphate fertilizer are reflected in the P-requirement factor, and these soil test results could be used as a basis for fertilizer rate recommendations. When a sufficient amount of data has been generated, such information could easily be validated as a guideline to be used by extension personnel for fertilizer recommendations to farmers on the basis of soils test values.

Therefore, to calculate the phosphorous fertilizer amount required for the specific soil data is $P_r = (10-P_0) \times 6.89$, where p_0 is the soil phosphorous in ppm. Following this result a verification trial was conducted in 2013 at Yilmana Densa and Debre-Elias on farmers' fields. A total of Nine locations. The number of plots for each site was two with plot sizes of 10m by 10m each. One plot receives the bulk recommended P2O5 rate and the other plot received based on initial soil test from the field taken before planting. The determination for the amount of P fertilizer rate for the plot that received soil test based P fertilizer recommendation was based on the following formula, rate of P fertilizer to be applied = $(P_c - P_o) \times P_f$

The values of the critical P concentrations and P requirement factors for the study locations were already determined. For the initial P values composite soil samples from each demonstration site were taken and available P values determined by laboratory using the analytical method employed during the calibration study. All yield and yield component data were collected at the appropriate time. Data on weed density and occurrence of diseases and pests was also collected.

Figure 2 shows the results of the verification trial. The red bars represent the grain yields obtained from application of the recommended P rate, and the blue bars show the yields obtained from application of P fertilizer based on soil test P values. The recommended values for Yilmana Densa are 74 kg/ha P_2O_5 and for Debre-Elias 46 kg/ha P_2O_5. The figure representing the blue bars are the P fertilizer rates applied based on initial soil tests.

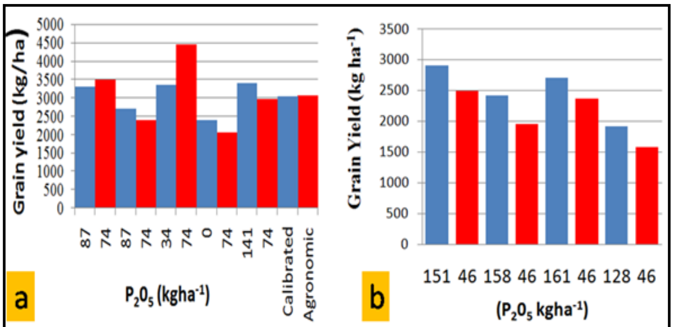

Figure 2: Graph showing grain yield responses of bread wheat at calibrated P values compared with agronomic recommendation at Yilmana Densa (a) and Debre-Elias (b)

Figure 2 shows the results of the verification trial.

The yield results obtained from soil test p applied plots should be close to the yield results from the recommended plots. To evaluate how good the soil test p recommendation was, data of initial soil test P values done before the trial is necessary. The report given contains the results of graphical analysis only. From visual observation of figure 2, the results indicate that the yields of the two treatments (calibrated P and agronomic recommended P) from 9 out of 10 locations were very closely related. When we see the results from Debre-Elias, the yields from 5 out of 6 locations are very close to each other. It should be noted that the yields from the soil test P applied plots should not be expected to be exactly equal or higher that the yields from the recommended P. Some researchers believe that soil test based fertilizer recommendations should increase yields as compared to the recommended one. However, this is not the case. I believe that the ultimate goal of this method is for economical use of P fertilizers in soils that have long history of high P fertilizer use, as P can build up in soils through continued applications and create high reserve P. Hence, soil test P recommendations are done for providing site-specific fertilizer P recommendation based on the soil P reserve determined from initial soil tests done before cropping seasons. Fields that had high reserve P values greater than the critical P received no application of P fertilizer. When the yields from such fields are close to the yields from fields that recommended P, the results verify the validity of the method for use. However, I believe that the level of increase in the productions and productivity of wheat depends on whether the existing N and P recommendations are optimal or not. In this regard the researchers from Adet ARC have gone one step ahead. They evaluated the existing recommendation by undertaking one year fertilizer N trial and determined the optimum N values as phase I of the activity.

References

Bartholomew WW. 1972. Soil nitrogen-supply processes and crop requirements. North Carolina State University. Int. Soil Testing Ser. Tech Bull. 6

Cate RB and LA Nelson. 1965. A rapid method for correlation of soil test analysis with plant response data. North Carolina Agric. Exp. Stn., International soil Testing Series Bull. No. 1.

Dahnke WC and RA Olsen. 1990. Soil Test Correlation, Calibration and Recommendation. P 45-71. In: R. L. Westerman (ed.) Soil Testing and Plant Analysis, 3rd ed., SSSA Book Series: 3, Soil Science Society of America, Madison WI

Singh VK and HP Agarawal. 2007, Development of Dris norms for evaluating, nitrogen, phosphorus potassium and sulphur requirements of rice crop. J. Indian Soc. Soil Sci., 55: pp. 294-303.

Verification and Demonstrations of Soil test-based Fertilizer Phosphorous Management in Hawzen District of Tigray Region

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Introduction

Although chemical fertilizer is the major purchased input for wheat production in Ethiopia, the response of wheat to these inputs varies from place to place, mainly depending on soil type and climate. In all regions of the country, the fertilizer recommendations are of a generalized blanket type and are not based on soil test results.

To develop a guideline for fertilizer recommendation on the basis of soil test results, however, a lot of field experimental data has to be generated by conducting sufficient numbers of soil test based field correlation and calibration studies for different types of crops (Singh and Agarwal, 2007). Because of this fact, a large number of calibration studies had been conducted in selected agro-ecologies of the wheat producing areas of Tigray to develop quantitative phosphorus recommendation guidelines. Based on the studies conducted before this verification trial, the critical P values were determined for a number of locations using the Cate-Nelson graphical method (Cate and Nelson, 1965) and the P requirement factors calculated. Therefore, the current study was carried out to verify the already established soil test based P calibration in Tigray for wheat.

Methodology

The verification trail was conducted in 2013 growing season at Hawzen district, Tigray, Ethiopia in three farmers' field. Hawzen district is located in tepid to cool sub moist mountains plateau agro ecological zone. Single observation trails with two treatments were evaluated in 10 m x 10 m plots.

The treatments were blanket recommendation of N and P (41 N kg/ha + 46 P_2O_5/ha) and soil test based P and Recommended N (41 N kg/ha). Soil samples were collected before planting from the trial fields for determination of initial available phosphorus. The following formula was used for determination of P fertilizer required for each trial site.

$$\text{Rate of P fertilizer to be applied} = (P_c - P_o) \times P_f$$

Based on the P-requirement factor (6.54) and P-critical (6.5) established earlier for wheat in the nearby Enderta district of Tigray, the calculated amounts of phosphorous required to each trial site were applied all at planting. The existing recommendation of Nitrogen was applied half at planting and the other half during tillering. Above ground biomass samples taken from sample quadrants were sun-air dried before weighing. The spikes were threshed and cleaned and grain yield was weighed. The straw yield was calculated by subtracting grain yield from the above ground biomass. Grain and straw yields were adjusted to 12.5 % moisture content.

