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Evaluating Integrated Application of Lime and Organic Materials on Yield and Yield Components of Wheat S Under Acid Soils of Aneded District, Northwest Ethiopia

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***Abstract* – Soil acidity and nutrient deficiencies are the major constraints causing low crop yield and food insecurity problem in highly weathered and leached tropical soils of Ethiopia. A field experiment was conducted at Aneded district, Northwestern Ethiopia during 2022-2023 main cropping seasons to evaluate the effects of combined use of FYM and lime on wheat yield. The experiment consisted of four rates of lime [25%, 50%, 75% and full dose of lime based on exchangeable acidity in combination with 50% of FYM and 50% of inorganic N fertilizer), 50% of FYM+50% of inorganic N, full dose of lime based on exchangeable acidity + recommended NP and sole recommended NP fertilizer] arranged in a randomized complete block design with three replications. Before implementing the experiment, composite soil sample from (0-20cm) was collected. Wheat growth parameters (plant height and spike length) and grain yield, biomass yield and HI were measured following standard procedures. Compared to sole application of mineral fertilizer (control), application of 50% of FYM + 50% of lime + 50% of inorganic N fertilizer increased wheat grain yield, biomass yield and HI by 48.14%, 41.71% and 8.63%, respectively. Besides, the combined application of FYM and lime provided the highest plant height (93.91cm) and spike length (8.40cm), which was noticeably greater than the control (81.02cm and 6.90cm). Therefore, application of lime and organic nutrient in combination is an effective option to curb soil acidity while enhancing soil nutrients availability and crop yields at lower input costs. However, to determine the application frequency, long-term effects of compost and lime in combination on acidic soil properties and crop yield need to be investigated through further research.**

***Keywords* – Farmyard Manure, Crop Yield, Liming, Soil Acidity.**

I. Introduction

Soil acidity is one of the major and widespread constraints affecting the growth of plants and ultimately limits crop productivity and profitability in many parts of the world (Fageria, 2009). Large areas of Ethiopia's highlands are affected by soil acidity and low availability of major plant nutrients especially phosphorus due to a non-sustainable form of agricultural practices and leaching of base-forming basic cat-ions attributed due to high precipitation (Olpala et al; 2015). Ethiopian Soil Information System (EthioSIS, 2016) revealed that about 43% of the cultivated land in humid and sub-humid highlands of Ethiopia are affected by soil acidity of these about 28.1% of soils are dominated by strongly acidic soils (pH 4.1-5.5). Toxic levels of Al, Mn and Fe, high P fixation and limited nutrients availability are the key constraints hampering crop productivity in acidic soils. Besides, Al toxicity severely limits crop production by impairing root growth and inhibiting lateral root formation, thereby restricting nutrients and water uptake by plant roots (Baquy et al., 2017). This soil acidity problem forced most farmers to grow acid tolerant crops at the expense of economically important crops or to allocate their cultivated lands to eucalyptus plantation. To fulfill the increasing demand of population for food and raw materials, maintaining soil health and fertility has remained as the major factor to increase and sustain crop yields. This calls for proper use of knowledge of soil acidity and its amelioration mechanisms to maximize agricultural productivity.

Wheat is one of the most important stable foods and used as raw material for industries in Amhara Region. However, the productivity has been declining from year to year in northwestern Ethiopian highlands, in general and in the study area in particular. The major problems are low soil fertility, low levels of input including fertilizer and quality seed and soil chemical degradation (soil acidity). Among the above problems, soil fertility decline due to soil acidity is one of the main constraints causing low crop yields in the Ethiopian highland areas (Elias et al., 2020).

Properly amending acidic soils through lime together with manure has been suggested an effective measure to amend acidic soils for the growth of crops. Liming increases soil pH and availability of essential nutrients such as Ca, P and Mo, thereby decreasing the solubility of toxic elements (Al and Mn) in the soil and enhances root development, water and nutrient uptakes (Marschner, 2011). Similarly, application of manure on acidic soils reduces Al3+ toxicity and increases nutrient content of the soils. However, resource-poor farmers cannot apply the recommended rates of mineral fertilizers and lime due to its high cost (Tamene et al., 2017). In Anded district, soil acidity is a well-known problem that limits crop productivity. As part of the solution to such a problem in soils, the combined application of lime and FYM on wheat has not been investigated in the area, in which wheat was one of the potential cereal crops in the area. Having the above points in mind, an experiment was implemented to determine the effects of integrated use of lime and farmyard manure on wheat yield in the study area.

