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Scaling up of largescale acid soil reclamation through lime technology and improved wheat verities in West Shewa Zone, Ethiopia

By

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Abstract: Acid soils are a major constraint to agricultural productivity in the West Shewa Zone of Oromia Regional State. Restoring soil pH to optimal ranges for agriculture can have a significant impact on yields. The application of agricultural lime is the standard corrective. Lack of farmer awareness, and weak or non-existent lime supply chains, insufficient training, limited participatory on-farm demonstration of technologies given to the farmer and development workers make this a complex problem to address at a large-scale technology that has not reached the intended target efficiently and effectively. To this work of large-scale acid soil reclamation through lime technology, no large-scale farmer trials of lime application have been undertaken in Ethiopia. To overcome these constraints, an Acid soil management research team of Ambo Agricultural Research Center, in collaboration with an integrated wheat project demonstrated proven liming technologies for acid soil management in the west Shewa Zone of the Oromia region using full package technology a large-scale-clustered farm approach. Lime (Calcium carbonate) and improved wheat varieties (wane) were demonstrated. The experimental Sites were selected based on the acid saturation of the soil, farmers' willingness and accessibility for supervision, and input transportation. A total of 182 farmers were targeted in both districts and these farmers were involved in six clusters on 55 hectares of land. The training was given before the implementation of the activity for a total of 24 development Agents (18 male and 6 women) and 16 agricultural experts (12 male and 4 female). Advisory services were continuously given to farmers from land preparation up to harvesting. Inputs including 110-ton lime, and 10-ton wheat seed (Wane variety) were distributed to these beneficiaries. The lime requirement (LR) of the soil was determined based on the EA or acid saturation of the study soil. Improved bread wheat varieties of "Wane" for both districts were planted at the seedling rate of 150 kg/ha. Field days were organized with participants of 50 agricultural experts, 35 Development agents, 48 AmARC workers, and 338 farmers. The maximum grain yield (44.3 qt/ha) was recorded from the limed acid soil of the Bodda Cluster in the Dandi district. However, the overall average grain yields obtained from a hectare of land under limed and unlimed acid soil accounted for 35.73 and 22.73 quintals respectively, which is 57.37% of yield variation due to lime amendment. Based on this productivity per hectare across districts; using lime amendment technology for acid soil had been by far better than unlimed/without any amendments under acidic soil of the study area. Therefore, it is better to strengthen liming technology awareness and should be continued for improving acid soil and productivity of the crop in acid soil areas.

Keywords: Lime; cluster and Amendment

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INTRODUCTION

Soil acidity is a serious agricultural and environmental problem that limits the growth of pasture and crops, and it is often an insidious soil degradation process, developing slowly, although indicators, such as falling yields, leaf discolorations in susceptible plants, lack of response to fertilizers may show that soil pH is falling to critical levels (Angaw and Desta, 1988). The summation of different anthropogenic and natural processes including leaching of exchangeable bases, basic cation uptake by plants, decomposition of organic materials, application of commercial fertilizers, and other farming practices produce acidic soils (Brady and Weil, 2002). Soil acidity is mostly distributed in developing countries, where population growth is fast and demand for food is increasing. It comprises 50% of the world's potentially arable land, and thus, is a significant limitation to crop production worldwide (Uexkull and Muter, 1995). A recent study showed that about 43% of Ethiopian arable land is affected by soil acidity (Ethiosis, 2014). In Ethiopia, vast areas of land in the Western, Southern, Southwestern, and Northwestern and even the central highlands of the country, which receive high rainfall, are thought to be affected by soil acidity (Mesfin, 2007).

Different woredas of West Shewa zone are one such area with very strongly acidic soil. Several agricultural practices have been recommended to overcome soil acidity problems for crop production in West Shewa Zone of Oromia, Ethiopia, and worldwide. Among them, the most common and widely used practice is liming, which is the application of ground calcium and/or magnesium carbonates, hydroxides, and oxides aiming at increasing the soil pH and subsequently, modifying soil chemical and biological properties (Edmeades, 2004). These useful research results have not reached the intended target (goal) efficiently and effectively, because of the lack of transfer of these technologies. And also, in small-scale farming systems on acidic soils, low availability of liming technology, Lack of farmer awareness, weak or non-existent lime supply chains, insufficient training, and limited participatory on-farm demonstration of technologies given to the farmer and development workers make this a complex problem to address at a large scale/this hindered this technology has not reached the intended target efficiently. To overcome these constraints an acid soil management research team of Ambo Agricultural Research Center; in collaboration with an integrated wheat project demonstrated proven liming technologies for acid soil management in different woredas of the West Shewa zone of the Oromia region using full-package technology in a large-scale-clustered farm approach. Hence, this work was designed: To demonstrate acid soil management technologies and management options in comparison with best cultural practices for wheat; to improve farmers' awareness, access, to and adoption of full package production technologies of the wheat crop on acid soils of West Shewa zone, to improve production and productivity of wheat crop in the zone, and also to strengthen research and extension linkage for joint technology dissemination efforts.