Results and Discussion

Phosphorous requirement: the initial available phosphorus content, phosphorus requirement factor and critical phosphorus concentration for wheat of the observation plots are presented in Table 1.Field experimentation of farmer1 and farmer2 required phosphorous application to the soil while phosphorus was not required in farmer3 field.

Grain and straw yields

Grain yield of wheat was higher in two of the observation trials in the soil test based phosphorus (P) plus recommended nitrogen than the recommended nitrogen (N) and phosphorus (Table 2). However in one of the observation trial straw and grain yield of wheat was higher in the recommended N and P than the soil test P plus recommended N, indicating other factor might have contributed to the higher yield in the recommended N and P plot.

Table 1 Phosphorous requirement based on soil test based

Farmers code	P-initial (mg/kg soil)	P-critical	P-factor	P required (kg/ha)
Farmer1	2.96	6.5	6.54	23.15
Farmer2	4.14	6.5	6.54	15.43
Farmer3	8.26	6.5	6.54	0

Table 2 Grain and straw yields in phosphorous verification study at Hawzen (Tigray)

	Adjusted grain yield (kg/ha)	Adjusted straw yield (kg/ha)
Farmer 1		
Recommended N and P	1567	4755
Soil test based P and Recommended N	1869	5507
Farmer 2		
Recommended N and P	1828	4492
Soil test based P and recommended N	1415	3853
Farmer3		
Recommended N and P	1642	3623
Soil test based P and Recommended N	1997	3265

Conclusions

There is an indication in two of the farmers' field that soil test based phosphorous recommendation was better in its grain yield. There is also inconsistence in one of the farmers field where the blanket recommended N and P was better both in straw and grain yield. However, the results obtained from farmer 3 field clearly indicated the importance of soil test P fertilizer recommendation. The soil, which received no P fertilization, provided greater yield as compared to the soil with recommended P. One explanation could be the soil that received no P fertilization has very high initial soil test P (8.26 mg P/kg soil) as compared to the critical P (6.5 mg/ kg soil). The grain yield obtained from farmer 3 field, which received no fertilizer P (determined from initial soil test data and critical P) proved the advantages accrued to the method of site-specific fertilizer P recommendation as compared to the existing practice of recommended P.

However, improving the production and productivity of wheat depends on whether the existing fertilizer N and P rate recommendations are optimal or not. If the long existed recommendation of N values is below optimal, the effectiveness of nutrient P rates for improving yields during the P calibration studies, verification trials, and its applications by end users can be reduced. The other important point to include in the conclusion is that the trial results were from three locations only; and so, the inconsistence between the yields from the two verification trial treatments could have been smoothened if the number of trial sites were increased.

References

Cate RB and LA Nelson. 1965. A rapid method for correlation of soil test analysis with plant response data. North Carolina Agric. Exp. Stn., International soil Testing Series Bull. No.1.

Singh VK and HP Agarawal. 2007, Development of Dris norms for evaluating, nitrogen, phosphorus potassium and sulphur requirements of rice crop. J. Indian Soc. Soil Sci., 55: pp. 294-303.

Verification and Demonstration of Soil Test -based Phosphorous Management in Alamata District of Tigray Region

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Introduction

Soil test based fertilizer P management research was conducted by Alamata Agricultural Research Center as part of the national program to develop appropriate soil fertility management technologies that consider the site specific soil P conditions and crop specific fertilizer P requirements. Soil test P fertilizer calibration studies are conducted for each crop type and the recommendations need to be made are crop specific. With this initiative a trial was conducted at the southern Tigray wheat producing areas to develop soil test based fertilizer P management recommendation that enhances sustainable agricultural productions and productivity of bread wheat. This report contains the results of verification and demonstration trial conducted based the outputs from the soil test based P calibration studies.

Methodology

Verification and demonstration on soil test based phosphorus fertilizer recommendations were conducted on four farmers' fields. The number of treatment plots for each site was two with plot sizes of 10m by 10m each. One plot received the bulk recommended P2O5 rate and the other plot received based on initial soil test P from samples taken before planting. The amount of fertilizer P rate for the plots that received soil test based P fertilizer recommendation was derived using the following formula.

$$\text{Rate of P fertilizer to be applied} = (P_c - P_o) \times P_f$$

The values of the critical P concentrations and P requirement factors for the study locations were already determined (table 1). For the initial P values composite soil samples from each site were taken and available P values determined by laboratory using the analytical method employed during the calibration study. All yield and yield component data were collected at the appropriate time. Data on weed density and occurrence of diseases was also collected.

Treatments

- Soil test P recommendation and recommended N fertilizer for the area; and
- Existing NP fertilizer recommendation (100kg DAP and 100kg Urea) (control)

Results and Discussion

Comparison of grain yields at each site showed that higher yields were obtained from plots that received soil test based fertilizer P (F1, F3, and FTC; table 2). In site 2 (F2) the yield from the plots that received recommended P were higher. Comparison of yields from FTC showed that the yields from plots that received the soil test base P were higher by 160% as compared to the yield from the plot with recommended P. Referring to the initial soil test value (table 1), it is higher by 70%. Because of this, it did not receive any P, as it was already higher than the critical P value (6.5 mg/kg soil). Such result, with very high extra yields from plots that received no P as compared to plots that received the recommended P, cannot be expected. But one explanation that can be given is that the existing recommendation is below optimal for the location; as a consequence of which the very high difference between in the initial soil test P value and the critical P value could have accounted for the very high difference in the response of the crop from the respective plots. The difference between the yields of the two treatment plots in relatively low and acceptable; and so does not need any explanation. But the difference in field 2 is very high. When the P nutrient applied in STB plot of F2 based on the Pf value is combined with the nutrient supply due to the initial P nutrient available (table 1), the effect on the response of the test crop could be higher as compared to the plot that received the recommended P.