II. Materials and Methods

2.1. *Description of the Study Area*

The experiment was conducted during the main cropping seasons at Enechifo Kebele, Anded District, and northwestern Ethiopia. The study site is geographically located in 037°46’47.2’’ to 10°16’14.5’’ N latitude and 38°4’ 3’’ to 38°6’14’ with the altitude 2493 meters above sea level. The area has mean annual precipitation of 1482.30 mm. Rainfall distribution of the area is uni-modal, and the main rainy season extends from May to September. Based on the information obtained from Anded District Agricultural Office (unpublished), land use types of the district consist of arable land (64.7%), grazing (10.2%), forests and shrubs (0.6%), settlement (7.8%) and wetlands (16%). The farming practice is described by a subsistence crop-livestock mixed system where barley (*Hordeum vulgare*), wheat (*Triticum aestivum*), tef (*Eragrostis tef* Zucc. Trotter), potato (*Solanum tuberosum*) and faba bean (*Vicia faba* L.) are the major crops cultivated.

2.2. *Experimental Procedure*

The experiment consisted of four rates of lime [25%, 50%, 75% and full dose of lime based on exchangeable acidity in combination with 50% organic source and 50% of inorganic nitrogen fertilizer), 50% organic source+50% of inorganic nitrogen, full dose of lime based on exchangeable acidity recommended NP and sole recommended NP fertilizer] arranged in a randomized complete block design with three replications.

The gross plot size was 3m*3m (9m^2) with net plot area of 2.6m*3m (10.8m^2). The distance between adjacent blocks, plots and rows were separated by 1m, 0.5m and 0.2m, respectively to avoid treatment contamination.

The experimental site was oxen plough before treatment application as per the conventional practice in the study area and after lime and farmyard manure application; the plot was dig out manually to incorporate with the soil. Improved bread wheat (Denda'a) variety was used as a test crop. Based on the treatment allocation, urea was applied in splits half during planting, while the remaining half dose of was applied at tillering stage. Lime and farm yard manure (FYM) amendments were applied once alone at the start of the experiment, while mineral fertilizers were incorporated during each cropping season. The lime rate was estimated using the equation given by (Demissie *et al.*, 2017).

$$LR = \frac{Exch.ac * BD * depth\ (m) * 10000m2}{2}$$

Where LR = Lime requirement ($CaCO_3$ kg ha^{-1}); Exch. Ac is exchangeable acidity of the soil (cmol (+) kg^{-1}); BD is bulk density of the soil (g cm^{-3}) and depth is the depth of the plough layer (0.15m).

2.3. *Soil Sampling and Analysis*

Representative composite soil samples were collected at a depth of 0-20cm before treatment application to determine selected physicochemical properties. The collected soil samples were air dried, crushed and sieved in 2mm diameter screen sieve mesh to analyze soil pH, exchangeable acidity, available phosphorus, total nitrogen, organic carbon and CEC. The particle size distribution was analyzed with the Hydrometer technique (Bouyoucos 1962). Soil bulk density was estimated from undisturbed soil collected using core sampler (Blake and Hartge, 1986). Soil pH was determined as wet digestion method (Bremner and Mulvaney, 1982). Available phosphorus (AP) was analyzed using $NaHCO_3$ extraction method (Olsen *et al.*, 1954). Exchangeable acidity was determined by 1M KCl extraction and with 0.02M NaOH titration method (Rowell, 2014).

2.4. *Agronomic Data Collection*

Data on a plant basis was recorded from the central net harvestable rows/plots of 10.8m^2 (3.6m* 3m). Plant height (cm) was recorded from 10 randomly selected plants at physiological maturity measured from the base of the stem of the main plant to the tip of the main shoot or spike, excluding awns. Spike length (cm) was measured from 10 randomly selected representative plants with scale from the basal joint of the spike till the terminal spike excluding the awns. Total biomass yield of wheat was measured using graduated balance following complete sun-drying of sample plants taken from each net plot area. Initially, the grain yield was threshed, cleaned from straw and debris, and then weighed using a sensitive electrical balance. Grain yield was adjusted to 12.5% moisture content and converted to a hectare basis. Straw yield was quantified by subtracting grain yield from biomass yield.

2.5. *Data Analysis*

The collected data were subjected to analysis of variance (ANOVA) appropriate to RCBD using SAS Institute (2012) 9.3 version software and the interpretations were made following the procedure described by Gomez and Gomez (1984). The least significant difference (LSD) test at a 5% probability level was used for treatment mean comparison when the ANOVA showed significant differences among treatments.

III. Results and Discussion

Effects of Integrated use of Farm Yard Manure and Lime on Wheat Growth Attributes

Table 1. Soil physico-chemical properties before implementing the experiment.