Materials and Methods

Description of the study area

The scaling up was executed at different woredas of the west Shewa zone (Dandi, toke kutaye, and Liban jawi woredas) during the 2021-2022 main cropping season. The capital city of West Shewa (Ambo) is located 114 km away from Addis Ababa of the Oromia Regional National State. And Dandi, toke kutaye, and Liban jawi woredas are found at a distance of 30, 11, and 50 km from Ambo town respectively.

Soil Sampling and Analysis before Planting

Prior to planting both undisturbed and disturbed samples were collected. From each cluster, five undisturbed samples were taken by the core sampler. Fresh weight and an oven-dry weight at 105 ^{o}C and used to determine the bulk density (Baruah *et al*., 1997). The disturbed representative composite soil sample was collected from each cluster/the selected site using an auger from a plow layer (0-20cm) of the whole farm cluster before lime application to measure the threshold level of soil acidity and for estimation of the liming rate. The soil samples were air-dried, thoroughly mixed, and ground to pass through a 2 mm sieve for soil pH and Exchangeable acidity analysis followed standard laboratory procedures. The soil pH was determined as a soil water suspension of 1:2.5 (soil: water ratio) using a pH meter, as described by Van Reeuwijk (1992). Exchangeable acidity was determined by saturating the soil samples with potassium chloride solution and titrating them with sodium hydroxide as described by Mclean (1965).

Farmer selection and forming the group of farmers

The Large-Scale Demonstration (LSD) of liming and improved wheat variety was implemented in Oromia Region, West Shewa zone woredas. The site was selected from the study woredas based on the soil exchangeable acidity, soil pH, and potential for the production of wheat crops. Representative kebeles were purposively selected based on the acid saturation of the soil and accessibility for field monitoring and follow-ups. From each Kebele participating farmers were selected based on their interests and the availability of adjacent

farm plots. The selection of farmers and clusters was done in collaboration with researchers, DAs, and woreda and kebele administrators. A total of **182** farmers of these (149 male and 33 female) were selected from the selected kebeles and clusters were formed as shown in (figure 1)

Fig 1. Picture captured during Site Selection with a multidisciplinary research team

Advisory Service

Prior to the actual implementation of the activities, the advisory was given to farmers, development agents (DAs), and woreda experts on the production and management techniques of wheat (land preparation, planting, weeding, disease, and other pest management) and acid soil management techniques. Generally, advisory services were continuously given from the land preparation up to harvesting and threshing.

Lime and wheat seed/Input supply

The recommended amount of lime was delivered to hosting farmers in the cluster. The wheat seed (wane) variety was also delivered free of charge hosting farmers in the cluster. All farm plots in the cluster were measured and the amount of input required for each cluster was determined.

Lime applications and incorporations with soil

The amounts of lime applied were determined based on the exchangeable acidity, mass per 0.15m furrow slice, and bulk density of the soil (Shoemaker *et al*., 1961; Van Lierop, 1983), considering the amount of lime needed to neutralize the acid content (Al + H) of the soil up to the permissible acid saturation level for wheat growth.

$$LR, \frac{CaCo3kg}{ha} = Cmol\frac{EA}{Kg}of\ soil * 0.15m * 10,000m^2 * BD\left(\frac{g}{cm^3}\right) * 1000 * crop\ factor$$

=1633 kg/ha

2000

Where: BD = bulk density, EA = exchangeable acidity (exch. H+ + Al3+), LR= lime requirements, 0.15m= plow depth/depth of lime incorporation. Crop factor = 1.5. note: the average value of exchangeable acidity was taken for each cluster, BD=1.3g/cm^3, 2000 = to convert exchangeable acidity per kg of soil to per hectare

Sowing/planting of wheat seed

Improved bread wheat varieties of wane for all selected districts were planted in rows at a rate of 150 kg/ha. The variety was selected based on its suitability to the agroecology of the study area, yield potential, disease resistance (wheat leaf rust) and etc. All farm operations land preparation, planting, weeding, chemical spray, harvesting, and threshing were carried out by the participating farmers with close supervision of researchers and district-level agricultural experts. The overall agronomic practices have been implemented as per the recommendation for wheat

