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Response of Food Barley and Bread Wheat to the Application of Lime, in Organic and Organic Fertilizer on Acidic Nitisols of West Shewa Zone, Ethiopia

Tolossa Ameyu[1*]
[1]Ethiopian Institute of Agricultural Research; Ambo Agricultural Research Center, P.O. Box 37, Ambo, Ethiopia

Abstract: Acidic soils limit the production potential of crops because of low availability of basic cations and excess of hydrogen (H+) and aluminium (Al3+) in exchangeable forms. Lime and Organic amendments can contribute to correct soil acidity and soil degradation. The combined application of lime and VC onwheat has not been investigated in the area, in which wheat and barley was one of the potential cereal crops in the area. A field experiment was conducted on acidic nitisols of west shewa zone of two districts (Jibat and Ilfata) in two locations at 2020 cropping season to evaluate the role of integrated soil acidity management, including applications of lime and Vermicompost on food barley and wheat growth and grain yield integrated with the use of inorganic fertilizer alone. The treatments were arranged in a randomized complete block design. Growth, yield and yield components result showed a significant effect ($p<0.05$) on plant height, spike length, number of seed per plant, above ground biomass of wheat and barley. Most of treatment receive amendments were statistically equal, however the combined application of lime at 50% + 50% VC and 50% RSSF ha-1 gave the highest growth and other yield and yield components parameters equally with full dose application whereas the lowest was from control plots for both test crops. Generally, integrated use of properly managed lime, organic (VC) and inorganic/mineral fertilizer could be used for soil acidity management and crop production in acid soil of the study area.

Keywords: Food barley, Bread wheat, Lime, Vermicompost, inorganic fertilizer and Soil acidity.

Research Paper

***Corresponding Author:**
Tolossa Ameyu
Ethiopian Institute of Agricultural Research; Ambo Agricultural Research Center, P.O. Box 37, Ambo, Ethiopia

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INTRODUCTION

Soil acidity considerably limits agricultural productivity (Agegnehu *et al*., 2014). In the central and southwestern Ethiopian highlands, wheat, maize, faba bean, barley and teff are commonly planted (Haile and Boke, 2011). But productivity is declining because of soil acidity-induced fertility problems (Agegnehu *et al*., 2014). Based on the problem that soil acidity causes on a larger area in Ethiopia, it needs due attention to be addressed by different coping mechanisms. The productivity of crops in acid soils with Al toxicity and low soil availability of P may be improved by use of lime, fertilizers with liming effects, and/or organic materials. Soil acidity can also be managed with mineral fertilizers, lime, compost and manure, used as acid soil management elements (Abate *et al*., 2013). Agegnehu *et al*., (2014) and Chimdi *et al*., (2012) also identified that in Ethiopia particularly, liming and applying organic fertilizers are commonly accepted strategies. The addition of organic residues to acid soils is potentially an attainable low-input strategy for raising soil pH, decreasing concentrations of phytotoxic Al and decreasing lime requirements (Abate *et al*., 2013).

Studies have found that the application of lime increases soil pH and can improve crop yields (Agegnehu *et al*. 2014). Abate *et al*., (2013) also found that lime application rate reduces exchangeable acidity and available micronutrients but increases cation exchange capacity, soil organic matter and available phosphorus. Organic fertilizer application has been reported to improve crop growth by supplying plant nutrients as well as improving soil physical, chemical, and biological properties (Mengesha D, Mekonnen L., 2012). Vermicompost (VC) is one of the stabilized; finely divided organic fertilizers with a low C: N ratio, high porosity, and high water-holding capacity, in which

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most nutrients are present in forms that are readily available for plants (Arancon N., *et al*., 2004).

Current trends in agriculture are centered on reducing the use of inorganic fertilizers by bio-fertilizers such as VC (Haj M, *et al.*, 2013). There is good evidence that Vermicompost (VC) application promotes growth of plants and positive effect on growth and productivity of cereals and legumes (Glenda S *et al*., 2009). When itis compared with conventional compost, Vermicompost (VC) promotes growth from 50 to 100% over conventional compost and from 30 to 40% over chemical fertilizers (Sinha R, *et al*., 2010). The combined application of lime and organic materials could be an alternative for controlling soil acidity with reasonable cost for sustainable crop production in low input agriculture. Hence, the objective of this study was to evaluate the role of integrated soil acidity management, including applications of lime and Vermicompost on food barley and bread wheat growth and grain yield integrated with the use of inorganic fertilizer.