Table 1: Calculated P required for trial plots based on P_o, P_c, and P_f values

Farmer	P0	Pc	Pf	$P_2 0_5$ (kg/ha)
F1	5.13	6.5	6.54	20
F2	3.03	6.5	6.54	52
FTC	11.08	6.5	6.54	0
F3	6.48	6.5	6.54	0.297

Table 2. Effects of soil test based phosphorus application (STB) on bread wheat yield and yield component. F1, F2, F3 refer to farmer fields and FTC is farmers training center

Farmer	Treatment	Grain yield (t/ha)	Seeds per spike	Biomass yield (t/ha)
F1	STB	5.23	28.1	10.8
	Control	4.79	34.3	11.2
F2	STB	2.86	37.1	6.28
	Control	4.06	35	9.13
FTC	STB	4.06	32.6	10.2
	Control	1.56	31	4.02
F3	STB	2.6	27.8	5.99
	Control	2.08	33	4.91

Conclusion

The verification and demonstration of soil test based P recommendation trials in F1 and FTC indicated the advantages of the method for fertilizer P management. However, it is not possible to testify the usefulness of the method by seeing the results from F2 and F3 fields. However, it is noteworthy to understand that the precision of our recommendation depends on how well the correlation and calibration studies were conducted under field conditions, how precise our determination of critical P values using graphical methods were, and how appropriate the already recommended N for studied locations were. Generally, the benefits of soil test based fertilizer P management are evident even from some of the existing data; but a number of factors are affecting the reliability of the works. It is also important to take in to account the need for revision of N and P recommendations for all areas before undertaking correlation and calibration studies. The lack of precision in the correlation studies continues to affect the accuracy of the result unless the researchers responsible for such activity start to evaluate their previous results and determine the factors contributed to inconsistencies in the obtained results. Based on such conviction on the status of this trial it is, therefore, be not appropriate to recommend repeating the trial.

Influence of Lime and P Fertilizer on Yield and Yield Components of Bread Wheat on Acid Soils of Lemu Bilbilo, Arsi Zone

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Introduction

Soil acidity is among the major land degradation problems in Ethiopia, and large areas of agricultural lands are affected by soil acidity. It is stated in various literatures that about 40.9 % of the Ethiopian total land is affected by soil acidity, with areas varying from moderately acidic, to strongly and extremely acidic. Out of the total estimated 40.9 % of acid soils in the country, 13.2 % are strongly to moderately acidic (< pH: 5.5), with Nitisol/Oxisol zones being the main soil classes dominated by soil acidity (Mesfin Abebe, 2007).. Some of the well-known areas severely affected by soil acidity in Ethiopia are Ghimbi, Nedjo, Hossana, Sodo, Chencha, Hagere-Mariam, and Awi Zone of the Amahara Regional State. Soil pH measurements done by Kulumsa ARC/ EIAR in the highlands of Arsi zone, particularly at Bekoji and Meraro Districts also showed that they are dominated by moderately to strongly acidic soils. Some areas have pH values of less than 5.5. These areas receive average annual rainfalls in excess of 1000 mm, and the soils are mainly Nitosols.

Since highland soils are part of the high potential areas for crop productions in the country, developing a strong acid soils management strategy was taken as one of the Ethiopian government priority areas to meet the agricultural development goals of the country. In line with the agricultural development goals of the country, the Ethiopian Institute of Agricultural research (EIAR) embarked on the project for the management of acid soils in the country with focus on the central, western and south western highlands. The activity on management of acid soils of southeastern highlands has also been part of the acid soils management project of EIAR Soil and Water Research Process.

The objective of this project is, therefore, to determine the appropriate lime requirement for the management of acid soils of Bekoji area, Lemu-Bilbilo district, Arsi zone.

Methodology

The experiment was laid out in randomized complete block design (RCBD) in complete factorial arrangement with five levels of lime (0.0x, 0.5x, 1.0x, 1.5x and 2.0x, exchangeable $\mathbf{Al^{+3}}$ and $\mathbf{H^{+1}}$) and four levels of P_2O_5 (0, 23, 46, 69 kg/ha) applications, replicated three times. The gross plot size was 4m* 4m, and the test crop used was bread wheat (Variety, Damphe). The trial was conducted at Bokoji sub-station. Prior to undertaking the field trial, composite soil samples were collected from Bekoji on-station from 0-15 cm depth. The soils were air dried, sieved through a 2 mm stainless steel sieve and subjected to chemical analysis at soil and plant nutrition laboratory of Holeta ARC. The result of soil chemical analysis and lime requirements levels determined is shown in table 1.

Table 1. Soil Chemical Analysis Result for the Soils of Bekoji station

Block	PH	Available P (ppm)	Exchangeable acidity (cmol/kg soil)	Lime requirement (kg/ha)
Block 1	5.12	12.00	0.35	297.00
Block 2	5.80	14.00	0.14	119.00
Block 3	5.22	12.00	0.20	170.00
Block 4	5.28	12.00	0.22	186.00
Block 5	5.35	14.00	0.22	186.00
Average	5.35	12.80	0.23	191.60

The amount of lime that will be applied at each level was calculated on the basis of the mass of soil per 15 cm hectare-furrow-slice, soil sample density and exchangeable Al^{+3} and $H^{+1}$of the site. The mathematical model employed to calculate the lime requirement is described by eq 1. The calculation was done with the assumption that one mole of exchangeable acidity would be neutralized by equivalent mole of $CaCO_3$.

$$LR, CaCO_3\ (kg/ha) = \frac{cmolEA/kg\ of\ soil * 0.15\ m * 10^4\ m^2 * B.D.(Mg/m^3) * 1000}{2000}$$

(eq 1)

The lime treatment levels are developed from the LR values determined by the equation using the average exchangeable acidity values of the soils. Two levels above and two levels below the LR value, with interval of 0.5LR were set to make five LR levels (Table 2). Arrangement of treatment levels for the two-factor combination is presented in Table 2. The full dose of lime treatments per plot was broadcasted uniformly by hand at once and incorporated into the soil before planting. Triple super phosphate was used as the source of P. The recommended rate of N from UREA was applied uniformly to all treatments. Urea was split applied in to two, while the entire rate of phosphorus was applied at sowing in band.

Table 2: factorial arrangement of treatments consisting of 5 levels of lime and 4 levels of P_2O_5.