Soil Properties	Value	Rating	Reference
Total N (%)	0.19	Medium	Tekalign, 1991
Available P(ppm)	7.33	Low	Jones and Benton, 2003
pH 1:2.5 (H_2O)	4.90	Strongly acidic	Tekalign, 1991
Bulk density (gcm^{-3})	1.25	Optimum	Hunt and Gilkes,1992
CEC	17.8	Moderate	Hazelton and Murphy, 2007
OC (%)	2.14	Medium	Tekalign, 1991
Exchangeable acidity (meq/100g)	0.98		
Sand (%)	38		
Clay (%)	46		
Silt (%)	16		
Soil textural class	Clayey		

The over years mean results showed that integrated application of lime and farm yard manure highly and significantly ($p<0.01$) affected most of the measured wheat growth parameters.

The average results indicated that the highest plant height (93.91cm), spike length (8.40cm) were obtained from plots that received combined use of 50% of farmyard manure combined with 50% of based on N equivalence and exchangeable acidity for manure and lime respectively. However, the lowest values of plant height (81.02cm) and spike length (6.90cm) were recorded from the control plots. Plots amended with 50% of farmyard manure combined with 50% of lime increased plant height and spike length 15.91% and 21.74%, respectively, compared to the control. Besides, plant height and spike length were 14.12 and 19.32% higher, respectively, under combined addition of 50% of farmyard manure and 50% of lime compared to the control. The two years results showed that wheat's plant height and spike length performed better in 2022 than 2023 cropping season, which might be as lime and organic nutrient sources decompose and release nutrients slowly (Rheinheimer *et al.*, 2018). The greater increment of plant height and spike length of wheat from combined application could be related to reduce soil acidity and increased availability of nutrients that may enhance vegetative growth (Melese *et al.*, 2015). In addition, the application of organic materials alone or integrated with mineral fertilizers improved soil bulk density and water holding capacity of the soil, resulting in better roots growth and nutrients use efficiency. The current result is in line with the finding of (Agegnehu *et al.*, 2016), who reported that the addition of organic and inorganic fertilizers together provided the highest plant height. Similarly, Ali *et al.* (2020) also reported that combined use of mineral fertilizers enhanced plant height which could be related to better supply and uptake of nutrients for cell division, and expansion leads to better vegetative growth.

Table 2. Effects of combined applications of lime and FYM on plant height and spike length of wheat.

Compost Rate	N rate	Lime rate	Plant Height (cm)			Spike Length (cm)		
			2022	2023	Mean	2022	2023	Mean
0	RNP	0	82.4c	82.2d	82.30e	7.0bc	7.09	7.04c

Compost Rate	N rate	Lime rate	Plant Height (cm)			Spike Length (cm)		
			2022	2023	Mean	2022	2023	Mean
0	RNP	100%	92.8a	93.1ab	92.92ab	8.1ab	7.91	7.99ab
50%	50%	0	79.8c	82.3d	81.02e	6.4c	7.39	6.90c
50%	50%	25%	84.9bc	88.6c	86.75d	7.2bc	7.57	7.40bc
50%	50%	50%	92.4a	95.4a	93.92a	8.7a	8.06	8.40a
50%	50%	75%	88.6ab	91.5bc	90.00bc	8.5a	7.63	8.08a
50%	50%	100%	90.1ab	89.8c	89.93c	7.9ab	8.03	7.98ab
CV (%)			3.44	3.02	3.44	8.06	4.96	7.50
LSD (0.05)			5.35	3.20	5.35	1.20	ns	0.68
P – value			**	**	**	**	-	**

Effects of Integrated use of Farm Yard Manure and Lime on Wheat Yield Attributes

Integrated application of lime and farmyard manure showed a significant ($p<0.01$) effect on above ground biomass and grain yields of wheat as shown (Table 2.).

The average results of the two cropping seasons showed that the application of 50% of farmyard manure, 50% of lime and 50% of recommended mineral nitrogen fertilizer gave the highest grain yield, biomass yield and harvest index of wheat (3203.8kgha^{-1}, 7959.3kgha^{-1} and 42.04%), respectively. In case above ground biomass yield the highest value (7959.3 kgha^{-}1) recorded from combined application 50% of farmyard manure, 50% of lime and 50% of recommended mineral nitrogen fertilizer was stastically at par with plots treated with 100% recommended mineral fertilizer with 100% of recommended lime. Plots treated with combined application 50% of farmyard manure, 50% of lime and 50% of recommended mineral nitrogen fertilizer produced 48.14% yield advantages compared with application of mineral fertilizer alone. Similarly, plots received 50% of farmyard manure, 50% of lime and 50% of recommended mineral nitrogen fertilizer biomass yield by 41.71 compared to the control (application of sole mineral fertilizer).