MATERIAL AND METHODS

Description of the Study Site

The field experiments were conducted in West Shewa Zone of two District in two locations at Ilfata and Jibat woredas on farmer's field based on a contractual agreement with respective farmers for the cropping season, in the central highland of Ethiopia. The first experimental sites (Ilfata) were located at 9° 74′ 83″ N latitude and 37° 74′ 33″ E longitude with an altitude of 2963 m.a.s.l. and the second experimental site (Jibat) at 8° 09′ 63″ N latitude and 37.5° 9′ 49″ E longitude with an altitude of 2467 m.a.s.l, respectively. The predominant soil type is Nitisol, which is dark red brown, and characterized by very strong to moderately acidic soil, and low soil P, specifically around experimental sites.

Distribution of Soil Acidity in the Study Districts

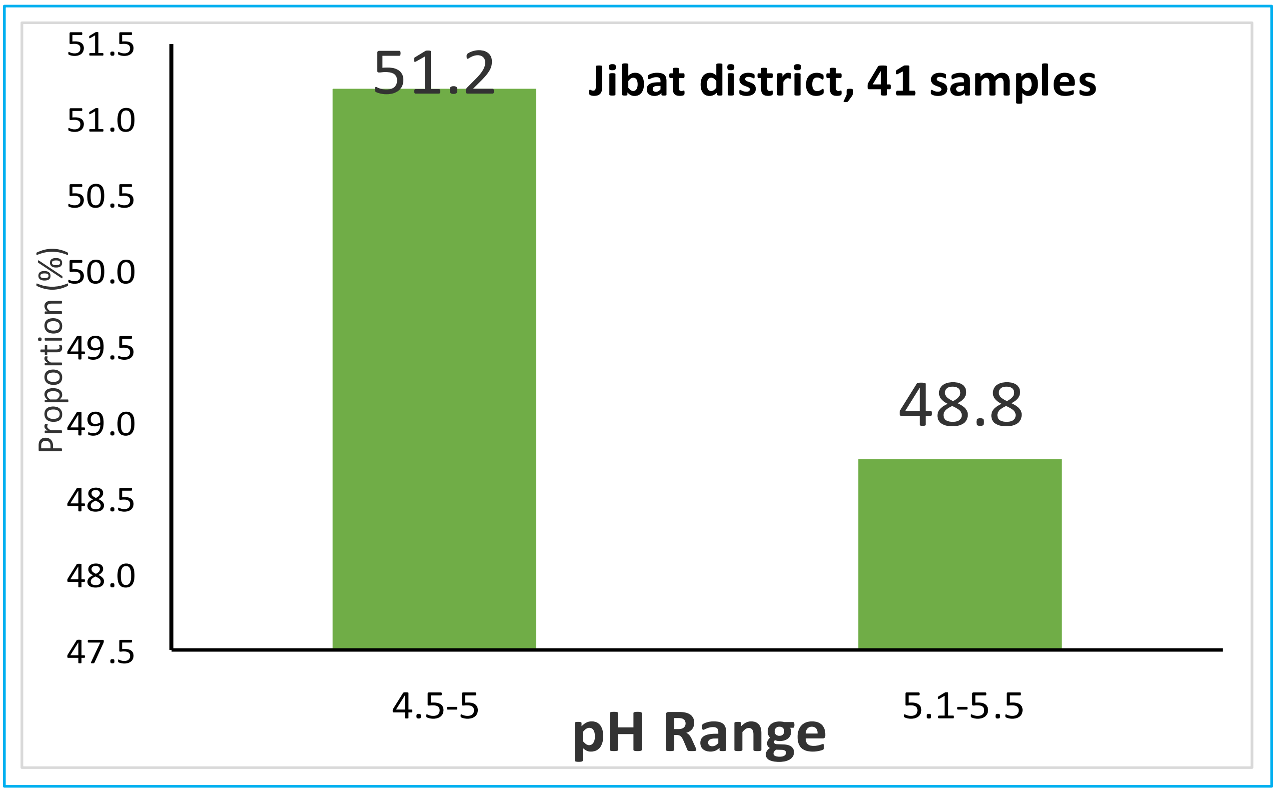

Fig. 1: Level of soil acidity based on soil pH at Jibat district of the study area

In the study area soil acidity is apparently increasing both in area coverage and the severity of the problem. The acidity status of Ilfata districts of the study area indicates that more than the maximum soil exchangeable acidity is 5.79 cmol which indicates that the land is highly affected by soil acidity (Figure below).