Treatment (kg/ha)	Treatment (kg/ha)	Treatment (kg/ha)
T1 = No input	T8 = 0.5 / 69 / 50 LR / P2O5 / N	T15 = 1.5 / 46 / 50 LR / P2O5 / N
T2 = 0 / 23 / 50 LR / P2O5 /N	T9 = 1.0 / 0 / 50 LR / P2O5 / N	T16 = 1.5 / 69 / 50 LR / P2O5 / N
T3 = 0 / 46 / 50 LR / P2O5 / N	T10 = 1.0 / 23 / 50 LR / P2O5 / N	T17 = 2.0 / 0 / 50 LR / P2O5 / N
T4 = 0 / 69 / 50 LR / P2O5 / N	T11 = 1.0 / 46 / 50 LR / P2O5 / N	T18 = 2.0 / 23 / 50 LR / P2O5 / N
T5 = 0.5 / 0 / 50 LR / P2O5 / N	T12 = 1.0 / 69 / 50 LR / P2O5 / N	T19 = 2.0 / 46 / 50 LR / P2O5 / N
T6 = 0.5 / 23 / 50 LR / P2O5 / N	T13 = 1.5 / 0 / 50 LR / P2O5 / N	T20 = 2.0 / 69 / 50 LR / P2O5 / N
T7 = 0.5 / 46 / 50 LR / P2O5 / N	T14 = 1.5 / 23 / 50 LR / P2O5 / N	

Results and Discussions

According to the result of statistical analysis, application of lime and phosphorus brought a very significant increase in wheat yield and yield components. Combined application of lime and P fertilizer resulted in the very significant wheat grain yield increase. The highest grain yield (6580.9 kg/ha) was obtained from application of full dose (1x) of lime along with 46 kg P_2O_5/ha. Application of full dose (1x) of lime along with 46 kg P_2O_5/ha brought two advantages when compared to the recommended rate of phosphorous for wheat for the study area, Bekoji. On one hand it decreased the use of phosphorous by 23 kg/ha. On the other hand it brought 23% (1233 kg/ha) more grain yield over application of recommended phosphorous to the study area. This has been indicated in table 3. The result of statistical analysis run for the experiment has been summarized in table 3.

As can be seen in table 4 the yield increment from application of P fertilizer and lime as compared to the control is 38% for 46 kg/ha P_2O_5 and 29% for 1.5 X LR. But the interaction of P and lime was very important, since higher yields were obtained from 46 kg/ha P_2O_5 plus 1.0 X LR and 69 kg/ha P_2O_5 plus 1.5 X LR.

Table 3. ANOVA for the influence of lime and P fertilizer on grain yield of bread wheat

Source of variation	Parameters					
	SD	SPM	PH	HI	AGY	BY
REP	NS	NS	NS	*	NS	NS
TRT	***	***	***	***	***	***
LSD	5.5089	8.0669	5.3701	2.5999	662.01	1383.8
MEAN (kg/ha)	71.15	46.95	107.8	42.91767	5344.914	12681.87
CV %	4.68426	10.39491	3.013809	3.665041	7.49333	6.60144

Table 4. Effects of lime and P fertilizer on grain yield of bread wheat

Lime requirement	P_2O_5 (kg/ha)			
	0	23	46	69
0	4239.4g	4879.8efg	5851.7bc	5347.9cde
0.5	5026.1 def	5443.6bcde	5570.4bcd	5117.1def
1	4600.9fg	5163.2def	6580.9a	4969.0 def
1.5	5469.3bcde	5473.0bcde	5045.4def	6052.7 ab
2	4998.8def	5615.3bcd	5539.5bcde	5914.5bc

Conclusions

Application of lime with 1.0 X LR (191.6 kg/ha) with the recommended NP gave the highest yields. This combined lime and recommended NP application is necessary to improve productions and productivity of bread wheat in the studied areas. The high yield obtained with the control treatment may be attributed to the occurrence of residual fertilizers, especially P, in the soils of the sub-station. The result from the control treatment, if performed under farmers' fields, could have been different. Nutrient by pass between plots may be another explanation for the high yield from the control treatment, as our input application methods cannot guarantee the immunity of adjacent plots from such effects. The inconsistence in the response trends could also be explained partly by the nutrient by pass effects attributed to field management conditions, as the precision of most field management techniques remain to be questionable.

For improved precision of field management and accuracy and reliable interpretations of results, a shift from traditional techniques to adoption of modern field equipment and management techniques should be seriously considered.

Evaluation of Lime Amount and Application Methods to Reclaim Acidic Soils of Amhara Region

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Introduction

Soil acidity is one of chemical soil degradation and covers 40.9 % of the highlands of Ethiopia. (Mesfin Abebe, 2007). This problem hinders crop production in high rainfall areas. Recognizing this challenge the Government of Ethiopia starts liming program since 2006. However, the current lime recommendation amount is beyond the affordability and management of farmers. Experience in china and India showed that applying lime in row is effective. However, there is no information whether this practice has good response in our climatic condition.

Therefore the objectives of this study were:

- To evaluate different lime application methods;
- To evaluate the agronomic efficiency of row application; and
- To enhance liming technologies so that to improve production and productivity

Materials and Methods

This trial was conducted in three districts: Banja, Sekela, and Gozamen. From these three locations composite soil samples was collected from 0 to 15 cm depth and analyzed for exchangeable acidity and pH prior to planting. For the second time soil was collected during harvest. The amount of lime that was applied at each level was calculated on the basis of the mass of soil per 15 cm hectare-furrow-slice, soil sample density and exchangeable Al^{+3} and H^{+1} of each site. Assuming that one mole of exchangeable acidity would be neutralized by equivalent mole of $CaCO_3$, the amount of lime applied was calculated based on the following formula.

$$LR, CaCO_3\ (kg/ha) = \frac{cmolEA/kg\ of\ soil * 0.15\ m * 10^4\ m^2 * B.D. (Mg/m^3) * 1000}{2000} * 1.5$$

Based on the calculated lime rate a field trial was conducted at Banja, Sekela, and Gozamen districts in the first year. The lime rates determined for the three districts were 1283.7, 5368.4, and 3763 kg/ha. These rates were recommended to be applied one time using broadcast application method. However, they were considered very high to be accepted by resource poor farmers. Although the one time application of these high rates is economically less acceptable by farmers, its residual acid ameliorating effects could continue for three or four years. Nonetheless, an alternative recommendation that can reduce the high initial costs involved in the production process was considered necessary. It is believed that this can be achieved through methods that involve localized applications. Therefore, a trial with localized or furrow application method was conducted the following year.

Treatments

The trial consisted of nine treatments arranged in RCBD, replicated three times. Gross plot size is 1.6mX3m = 4.8m^2, and net plot size of 1.2mX3m= 3.6m^2. The detail of treatments is as described below.

1. 1/4 times exchangeable acidity row application
2. 1/5 times exchangeable acidity row application
3. 1/8 times exchangeable acidity row application
4. 1/10 1 times exchangeable acidity row application
5. 1/20 times exchangeable acidity row application
6. 1 times exchangeable acidity broad cast application
7. 1.5 times exchangeable acidity broad cast application
8. Recommendation by soil laboratory with broad cast application (control) using acid saturation method.
9. Control no lime with recommended urea and DAP.

For broadcast application, lime was broadcasted uniformly by hand and incorporated into the soil during planting. For row application, lime was applied during planting in the row. Urea and DAP was used as the source of N and P, respectively. The recommended rate of N and P was applied uniformly to all treatments. Application of urea was in two split, while the entire rate of phosphorus was applied at sowing in band for row planted crops. Improved variety of wheat (Tayi) was used. Frequent follow up and participatory monitoring and evaluation was done.

