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Demonstration and Popularization of CaO-Containing Blended Fertilizers to Ameliorate Acid Soils of East Gojjam Zone, North west Ethiopia

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***Abstract* – Liming acid soils is one of the best technologies used to amend soil acidity and increase crop production and productivity. However, because the soil is highly degraded (acidic), a huge amount of lime is required to rehabilitate the surface soil and increase the productivity of these acidic soils. This high rate of lime requirement becomes economically and logistically challenging for many subsistence farmers in Ethiopia due to its high cost. Thus, the use of lime containing blended fertilizer remains an alternative technology to ameliorate acidic soils thereby to boost crop production in Ethiopia's highlands. Afield experiment was conducted on Nitisols of D/Eliase and Basoliben Districts, Northwestern Ethiopia during 2022/23 main cropping season to demonstrate CaO - containing blended fertilizer formulas to amend acidic soils. The treatments were (1) new customized blended fertilizer formulas, (2) compound NPS fertilizer alone and (3) NPS along with lime. The experiment was arranged in Randomized Complete Block Design (RCBD) replicated across farmers' fields. The collected data was subjected to ANOVA using SAS 9.3 version software. The results revealed that new customized blended fertilizer formulas brought significant effect on grain yield and biomass yield. Moreover, application of new customized blended fertilizer formulas produced the maximum net benefits with acceptable marginal rate of return. Therefore, we can recommend that the newly produced blended fertilizer formulas can be used as an alternative technology to amend acidic soils. But, it needs further to demonstrate/ scale up the result in large scale field.**

***Keywords* – Blended Fertilizer Formula, Economic Return, Yield.**

I. Introduction

Currently soil fertility degradation is the bottleneck problem to assure nations food security in Ethiopia. From several obstacles, soil acidity is a major constraint to crop growth and productivity in Ethiopian highlands, where it accounts 43% of the total land under arable cropping (Tegbaru, 2015 and Ethio SIS, 2016). Due to their poor in plant nutrient content, aluminum toxicity and fragile soil structure, their agricultural productivity is low and declines rapidly under cultivation (Tegbaru, 2015). In these acidic conditions, there is a complex interaction of growth limiting factors. One or more of the following may restrict plant growth thereby the final plant economy: Al or Mn toxicity; Ca Mg, P and Mo deficiency; and reduced mineralization, nitrification, nodulation, and mycorrhizal infections in the soil system (Taye et al; 2020). Under these conditions, the yield of stable food crops is very low, averaging 1.0 t ha^{-1} against a potential of about 6.0 t ha^{-1} if the soil is well managed by replenishing the essential nutrients.

Liming is one of the best option and correction of modern acid soil management since other technologies including the use of organic inputs and rock phosphate (RP) have their own limitation in their use (Alemu et al., 2017; Desalegn et al., 2017). Based on this the use of agricultural liming material in Ethiopia is well demonstrated since 2014 in the country. In this regard, extension agents and farmers in acidic area have an awareness of the importance of lime. However, because the soil is highly degraded (acidic), reaching about 6 cent mole/kg soil exchangeable acidity that indicates a very high amount of lime is required to rehabilitate the surface soil and increase the productivity of these acidic soils. This high rate of lime requirement becomes economically and logistically challenging for many subsistence farmers and the government and its overall high cost prevents the use of lime. The use of inorganic fertilizer is recognized as an effective way for overcoming nitrogen and phosphorus deficiencies to boost productivity. However, in acid soils, response to fertilizers may not occur because of constraints imposed by soil acidity. Thus, low fertilizer response efficiency along with the cost of inorganic fertilizers at the season of application has reduced their use by smallholder farmers in acid soils. But, the use of fertilizer and lime remains the key to increasing food productivity in Ethiopia's highlands.

Having the above points in mind, OCP project developed new blended fertilizer formulas tailored to acid soils with the hypothesis that blending most crop-limiting nutrient fertilizers with granulated lime of high quality will reduce the existing farmers' bulk lime use associated constraints such as bulky transportation, laborious application and high investment costs while making fertilizers more suitable both for the soil and crops. As a result, OCP has financed and provided new products to the Ethiopia Institution of Agricultural Research and Regional Research Institutes to conduct multi-location trials on new formulas as an alternative strategy to increase production and productivity on acid soils where the current compound fertilizers are marginally effective.