According to the below figure and sample size about the soil pH of the study area is mostly below 4.6 and it shows that cultivated land is affected by soil acidity.

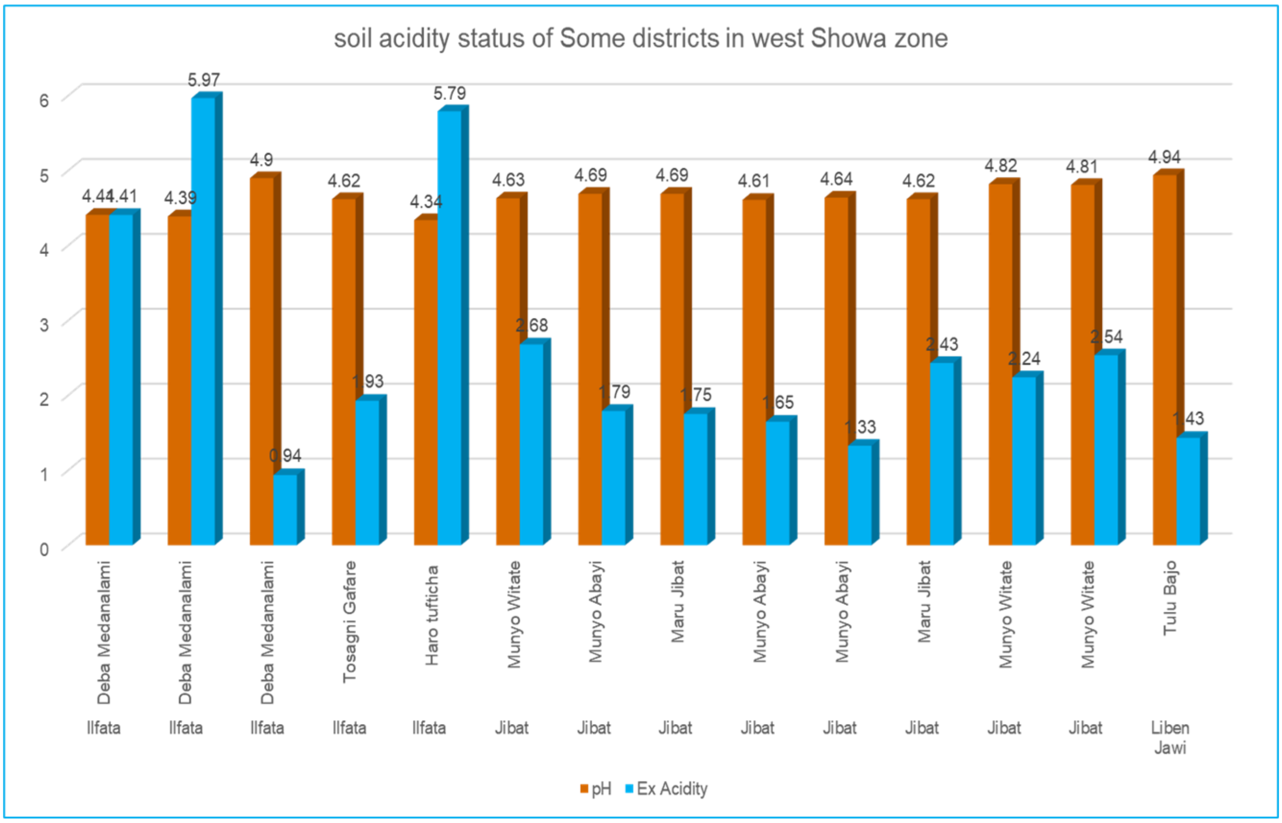

Fig. 2: Distribution of soil acidity in Jibat and Ilfata District of the study site based on soil exchangeable acidity and pH of collected soil sample

Soil Sampling, Preparation, and Analysis before Planting

Prior to the field experimentation both undisturbed and disturbed samples were collected. Three undisturbed samples were taken by the core sampler. Fresh weight and an oven-dry weight at 105 ºC and used to determine the bulk density (Baruah *et al*., 1997). A representative composite soil sample was collected from the selected site using an auger from a plow layer (0-20cm) of the whole experimental field before treatment 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, and the analysis for soil Exchangeable acidity followed standard laboratory procedures. The disturbed composite soil samples were analyzed for particle size distribution (soil texture), which was done by the Bouyoucos hydrometer method as described by Bouyoucos (1962) are among the physical soil parameters, while soil exchangeable acidity for soil chemical analysis were selected. Exchangeable acidity was determined by saturating the soil samples with potassium chloride solution and titrating with sodium hydroxide as described by Mclean (1965).