Results and Discussion

From one year data result it can be clearly seen that one fourth and one fifth of full recommendation of lime gave equivalent yield as compared to application of full dose at once. However, the lime amount was reduced by 4-8 times without much yield penalty in Banja and Gozamen woredas. In Gozamen woreda maximum yield was recorded by applying ¼ times the recommended lime rate. Using one fourth and one five of the recommended lime in row application gave 1240, 2454 and 1250 kg ha^{-1} more yield as compared to with recommended NP fertilizer without lime at Banja Sekela and Gozamen respectively. Even reducing the lime rate by one eight gave increments of 425, 892 and 972 kg ha^{-1} yield as compared to the recommended NP fertilizer without lime at Banja Sekela and Gozamen respectively.

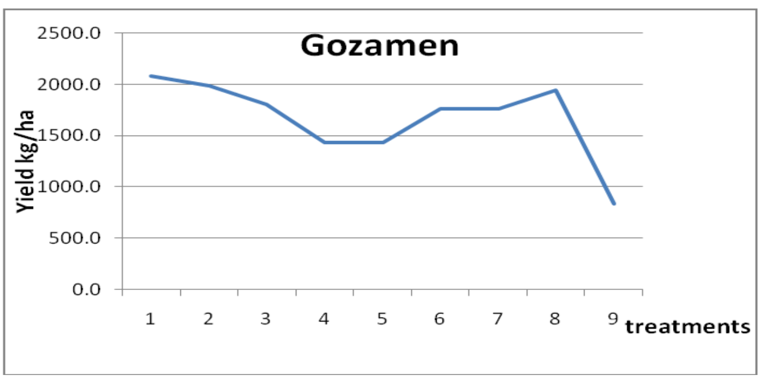

Fig 1. Yield trend for different rate of lime and application method

Conclusion

The results of this trial clearly showed that localized application of lime can reduce the full dose recommendation made using the exchangeable acidity method to a very low level that can be well accepted by resource poor farmers, without yield penalty. Even the 1/8th of the full dose provided yields very close the yield obtained from treatment determined using the acid saturation method.

The 1/4th, 1/5th, and 1/8th of the full dose (3763 kg/ha) provide yields high above the yields from treatments that consisted of 1.0 and 1.5 times the exchangeable acidity with broad cast application. Therefore, it can be concluded that the localized application method is the best method for amelioration of soil acidity and improved production and productivity of wheat under acidic soils conditions.

The findings can be applied to other locations as well until further research is done in the other location to support the new recommendation. Treatments consisting of 1/4th, 1/5th, and 1/8th of the full dose (3763 kg/ha) provided the best yields: 2083, 1990, and 1806 kg/ha, respectively. Therefore, farmers can use lime rates within the ranges of 470 – 940 kg/ha for Gozamen area. Sekela is extremely acidic. By extrapolating the same results to Sekela area lime rates within the ranges of 670 – 1340 kg/ha can be used. The same ratios can be applied to Banja area too. Farmers with very poor capacity to invest can apply the lower boundary with localized application method under row method of planting. This method cannot be practical for broadcast method of planting. The results of this trial is an indication for an alternative option of using localized application by reducing the LR determined by the exchangeable acidity method in laboratories between 1/4th and 1/8th. However, it would be necessary to support this argument by field verifications trials.

Developing Prediction Models to Determine Lime Requirements Acid Soils

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Introduction

The central, western, south eastern, northwestern highlands are part of the high potential areas for bread wheat production in Ethiopia. Some of the soils in these areas are highly acidic with pH ranging from 3.5 to 5.5. Moderately steep-to-steep slopes characterize the agricultural landscapes, due to which Soil acidity and erosion are posing major threats and challenges to the success of agricultural development goals of Ethiopia.

Crop yields are increasingly adversely affected by increased soil acidity; and the lower pH limit for bread wheat to withstand the effects of soil acidity is known to be 6.0. The adverse effect of low pH on crop yields is attributed to reduced availability of important nutrients and the influence on the sorption or precipitation of nutrients, especially P, with Al and Fe (Bohn, et al, 2001; Fageria and Baligar, 2003).

Researches on acid soils management has been going on for decades in the central and western parts of Ethiopia; and some significant advances have been made in the findings, especially in terms of spatial coverage. Yet more and more needs to be done to deal with production constraints under such environment. Adoption rates of recommended practices are also low; and the challenges for the low adoption remain unanswered.

Acid soils management research is mainly related to the determination of amount of liming material required to reclaim unit area of land, usually known as lime requirement (LR). The LR of soils is measured most directly by field trials. However, these methods are expensive and time consuming. When such activities are intended to be done on a large scale, the time and money required to develop recommendations would be very high. To account for such difficulties that would be involved in the development of recommendations at a large scale, tools that can model the relationship between measurable parameters of soils and LR are in use. The development of an equation or a set of equations that can enable users to quantify or predict the amount of lime required to reclaim a unit mass of soil in a given parcel of land is a more efficient technique, in terms of time and economy, than conducting individual field experimentation on wide ranges of acid soils. Data for the development of equations is obtained from laboratory incubation experiments. The results of incubation experiments can also be used for the determination of buffering capacity of soils (BC). Users to calculate the lime requirements of acid soils based on initial pH and predetermined target pH values can apply the determined BC values.

The main reason for measuring the buffering capacity of soils is in relation to liming. It is, therefore, logical to mix soil with $CaCO_3$ or $Ca(OH)_2$ and measure the pH after a suitable period of incubation (David L Rowel, 1995). The appropriate period for incubation to obtain an equilibrium state between added bases and exchangeable acidity and bring a rise in pH can be determined through a separate experiment on a given number of soils determined based on locations. Some literatures indicated that a 24hrs incubation period is sufficient to reach equilibrium if highly reactive bases are used. Other literatures indicated that about a week may be required. Literatures indicating a suitable period of incubation of a month or more are also available. David L Rowel (1995) also noted that humid tropical soils do not necessarily require to neutralize all of the exchangeable Aluminum as the crops growing on these soils are less sensitive to acidity and rates of lime loss are high. The target pH values could be lower than 6.5. He also indicated that the sensitivity of grass crops like wheat is lower by 0.5 pH values as compared to other cereal crops. Generally, determination of LRs of acid soils of different locations using such techniques can be very useful for planning and management purposes at zonal and regional level. Thus, this activity was conducted with the objective of developing prediction models for soil test based lime recommendations for acid soils of the central, western, and south eastern highlands of Ethiopia.