Therefore, this demonstration activity was undertaken to validate the results attained during the trial period, and popularize the benefits of new blended formulas to smallholder farmers and extension practitioners using wheat as attest crop under acid soil conditions having an objective of to demonstrate and popularize the benefits of using new CaO-containing blended fertilizers on major crops grown on acid soils and to create awareness about the agronomic, logistic, and economic benefits of the new acid soil production innovation among policymakers, extension practitioners, and farmers.

II. Material and Methods

2.1. *Description of the Study Area*

The demonstration and popularization trials were executed in the Basoliben and Debre Eliase districts of the East Gojjam zone in the Amhara Regional State. Basoliben district is geographically located between 10.11°-10.16° E longitude and 37.75°-37.80° N latitude with an altitude of 2326 m a. s. l. While the Debre Eliase district is found geographically in between 10.27°-10.30° E longitude and 37.37°-7.40° N latitude with an altitude of 2183 m a. s. l. The mean annual rainfall of Debre Elias is 1266 mm. The average annual maximum and minimum temperatures of Debre Elias are 25°C and 15°C, respectively. In both districts, soil acidity is the major crop growth constraint, where production and productivity are severely affected. The predominant soil type of the study area in both districts is Nitisols, which have a reddish color. On average, the soils, where the trials were conducted, are deep, highly weathered, well-drained, sandy clay in texture, and strong to moderately acidic in their reaction; thus, the soils need reclamation to revert the adverse situation.

2.2. *Treatments Setup*

Each demonstration trial comprised of three treatments (Table 1.). The treatment includes new customized blended fertilizer formulas, compound NPS fertilizer alone and NPS along with lime. The last two treatments were considered as negative and positive controls, respectively. The three treatments for test crop were arranged in the following setup at one farm.

Table 1. Treatments setup for the current study used.

Treatments
Formula I: 17.3 CaO-containing blended fertilizer
NPS
NPS + lime
5.1N–37.4P_2O_5–4.25S + 17.3CaO
Formula II: 26.3 CaO-containing blended fertilizer
NPS
NPS + lime
0N–39.1P_2O_5–0S + 26.3CaO
Formula III: 31.5 CaO-containing blended fertilizer
NPS
NPS + lime
0N–32.3P_2O_5–0S + 31.5CaO

2.3. *Trial Establishment and Management Practices*

Before planting, about five (5) sub-samples were collected from each site at a 0-20 cm depth, and one representative composite soil sample was made for each demonstration site. Then, the collected soil samples were air-drying at room temperature, crushed using a mortar and pestle, and sieved to pass through a 2-mm mesh wire. The collected samples were subjected to analyses of soil reaction (pH) and exchangeable Al^{+3} and H^+ at Holleta, soil and plant laboratories. Based on the analytic results, each trial was established in those sites having high exchangeable Al^{+3} (>2 cent $mole_{+3}$ kg^{-1} of soils).

The trial fields were cultivated conventionally by oxen plough to a depth of 15-20 cm. The gross demonstration plot was 408m^2 (34m*x12m) and this gross demonstration size was divided into three equal-sized plots with an area of 100m^2 (10m*10m) to accommodate the above-mentioned three treatments in one demonstration at a time. Varieties used for the trials were Denda'a for wheat. The seeds were drilled along rows spaced 20cm apart, and the recommended seeding rates were used during sowing.

Based on the exchangeable acidity of the soils, the lime requirements were calculated, divided into four equal portions, and, the entire recommended quantity of lime was broadcasted across the entire area on the day of sowing. The rates of CaO-containing blended fertilizer formulas were calculated based on the recommended rate of 92 kg ha^{-1} P_2O_5. All the newly introduced CaO-containing blended fertilizer formulas and NPS fertilizers were applied once during sowing. Urea fertilizer was applied uniformly to each treatment depending on the selected test crop and the uniqueness of the soil conditions of the specific demonstration site in splits: half the recommended rate during sowing and the remaining half was top dressed at tillering stages of the crop. Other agronomic practices such as cultivation, weeding, and chemical spray against insects and pests were done unifo-

-rmly for all experimental units as required according to the research recommendation.