Our research results showed that the application of lime, farmyard manure and half of mineral fertilizer in combination noticeably increased wheat yield and yield attributes compared to sole applications mineral fertilizer, which could be associated with increased soil pH, reduced exchangeable Al^{3+} and increased levels of plant nutrients (Ejigu *et al.,* 2023). Moreover, the integrated use of organic and inorganic fertilizers increased crop yields related to greater soil organic matter content, better mineralization, and the release of available nutrients (Mamuye *et al.,* 2021). According to the finding of Ali *et al.* (2018) combined nutrient management enhances soil structure and water holding capacity, improving nutrient uptake and crop yields. The current result is in consistent with the finding of Singh *et al.* (2017) who showed that biomass and grain yields were 51.42% and 57.34%, respectively, higher by integrating mineral fertilizers and lime over sole mineral fertilizer application. Agegnehu *et al.* (2014) also noted that the grain yield of wheat was 151% higher from the application of 60/20 kg N/P ha^{-1} along with 50% manure and compost compared to the control.

Harvest Index

The harvest index was significantly ($p<0.05$) influenced due to combined application of lime, farmyard manure and mineral nitrogen fertilizer. Therefore, the highest harvest index (42.04%) was recorded from plots received 50% of farmyard manure, 50% of lime and 50% of recommended mineral nitrogen fertilizer, whereas the lowest harvest index (32.57%) was obtained from plot treated with combined use of 50% of farmyard manure and 50% of lime in the absence of mineral fertilizer. The possible reason could be that application of lime, farmyard manure and mineral fertilizer with optimum rate might have increased the efficiency of wheat to partition the dry matter into the reproductive seed sinks. The current result is in line with (Wegene and Lemma, 2023) who reported that the highest harvest index of maize was recorded from plots treated with combined use of lime and vermicompost.

Table 2. Effects of lime and FYM application on Grain yield and Biomass yield of wheat.

Compost Rate	N Rate	Lime Rate	Grain Yield ($kgha^{-1}$)			Biomass Yield ($kgha^{-1}$)			HI (%)
			2022	2023	Mean	2022	2023	Mean	
0	RNP	0	2140.2^{cd}	2185.2^{cd}	2162.7^{d}	5298.3^{d}	5935.2^{b}	5616.7^{d}	38.7^{abc}
0	RNP	100%	2513.9^{bc}	2792.7^{b}	2653.3^{b}	7284.6^{a}	8342.6^{a}	7665.5^{a}	33.7^{cd}
50%	50%	0	1850.0^{d}	2101.4^{d}	1975.7^{d}	6196.6^{c}	6027.8^{b}	6112.2^{cd}	32.6^{d}
50%	50%	25%	2348.2^{bc}	2448.3^{c}	2398.2^{c}	6506.8^{bc}	6768.5^{ab}	6637.7^{bc}	36.5^{bcd}
50%	50%	50%	3163.9^{a}	3243.6^{a}	3203.8^{a}	7576.1^{a}	8046.3^{a}	7959.3^{a}	42.0^{a}
50%	50%	75%	2735.2^{b}	2878.1^{b}	2806.6^{b}	7367.5^{a}	7194.4^{ab}	7281.0^{ab}	38.9^{ab}
50%	50%	100%	2653.7^{b}	2808.9^{b}	2731.3^{b}	7039.3^{ab}	8161.1^{a}	7600.2^{a}	36.8^{bcd}
CV (%)			9.00	7.06	9.00	6.07	12.69	11.37	11.80
LSD (0.05)			396.2	330.2	220.84	729.76	1627.8	933.28	5.12
P – value			**	**	**	**	**	**	*

IV. Conclusion

Results from the present study have demonstrated that application of manure and lime to acid soils has a profound influence on soil pH, exchangeable acidity and microbial populations. Combining 50% of FYM +50% of agricultural lime + 50% of mineral fertilizer is effective option in reducing soil acidity, increasing soil fertility consequently enhancing root length, dry matter and plant height. Thus, acid soils of Anded district and areas having similar agro ecological characteristics need manure in combination with lime to improve their chemical and biological properties and consequently their productivity.

Moreover, the application of lime and compost reduced soil acidity, increased soil nutrient contents and crop yields compared to sole application of mineral fertilizers. However, adding lime and FYM separately did not maintain the desired soil pH, exchangeable aluminium, soil nutrients, and wheat yields. Overall, the combined addition of organic nutrient sources and lime at optimum rates substantially increased growth and yield of wheat.

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