Methodology

Experiments were conducted in 2013 and 2014 in three agricultural research centers of EIAR with the aim of developing prediction tools for the determination of lime requirements for acid soils of different locations based on measurements of soil characteristics and then determination of buffering capacities (BC) and development of prediction models. Composite soil samples were collected from Gedo, Gebre Guracha, highlands of Butajira, Lemu-Bilbilo, and Meraro areas. The collected samples were subjected to chemical analysis: soil particle size distribution, pH, organic matter, bulk density, and exchangeable acidity. But pH data only was made available to be used for analysis and writing of this report. The laboratory experiment was conducted at Holetta Agricultural Research Center soil and nutrition laboratory. The field trials were done by Ambo Agricultural Research Center in Gedo and by Kulumsa Agricultural Research Center in Lemu-Bilbilo.

Sample screening and laboratory incubation experiment

Sixteen representative soil samples using standard sampling method were collected from major acid affected districts; and were air dried, sieved with 1cm aperture sieve size, and stored in appropriate condition. For incubation experiments and laboratory analysis 1kg of the air dried samples was passed in 2mm sieve. The initial pH of all soil samples collected from different areas (16 composited soil samples) was measured in soil water ratio of 1:2.5. Initial incubation experiment was conducted to determine the amount of time required to reach equilibrium levels for each soil following procedures similar to the main incubation experiment. Then the soil samples were divided in to three groups: soils with pH ranges of 3.8 – 4.5, 4.5 – 5.0, and 5.0- 5.5. Finally, samples taken from each group were mixed to make one composite sample for each group. The second incubation experiment was conducted on the composited soil samples. An array of 12 samples each 100g air-dried soil with ≤ 2mm were added in to 300 ml plastic bottles from every group. A series of 12 different dilute solution of $CaCO_3$ (0.1 - 0.6 g) treatments were pipetted to the same amount of given soils (100g each) in plastic bottles and was shaken for some times. David L Rowel (1995) indicated the use of six treatment levels of 0.1 - 0.6g of $CaCO_3$ per 100g soils, with increments of 0.1g, for medium textured soils to bring a pH rise of 3 units (from pH 4.0 to pH 7.0). In our trial 12 treatment levels with incremental average of 0.05 g/100g soil was used. The appropriate time for incubation of soils was determined using different levels of lime instead of incremental applications with time sequences to same soils. Measurements of pH were made according to standard laboratory procedure at every 24 hours for 3 days and at one-week interval starting from one week after the start of incubation. The measurement was done for six weeks, at which time the pH measurements for samples was found to reach equilibrium.

Development of Prediction Models

The array of data of incubation experiments run for six weeks were graphed in Excel spreadsheet to examine and determine the equilibrium levels of the soils response in pH to applications of 12 rates of lime (0.05-0.6 g CaO/ 100 g soils). The equilibrium levels for group 1 soils were obtained from 5th week, for group 2 soils from 3rd week, and for group 1 soils from 1st week data. These equilibrium data were used for the development of predictor equations for each group. Each data were evaluated to fit different regression models using SPSS 20 curve estimation method. Then the variables were transformed in to cubic form and run using linear regression method to develop model equations.

Determination of Soil BC and LR

The changes in pH measured against each treatment levels of the base was plotted to determine the buffering capacity of each soil from the buffer curve. The reciprocal of the slope of the buffer curve is the buffering capacity of the soil (David L Rowel, 1995). The value of the buffering capacity is the amount of lime required in kg per ha for each unit pH rise. Therefore, the BC values in g/100g soil was converted to kg/ha based on 1400 kg/m^3 bulk density and 0.15m slice of soils. If the change in pH required to reach the target pH value is more or less than 1, this factor is multiplied by the BC to determine the LR to raise the soil pH from initially measured values to a target value between 6.0 and 6.5. The value of the lime that corresponds to optimum pH for bread wheat production was determined from the curves corresponding to lime responses of each soil group and from regression equations developed by running regression analysis.

Field Experiment

Field experiments were carried out in 2014 to determine the relationships between responses of test crop with different rates of lime applications and soil characteristics; and also to evaluate the capacity of the model equation to predict the lime requirement of any acid soils based on the measured parameters within the range of the pH values initially taken from the different groups of soil samples. The treatment levels of the field experiment was determined from the measured values of pH change in relation to liming in laboratory.

The field experiment had four lime rates and three P rates for moderately to strongly acidic soils, and five lime levels with three P levels for extremely acidic soils. The treatment factors were factorially combined to make a total of 12 and 15 treatments, respectively, replicated 3 times.

Model validation

The results of the field experiment are planned to be used to validate the capacity of the model equation to predict the LR of the soils collected from different agroecologies. Initially, large number of locations were planned to be included in the validation experiment, but the workloads and lack of vehicles and staffs limited us to undertake the activity under few sites. Hence, Bokoji area was used for moderately acidic to strongly acidic soils, and Gedo area was used for extremely acidic areas. In the trial all other recommended agronomic and soil practices were implemented. For this report, however, the yield and yield component data are not made ready. Hence, the results of laboratory incubation experiment is presented, without validation of the developed models.

Data Analysis for incubation experiments

Data obtained from incubation experiments and laboratory analysis was subjected to correlation and regression analysis using SPSS 20 statistical software. The relationship between measured parameters from laboratory analysis and incubation experiments was determined from multiple regression equations; and the model equations are taken as predictors for lime requirements of different areas within the pH ranges used in the development of each model. The relationship of pH rise in relation to lime rates is also represented by graphs. Buffer curves drawn for each soil group, and developed from data of lime treatments and pH rise was used to determine the buffering capacity of each soil group.

Results and Discussion

The incubation experiment was conducted with 12 CaO treatments levels of 0.05 - 0.6 g/ 100g soils. For group 1, soils composed of soils with pH ranges of 3.52 – 4.42, bulked to give pH: 4.01, the responses of the soil in pH rise to the first four lowest treatments of CaO were below 6.0 even after 6 weeks of incubation. With increasing treatment levels, the responses continued to rise up to pH: 7.12 at the fifth week. At the final period of the incubation, the response reached near equilibrium level. Therefore, the data from the results of the fifth week incubation were used for the determination of BC and input for running regression analysis in relation to treatments. By using curve estimation method in the regression model of SPSS 20.0 statistical package, the relationship is determined using cubic models. Soil samples with pH ranges of 4.5-5.5 were grouped in to two with the assumption that differences in the responses to liming vary at the lower treatment rates. The responses of group 2 to the lime treatment levels were faster as compared to group 1, in terms of rise in pH and time. The first 24-hour reading was the highest under most treatment levels and the lowest reading recorded was at the end of second week of incubation. All other readings generally fall between the two. The third week readings were taken as the equilibrium level readings. The readings obtained at the end of the third week was also more precise predictor with R^2=0.949, next to R^2 values obtained from analysis of the first week readings. The response of the group 3 soils was somehow similar to group 2, in that the highest recordings were obtained from the first 24 hr readings, and the lowest recorded was at the end of the second week incubation. All other recordings fall between the two. However, the equilibrium level readings used were from week 1. The readings obtained at the end of the third week was also more precise predictor with R^2=0.987, next to the R^2 values from analysis of the 72 hour readings. Readings taken at the first four-incubation period for group 3 read above pH: 8.0. Most of the readings of group 2 soils obtained from treatment levels higher than the 7^{th} were also greater than pH:7.0. This is confirmed by David L Rowel (1995) that for the soil groups above pH:5.0 the measurements after weeks of incubation read even above pH:8.0.