2.4. *Data Collection and Analysis*

Yield and yield attribute data from each demonstration plot were collected from a net plot area of $49m^2$ (7m*7m), which were then converted to a hectare base. The collected data were subjected to analysis of variance (ANOVA) using SAS version 9.3 statistical software (SAS Institute, 2012) and the interpretations were made following the procedure described by Gomez and Gomez (1984). When ANOVA showed significant treatment effects, the separation of means was carried out using the least significant difference at ($p<0.05$) probability level. Economic analysis was done to investigate the economic feasibility of treatments that would give acceptable returns at low risk to farmers following the procedures (CIMMYT, 1988). While doing the economic analysis, the average grain yield obtained from each plot was adjusted to 10% downward to reflect the difference between researchers experimental plot yield and the yield farmers will expect from the same treatment because researchers are using small plot sizes and applying better crop management practices during experimentation.

III. Results and Discussion

3.1. *Initial Soil Chemical Properties*

According to Tekalign (1991) classification, the mean values of the analyzed soil pH of the soils in all study locations fell within the strong to very strongly acidic range (Table 2). When the soil pH values fall below 5.5, it needs to be amended to get optimum yield from the plots, which is the case for all the study areas. The soil's average exchangeable acidity was around 2 $cmol_{(+)}$ kg^{-1}soil (Table 2).

Table 2. Initial soil reaction and exchangeable acidity levels and amount of lime used.

Test Crop	Soil pH $H_2$0 (1:2.5)			Exchangeable Acidity [$cmol_{(+)}$ kg^{-1} soil]			Lime Applied [tha^{-1}]		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Wheat	5.59	4.80	4.69	1.23	2.19	1.72	1.80	3.21	2.50

3.1.1. *Wheat Response to Application of 17.3 CaO - Containing Blended Fertilizer*

The response of wheat to 17.3 CaO-containing blended fertilizer application over all the locations was significant as shown (Table 3). The application of 17.3 CaO-containing blended fertilizer produced the maximum mean grain yields of 3393 and 3477 kg ha^{-1}. The application of 17.3 CaO-containing blended fertilizer substantially increased the mean grain yield of wheat by 12.3% compared to the negative control (NPS) while the lowest mean grain yield was obtained from the negative control, which was NPS treated plot.

3.1.2. *Wheat Response to Application of 26.3 CaO- Containing Blended Fertilizer*

Analysis of variance revealed that the application of 26.3 CaO-containing blended fertilizer significantly influenced the mean grain and biomass yields of wheat (Table 3). The maximum mean grain yield of 3146 kg ha^{-1} was obtained from the conventional practice (NPS + Lime), which was statistically at par with the grain yield of 3020 kg ha^{-1} harvested from the application of 26.3 CaO-containing blended fertilizer. The application of 26.3 CaO-containing blended fertilizer increased the mean grain yield of wheat by 8% compared to the negative control (NPS).

3.1.3. *Wheat Response to Application of 31.5 CaO- Containing Blended Fertilizer*

The results of the present demonstration trials revealed that the 31.5 CaO-containing blended fertilizer significantly affected the mean grain and biomass yields of wheat. The application of 31.5 CaO-containing blended fertilizers gave the highest mean grain yield of 3383 kg ha^{-1}, which was followed by the conventional practice of NPS + Lime (2975 kg ha^{-1}). The application of 31.5 CaO-containing blended fertilizer provided 25% more grain yield of wheat relative to the application of sole NPS.

Table 3. Mean grain and biomass yields of wheat as affected by different fertilizer treatments.