Treatments, Experimental Design and Procedures

The treatments comprised of different factors namely; three lime level, three vermicompost level and three level of in organic fertilizers and totally fourteen (14) treatments were tested including the control. The treatments were laid out in complete randomized block design by systematic combination with three replications. The lime requirement (LR) of the soil for the plots was determined based on EA or acid saturation of the experimental soil. Calcium carbonate was used as the source of lime and the whole doses of lime of the respective plot treatment were broadcasted uniformly by hand and mixed in the top 15 cm soil layer, a month before sowing, to mix lime with soil properly. The planting materials used in the experiment was a recently released variety of wane variety for wheat and HB: 1307 improved barley cultivar was used during the study and sown by seeding at a seed rate of 125 and 150 kg/ha for barley and wheat respectively, and the row spacing was 20 cm and the plot size was 3 × 4 m for both test cops.

Data collection

Plant Height (cm)

To evaluate the effect of the treatments on crop development, five plants per plot were randomly selected before harvest and their heights were measured using a tape measure and the mean height of the five plants was recorded as plant height in cm

Spike length (cm)

To evaluate the effect of the treatments, five plants per plot were randomly selected before harvest and their spike length was measured using a tape measure the mean length of the five plants' spikes was recorded as spike length in cm

Above-Ground Dry-Biomass (kg ha^{-1})

The total above-ground biomass of the middle five rows of the net plot area was determined by harvesting close to the soil surface at physiological maturity by sun-drying to gain a constant weight. Finally, the biomass yield of the selected middle five rows was converted to per hectare and expressed in kg/ ha.

The Number of Seeds per Spike

Was counted from five randomly selected plants from five middle rows at harvest maturity and expressed as an average of each plant.

Grain Yield (kg/ha)

Was measured by harvesting the crop from the net plot area of the middle five rows. The moisture content of the grain was adjusted to 12.5% and then the weight was converted to kg ha^{-}1.

Total Number of Tillers per Plant

During harvesting random, selected sample plants were uprooted and the number of tillers which was raised from single plants were counted, whether productive or not and the average values were taken for each plot.

Productive Tiller

Number of effective tillers per plant is the same as total number of tillers per plant except that it considers only tillers which set grain or with effective spike.

Thousand Seed weight (TSW)

This was measured by using seed counter and TSW measuring device. Collected grain sample from each experimental plot was determined for their TSW result found from the measuring device.

Statistical Analysis

The data was subjected to analysis of variance (ANOVA) using Statistical Analysis System (SAS Institute, 2012) 9.3 Version software using proc GLM procedure. Results were presented as means with the least significance difference (LSD) at the $P < 0.05$ probability level to separate significantly differing treatment means after treatment effects were found significant.

RESULTS AND DISCUSSION

Except for grain yield, plant height, and aboveground dry biomass there were no significant differences ($p \leq 0.05$) among treatments (Table 1).

Table 1: Mean squares of treatments and error for different trait of food barley at Ilfata site

Parameter	Error mean square	Treatment mean square
Plant height(cm)	22.24	58.60*
Spike length(cm)	0.365	0.69ns
Total tiller	0.385	0.26ns
Productive tiller	0.354	0.32ns
Number of spikelet/spikes	0.588	1.07ns
Number of seed/spikes	15.25	7.72ns
Dry biomass(kg/ha)	1949038.2	6436944.64**
Grain yield(kg/ha)	739395.93	2292843.40**
Thousand seed weight	13.55	7.82ns
Harvest index	1949038.2	24.68ns

Plant Height of Food Barley and Wheat Affected by Integrated Acid Soil Amendment

From the analysis of variance showed there was a significant difference (P=0.05) for plant height. Application of integrated soil acidity management, including applications of lime, inorganic fertilizer and Vermicompost showed significant ($P<0.05$) influences on plant height.