Determination of LR Prediction Models and Buffering Capacity

Prediction models were developed by running the equilibrium pH data for each group in a linear regression model and setting the pH values as dependent variable and LR as independent variable. The models are developed in the form of third degree polynomial function. For models development a target pH value between 6.0 and 6.5 was used. The Principle of using target pH values is also applied in the determination of Buffering capacity of groups of soils. The regressed data from which the cubic models were developed are presented in table 1, 2, and 3.

Table 1: Regression coefficients for predictors model developed from soil samples of pH: 3.5-4.5

Model	Unstandardized coefficients		Standardized Coefficients	t	Sig.
	B	SE	Beta		
(Constant)	4.220	.073		57.677	.000
LR1	22.836	2.842	2.777	8.035	.015
LR2=LR*LR	-109.968	28.248	-3.483	-3.893	.060
LR3=LR*LR*LR	209.630	74.193	1.674	2.825	.106

Table 2: Regression coefficients for predictor model developed from soil samples of pH: 4.5-5.0

Model	Unstandardized coefficients		Standardized coefficients	t	Sig.
	B	SE	Beta		
(Constant)	4.695	.159		29.510	.000
LR1	26.351	5.026	4.008	5.243	.014
LR2	-132.524	41.083	-6.295	-3.226	.048
LR3	224.444	89.879	3.201	2.497	.088

Table 3: Regression coefficients for predictor model developed from soil samples of pH: 5.1-5.6

Model	Unstandardized coefficients		Standardized coefficients	t	Sig.
	B	SE	Beta		
(Constant)	5.239	.157		33.445	.019
LR1=LR	33.486	7.969	3.608	4.202	.149
LR2=LR*LR	-263.429	101.198	-5.920	-2.603	.233
LR3=LR*LR*LR	720.000	332.609	3.297	2.165	.275

The constant values for the models cannot practically be applied for prediction of LR for any soils based on initial soils samples pH data and predetermined target pH values. In the prediction process the initial pH values of the soils of interest are used as the constant values. Therefore, in the models the constant values are replaced by initial pH values for the soils of interest, generally designated as pH_i. Equations 1, 2, and 3 below are the LR predictor models developed by linear regression.

$$Equation\ 1\ for\ pH\ 3.8-4.5: pH_f = \mathrm{pH_i} + 22.836 * \mathrm{LR} - 109.968 * \mathrm{LR}^2 + 209.63 * \mathrm{LR}^3$$

$$Equation\ 2\ for\ pH\ 4.6-5.2: pH_f = \mathrm{pH_i} + 26.35 * \mathrm{LR} - 132.52 * \mathrm{LR}^2 + 224.44 * \mathrm{LR}^3$$

$$Equation\ 3\ for\ pH5.2-5.8: pH_f = \mathrm{pH_i} + 33.49 * \mathrm{LR} - 263.43 * \mathrm{LR}^2 + 720 * \mathrm{LR}^3$$

In the equations, pH_f and pH_i are used to designate the target and initial soils pH values. The target pH values for wheat are 6.0. Raising the pH values to by 0.5 above the target values is usually recommended. Considering the cost factors, raising the pH above 6.0 is highly expensive, as can be seen in graph 1, 2 and 3 for the three soil groups. The precision in prediction of the predictor equations lie in the ranges of initial pH values used. Applying the equation above and below the ranges indicated in the equations progressively reduce their validity in the determination of lime requirements.

Methods for practical application of model equations

The lime requirement for a soil of given initial soil pH value can be estimated by using the formula calculator in Excel workbook. Examples of calculated values are shown in appendix part, table 4 and 5. In the model, pH values are used as dependent variables and the lime rates as independent variables. Because of this, the model calculates the pH rise for every level of lime applied. Therefore, the estimated lime rates are read in the left column and the calculated values in the other columns read the pH rises that correspond to every level of lime applied.

Liming is a costly management when it is done with the intention of raising the soils pH to above to the neutral ranges. The rate of lime required to raise the soils pH every 0.1 unit increases with the increase in target pH values, as the rate of rise in pH declines with increased applications (Figures 1,2 and 3). Therefore, model estimates within the part of the lime response curves with steeper slopes are considered the economical ranges, as shown in the green colored cells of table 4 and 5. The red colored cells indicate values, which are not economical and recommendable.

Estimation of lime requirements using buffering capacity of coils

Use of buffer curves to determine the buffering capacity of the soil groups is an alternative option to determine the LR of soil samples. It is simple to use, but less precise. It is the amount of lime required to raise the pH of acid soils by 1 unit. BC is the reciprocal of the slope of the buffer curve. The LR is, therefore, determined based on the BC value, target pH, and initial soil pH using eq.4

$$LR = (Target\ pH - Initial\ pH\ of\ soil\ sample) * BC \qquad \text{eq.4}$$

The slope of the buffer curve is determined from the part of the curve that can approximate a straight line. The intercept of the curve on the y-axis is taken as the first point to determine the changes in the pH values per unit of lime applied.

However, calculation of BC values is subjective, and results can definitely vary from one individual estimate to another, leaving users at confusion. The general guideline is to take points on the curve that can approximate a straight line. The first rising part of the curve is a steep slope and estimates made based on this part of the curve only under estimate the BC values and consequently the lime requirements. This guide can be applied without question if we work on soils with pH above 5.0. Under such condition the lime response curve continue to be nearly straight up to pH6.0 or 6.5 and start to bend after that. Generally, the target pH levels for lime management for wheat fall between 6.0 and 6.5. The slope of the curve above pH 6.0 or 6.5 continually falls. Fortunately, this part of the curve above these points is not used for the determination of the slope and BC values. However, in the case of low pH soils, the lime response curve may start to bend or flatten after pH 5.0 but before pH 6.0. For such soils determination of the tangent of the curve (straight line) within the ranges of pH that include the target pH of 6.0 and above would be difficult. For relatively reliable and acceptable level of estimate, the slope of the curve should be determined to represent the ranges of soil initial and target pH values. For determination of BC and lime requirements based on data of incubation experiments, table 4 can serve as a guideline.