Treatments	GY $Kgha^{-1}$	BY $Kgha^{-1}$	Treatments	GY $Kgha^{-1}$	BY $Kgha^{-1}$	Treatments	GY $Kgha^{-1}$	GY $Kgha^{-1}$
17.3CaO	3393a	13636b	26.3CaO	3020a	11418.4a	31.5CaO	3383a	11535
NPS + Lime	3347a	14802a	NPS+ Lime	3146a	11351.8a	NPS+ Lime	2975b	12174
NPS	3022b	13514b	NPS	2785b	10185.8b	NPS	2702b	10335
LSD (0.05)	170.8	943.85	LSD (0.05)	189.62	987.05	LSD (0.05)	274.45	ns
Mean	3253.8	13983.7	Mean	2983.4	10985.3	Mean	3019.9	11347.8
CV (%)	3.03	3.9	CV%	4.36	6.16	CV (%)	4.01	12.09

Soil amendment using lime or CaO-containing blended fertilizers for wheat production gave higher net benefits (Table 4). Those additional net benefits were on top of the results. Bread wheat production using 17.3 CaO-containing blended fertilizers provided farmers with ETB 2,946.98 (2%) additional net benefits compared to the integrated application of lime with NPS (Table 4). The application of 26.3 CaO-containing mineral fertilizers also gave ETB 808.80 (1%) more net benefit relative to the conventional practice. Similarly, ETB 17,107.80 (13%) additional net benefits over the combined application of lime with NPS were also obtained when 31.5 CaO-containing blended fertilizers was used for bread wheat production.

Compared to the sole application of NPS, bread wheat production using 17.3 CaO-containing blended fertilizers provided farmers with ETB 14,730.50 (11%), additional net benefits. The use of 26.3 CaO-containing blended fertilizers also gave ETB 13,415.84 further net benefits relative to the control (NPS only). Similarly, ETB 29,066.19, additional net benefits were also obtained due to the application of 31.5 CaO-containing blended fertilizers. Those results generally indicated that CaO-containing blended fertilizers could be considered as an alternative source to lime for soil amendment and fertilization.

Table 4. Economic analysis to evaluate CaO-containing blended fertilizers for wheat production.

Treatments	Gross Field Benefit	Total Variable Cost	Net Benefit
NPS	158,573.68	18,396.00	140,177.68
NPS + Lime	175,016.34	23,055.14	151,961.20
17.3CaO	172,324.04	17,415.86	154,908.18
NPS	137,728.17	18,396.00	119,332.17
NPS + Lime	154,994.35	23,055.14	131,939.21

Treatments	Gross Field Benefit	Total Variable Cost	Net Benefit
26.3CaO	150,718.91	17,970.90	132,748.01
NPS	135,290.52	18,396.00	116,894.52
NPS + Lime	151,908.05	23,055.14	128,852.91
31.5CaO	164,206.26	18,245.55	145,960.71

3.3. *Farmers' Perception during Field Days*

Farmer's field day at physiological maturity stage of the crop was organized to evaluate the treatments at field conditions. Those field days were performed in the districts at which demonstrations were conducted to evaluate the performance of the new blended fertilizers. The numbers and compositions of the participant who attended the field days are shown in (Table 5). Participants' perceptions on the new blended fertilizer formulas were collected during field days. Based on the existing physiological performance of the test crops and some yield indicator parameters, farmers evaluated the new blended fertilizers (products) to the same level or somewhat better than the positive control (NPS+lime). They also testified that these CaO-containing blended fertilizers could be used as the best alternative for ameliorating soil acidity and improving wheat productivity in the study area.

IV. Conclusion

The results of the present study demonstrated that the applications of 17.3 CaO and 31.5 CaO-containing blended fertilizers improved the grain yield of wheat in East Gojjam Zone of North western Ethiopia. Similarly, the economic analysis revealed that net benefits improved by 2 and 3% due to the applications of 17.3 CaO and 31.5 CaO blended fertilizers formulas compared to the conventional practice (NPS + Lime). Therefore, the applications of 17.3 CaO and 31.5 CaO-containing blended fertilizers can be used as the best alternatives to lime and recommended for wheat production in the East Gojjam depending on the grain and net benefits improvements provided that the CaO-containing blended fertilizers are supplied to growers as per the prices submitted to EIAR. These conclusions and recommendations were made relying on the agronomic performances of the tested crops and economic analyses only. For a holistic conclusion, it is strongly recommended to investigate the changes induced in the chemical properties of the soils of the demonstration plots after harvesting of the test crops due to the application of particularly the CaO-containing blended fertilizers.

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