Fig 2. Lime applications and incorporation with soil

Fig 3. Pictures captured during the sowing of wheat at Dandi and Liban Jawi district

Data Collection & Analysis

Both quantitative and qualitative types of data were gathered. Quantitative data were collected on grain yield using the quadrant technique (1meter x 1meter) on evenly spaced spots per site to check the comparative advantage of lime treated against lime untreated (adjacent plot), a number of participants in field days and beneficiary farmers on liming technology demonstration by sex disaggregation. On the other hand, qualitative data were collected on farmers' opinions, perceptions, and feedback on lime-demonstrated technology in comparison with lime-untreated adjacent plots.

RESULT AND DISCUSSION

Cluster Formation Size, number, and Participants

A total of 182 farmers (149 male and 33 female) were selected from both districts (Table 1). During the 2021 cropping season, two clusters were formed, and during the second year (2022) of large-scale demonstration (LSD), four clusters (two clusters from Toke Kutaye, one cluster from Dandi, and one cluster from Liban Jawi districts) were organized according to the land continuity of farmers. In each study district, an average of 5-10 hectares of land were covered per cluster and a total of six clusters were formed during two cropping seasons (Table 1)

Table 1: Technology beneficiaries and total cluster size

Year	No clusters formed	Location	Cluster size(ha)	No of farmers' Beneficiaries(participants)		Sub-total
				Male	Female	
2021	2	Toke kutaye and Liban jawi	30	102	22	124
2022	4	Toke kutaye, dandi and Liban jawi	25	47	11	58
Total	6		55	149	33	**182**

Training/Capacity Building

Training on the contents of acid soil formation, its impact, and management, and also on wheat production; agronomic practices, disease, and pest management, as well as clustering approaches, have been given by different multidisciplinary researchers from Ambo Agricultural Research Center. From each Selected district, we took one-day training for woreda and zone agricultural experts and DAs. The training was provided before planting. This training has been given to 24 development agents (18 male and 6 women) and 16 agricultural experts (12 male and 4 women) (Table below). Due to security problems at the time, for the farmer's only orientation and Advisory service was given at their cluster farm site

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Table 2: Training and number of participants in acid soil management/ Lime technologies

Participants	2022		Total
	Male	Female	
Farmers	Only orientation and Advisory service were given due to security problems		
Development Agents	18	6	24
Woreda Experts	12	4	16
Total	**30**	**10**	**40**

Input Distribution

Except for fertilizer and pesticides, both inputs (seed and lime) were provided by Ambo Agricultural research center integrated wheat project. Totally, 100 qt of wheat seed and 1100qt of agricultural lime (calcium carbonates) were distributed for participated farmers for two cropping seasons (Table 3).

Table 3: Inputs (lime and wheat seed) distributed for large-scale demonstration

Locations (Districts)	Input Type			
	Lime (ton)		Wheat Seed (ton)	
	2021	2022	2021	2022
Dandi	-	20	-	2.0
Liban jawi	30	11.10	2.5	1.0
Toke kutaye	30	20	2.5	2.0
Sub Total	**60**	**51.0**	**5.0**	**5.0**
Total	**111**		**10**	

Evaluation of work and Experience sharing

Continuous follow-up and evaluation of activities were done by all stakeholders throughout the implementation processes of the activities. A core team composed of members from all the concerned stakeholders (Researchers, agricultural experts, DAs, and farmers) were organized and the team jointly monitor, supervise, and evaluate the implementation process and status of wheat every four weeks.

Fig.4: Joint team of researchers and woreda experts monitored, supervised, and evaluated the implementation process and status of wheat at Dandi Woreda during the 2014 cropping season

Field day

Finally, a field day was organized in selected clusters to evaluate the overall successes, challenges, and opportunities of the intervention, share experiences, and lessons obtained in other similar areas, and propose future directions. All concerned stakeholders, including farmers from participating and non-participating woredas of the Zone, take part in the field day. A total of 338 farmers and 131 other stakeholders have participated (Table 4). Several discussions were conducted at the demonstration site. During the field day farmers and other stakeholders evaluated the lime and improved wheat technology and give different feedback and comments. They evaluated the lime and improved wheat technology based on the stands of uniformity, spike length, and overall performance of the crops.