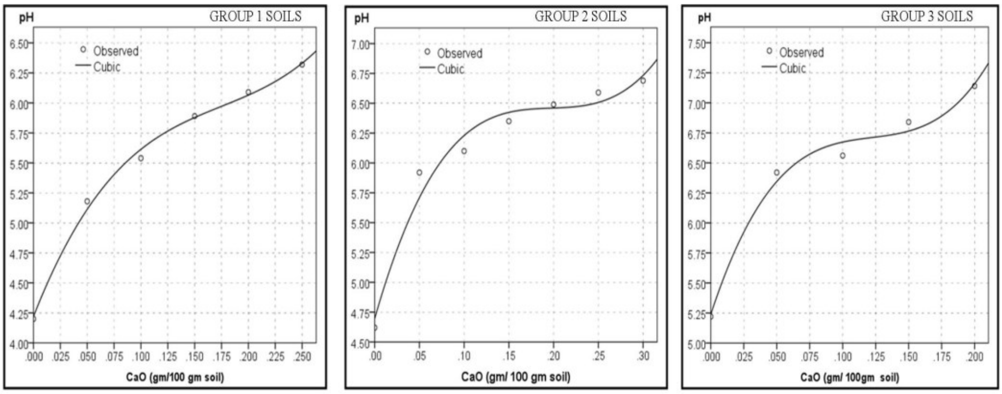
As can be seen in table 4, The ranges of pH values used for the determination of BC are 5.17-6.12 and 5.17-6.4 for group soils; 4.65-6.0, 4.65-6.3, and 6.63-5.61 for group 2; and 4.27-5.24, 4.27-5.61, 4.27-5.84, and 4.27-6.30 for group 1 soils. In the remark column, options are suggested for users to choose from based on the capacity of farmers to invest. I believe that lime recommendation should not be taken as fixed doses that cannot be modified. With some acceptable level of compromise on the yield, economical levels of lime rates can be chosen from the given choices given for one time application. But if the values are to be used as input for further research for determination of localized or furrow application rates, the BC values determined based on the pH ranges with target values above 6.0 are recommended. Consequently, the BC values to raise the pH of soils in the ranges of 5.1-5.6 to target values of 6.12 is 664 kg/ha CaO. Using this BC value the lime rate required to raise the pH from 5.2 to 6.0 would be 530 kg/ha. Examples of lime rate determinations for a range of initial soil and target pH values are shown in table 4. To determine the lime requirements for a range of soils, users must first get soil pH tests and use equation 4. Table 4 can be used as a guide for practical applications. Note that slight discrepancies can exist between estimated values using the buffering capacity (BC) method and the model equations estimates. Nevertheless, the differences are small enough to affect the use of the methods.

The buffer curves for the three groups soils are presented in figure 1 below. The range of soils responses in pH to lime that are used for the development of the curves and the model equations generally lie between 4.2 and 7.0. The points on the curves above pH 7.0 are excluded.

Table 4: Estimation of lime requirements for different soils using BC method

pH ranges used in the curve	Curve slopes	BC in g/100g soils	BC in kg/ha	Remark or Recommendation on the use of BC values	Examples of Lime rates to bring given soil pH to target pH		
					pH ranges		Lime rates (kg/ha)
					Initial	target	
Estimation of BC values and lime rates/ ha for soils with pH between 5.0 and 5.6 to bring the pH between 6.0 and 6.5							
5.17-6.12	31.61	0.0316	664	For soils with pH 5.0 - 5.6	5.2	6.0	530
5.17-6.4	24.87	0.0402	844	Acceptable, but less economical for one time use	5.2	6.4	1010
Estimation of BC values and lime rates/ ha for soils with pH between 4.5 and 5.0 to bring the pH between 6.0 and 6.5							
4.65-6.0	11.21	0.0892	1873	for soils above pH 4.6	4.8	6.0	2250
4.65-6.30	8.26	0.1211	2544	Expensive	4.8	6.30	3820
4.63-5.61	12.24	0.0817	1716	Cheap for one time use; perhaps, with insignificant yield penalty.	4.8	5.6	1370
Estimation of BC values and lime rates/ ha for soils with pH between 3.8 and 4.5 to bring the pH between 6.0 and 6.5							
4.27-5.24	16.24	0.0616	1293	Cheap for one time use; perhaps, with some level of yield penalty.	4.27	5.24	1254
4.27-5.61	13.48	0.0742	1557	Acceptable for one time use; perhaps with insignificant yield penalty	4.27	5.6	2070
4.27-5.84	11.23	0.0891	1871	Moderately Acceptable	4.27	5.8	2940
4.27-6.03	9.27	0.1079	2265	Expensive to bring the pH from below 4.3 to 6.0.	4.27	6.0	3918

Figure 1: Buffer curves obtained from data of group 1, 2, and 3 soils incubated to equilibrium for 5, 3, and 1 week



References

Bohn LH., BL McNeal and GA O'Conner. 2001. Soil Chemistry. 3rd edition. John Wiley & Sons, Inc. New York. USA.

David L Rowel, 1994. Soil Science: Methods and Applications. Longman Scientific and Technical.UK. pp 153-174

Dawit Habte, Alemayehu Assefa, Tadesse Desalegn. 2014. Research Activities Progress Report 2011-2013. Eastern Africa Agricultural Productivity Project-Wheat Regional Center of Excellence. Unpublished Report. pp 78-80

Hoskins BR. 1997. Soil Testing Hand Book for Professionals in Agriculture, Horticulture, Nutrient and Residuals Management. 3rd eds. Maine Forestry and Agricultural Experiment Station. University of Maine. Extracted from http://www.anlab.umesci.maine.edu.

IBM Corporation. 1989-2011. SPSS Statistical Software. Version 20.

Kanyanjua S, ML Ireri, S Wambua, SM Nandwa. 2002. Acid Soils in Kenya: Constraints and Remedial Options. KARI Technical Note. No. 11

Fageria NK and VC Baligar. 2003. Fertility Management of Tropical Acid Soils for Sustainable Crop Production. *In:* Zdenko Renge (ed0l. Handbook of Soil Acidity. Marcel Dekker Inc. New York

Mesfin Abebe. 2007. Nature and Management of Acid Soils in Ethiopia. Haromaya University. Ethiopia. pp 56.

SAS Institute .2002. The Statistical Analysis Software System for Windows. Version 9.00. TS Level 00M0. SAS Institute Inc., Cary NC. USA

Tisdale SL, WL Nelson, JD Beaton, and JL Havlin. 2002. Soil Fertility and Fertilizers. 5th ed. Prentice Hall of India. New Delhi. pp 388.

Water and land resource center. 2008. Geospatial Information System Ethiopia. EtihoGIS II. Addis Ababa, Ethiopia.