Table 4: Field Day participants on large-scale demonstration of lime technology and improved wheat production in Dandi and Liban jawi Districts for 2022 main cropping season

Participants	Number of Participants				Sub-total		Total
	Dandi district		Liban jawi district				
	Male	Female	Male	Female	Male	Female	
Farmers	165	15	147	11	312	26	338
Woreda & zonal agricultural experts	7	4	26	13	33	17	50
Development Agents (DAs)	6	4	16	9	22	13	35
Ambo Agricultural Research Center Workers	31	8	4	-	35	8	43
Other distinguished Guests	5	0	-	-	5	-	5
Total	214	31	193	33	407	64	471

Fig. Photos taken during field visits and recognition given after field day

Farmer's Perception During Discussion on Field Days

After field visits with different stakeholders' discussions were made and feedback was collected from farmers. All participants of the field day appreciated the large-scale demonstration of liming technology and improved wheat production following merits; perceived better performance, longer spike length, better resistance to disease (especially leaf rust), and perceived better seed weight than unlimed one. Even some farmers raise the number of seed per spike for limed soil condition and unlimed is far apart from each other, they positively witnessed for the combined effect of the technologies (liming and improved wheat variety) in wheat production. Some farmers also had complained on application of lime (large quantity), its effect on their eye during applications and also comment on the transportation of lime from main road to their farm land. The reason is directly related to labor. In all farmers witnessed use of liming technologies in acid soil what they call "biyyoo diimilee" in Afan Oromo was better performed than their previous without liming/adjacent plot which was lime untreated.

Fig. Photos taken during the discussion and ceremony after a field visit

Yield performance/productivity of wheat as a result of using liming under acid soil

The yield data were collected from each cluster of both Districts (Dandi, Liban Jawi, and Toke Kutaye). Accordingly, the mean grain yield of improved wheat integrated with lime demonstrated at Dandi, Liban jawi and Toke Kutaye were 44.3 $q \cdot ha^{-1}$, 33.6 $q \cdot ha^{-1}$, and 29.4 $q \cdot ha^{-1}$ respectively (Table.5). However, the mean grain yield of wheat under unlimed acid soil demonstrated at

Dandi, Liban jawi and Toke Kutaye were 26.6 q·ha^{-1}, 21.2 q·ha^{-1}, and 20.4 q·ha^{-1} respectively. The total mean yield under limed and unlimed was 35.76 q·ha^{-1} and 22.73 q·ha^{-1} respectively. This was 57.32% higher than the farmer unlimed (22.73 q·ha^{-1}). This difference is due to the liming amendment might improve the ability of the plant to absorb P when Al toxicity has been eliminated and the application of the recommended agronomic practices and field management. From these results, it is evident that the performance of wheat was found better under limed acid soil than in the unlimed acid soil of the study areas. The result also suggests the positive effects of liming technology demonstrations over the existing farmer's practice/without any acid soil amendment towards enhancing the yield of wheat with its positive effect on yield attributes. This result clearly indicated that farmers practices (without application of acid soil amendments) of grain yield performance were by far lower as compared to grain yield obtained by large scale liming technology demonstration. Hence, large scale demonstration of liming technology should be more emphasized in the acid soil areas of regions in the country .

Table.5: Average grain yield gained from large scale demonstration of liming technology with improved wheat in Dandi, Liban Jawi and Toke Kutaye district during 2022 main season

District	Kebele/cluster	Seed varieties	Average grain yield(qt/ha)
Dandi	Bodda	Wane	44.3
Liban Jawi	Liban Gamo	Wane	33.6
Toke Kutaye	Colba	Wane	29.4

CONCLUSIONS AND RECOMMENDATIONS

Cluster-based large-scale demonstration of lime technology and improved wheat verities was carried out on 55 ha of acidic farmland by 182 farmers in Liban Jawi, Toke kutaye, and Dandi Woredas. Though the yield performance of the limed acidic soil in these districts was better than the unlimed acidic soil (farmers' practices). Generally, it can ensure the sustainability of liming technology in acidic soil for improved wheat production agroecology in the country if more attention and a strong extension system were given. Moreover, the participant farmers of the activity liked the lime and improved wheat technologies in acidic soil areas for its high yield, high seed/spike, good plant height, good crop stand, and seed size. Also, they appreciated unproductive farm field was changed to productive ones after being treated with lime. However, there are still claims by farmers on the manual application methods of lime in large quantities on large areas of farms and transportation of lime from the main road to farmers' farm fields. As there is wide acidic farmland that has high potential production capacity if treated with agricultural lime, large-scale demonstration of lime and improved wheat variety, and wider scaling up activities need to be strengthened/ it is better to strengthen current liming technology awareness and should be continued for improving the productivity of the crop in a sustainable manner.

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