At Ilfata site the highest mean value of barley height (110.73 cm) was obtained from 100% (lime+NP+VC) treatment followed by 50% (lime, + VC) +100%NP with 107.26cm, 100% NP with 106.6cm, 100% (lime + NP) with 106.5cm, 100% (VC + NP) with 106.46cm, 100% lime +50%VC+50%NP with 106.26cm and, 100% (VC + lime) with 104.33 cm respectively, which was statistically at the same performance with the highest one (Table 2). This shows that all amendment used in this experiment reduced acid soil concentration and improve plant growth.

Similarly for wheat at Jibat Site the highest mean value of wheat height (68cm) was also obtained from 50% (lime + VC) +100%NP treatment which is statistically at par with 100% lime +50%VC+50%NP, 100% (lime+NP+VC), 100% (lime + NP), 100% (VC + NP), 50% (lime + NP), 50% (Lime + VC), and100% (VC + lime) treatments (Table 4). Application of these amendment have greatly contributed for the improvement of food barley and bread wheat growth (plant height). This growth because benefited either from combined application of lime, Vermicompost and inorganic fertilizer or independent applications of the amendments compared to control. Similar results were reported by Getahun Bore and Bobe Bedadi, 2016, that lime and inorganic fertilizer application contributed to wheat growth parameters.

Table 2: Plant height, spike length, above ground dry biomass and Total tiller of barley as affected by integrated use of lime, Vermicompost and inorganic fertilizer at Ilfata site during 2020

Treatment number	Treatment	Plant height(cm)	Spike length (cm)	Dry Biomass(kg/ha)	Total Tiller
11	100%(lime+NP+VC)	110.73a	6.067	9926a	4.07
14	50% (lime, + VC) +100%NP	107.26ab	5.70	8319abc	3.87
4	100% NP	106.6ab	5.53	8722abc	4.20
6	100% (lime + NP)	106.5ab	6.0	9704ab	3.87
7	100% (VC + NP)	106.46ab	6.0	10296a	4.33
12	100% lime +50%VC+50%NP	106.26ab	6.067	8111abcd	4.53
5	100% (VC + lime)	104.33abc	5.73	8815abc	4.07
9	50% (Lime + VC)	102.33bcd	5.87	7037cde	4.20
3	100% lime only	101.33bcd	5.60	7556bcd	4.40
8	50% (lime + NP)	101.20bcd	5.87	7370bcde	3.87
13	50% (lime + VC + NP)	99.86bcd	5.67	8481abc	3.67
10	50% (VC + NP)	99.73bcd	5.40	7222cde	3.80
2	100%VC only	96.53cd	4.73	5889de	3.53
1	Control (no input)	95.40d	4.47	5185e	4.33
CV (%)		4.57	10.74	17.35	15.31
LSD		7.91	NS	2343.1	NS
Mean		103.18	5.62	8045.23	4.05

CV= Co-efficient of variation; LSD= List significant different; Means with the same letters are statistically not significant ($p > 0.05$) different from each other.

Lime, inorganic and organic (VC) fertilizer additions showed a significant ($p<0.05$) effect on number of seed per spike, bio-mass and grain yields of barley and wheat (Table below). But the Harvest index, seed weight and spike length were not significantly ($p>0.05$) affected by sole and combined treatments at both locations for two test crops. At Ilfata site the highest barley grain yield (5590.3 kg/ha) was obtained from the application of 100% (VC + NP) followed by 100% lime+100% NP+100% VC which is 5238.1kg/ha which was statistically at par with 100% NP, 100% (lime + NP), 100% lime +50%VC+50%NP, and 50% (lime, + VC) +100%NP treatments.

The combined application of lime, Organic and in organic fertilizer increase yields because it reduces exchangeable acidity and increases soil pH and fertility (Onwonga *et al.*, 2010). Crop productivity of marginal fertile acidic soil can be improved through integrated use of soil amendment. The yield of bread wheat increased with increased application of lime and organic fertilizer (Geremew Taye *et al*., 2020, Mesfin Kuma *et al.*, 2022). In general, the yield high in those treated with integrated lime, vermicompost and inorganic fertilizer than in separate and control (untreated) in acid soils as shown in (Table 3, 5 and7).

Table 3: Grain yield and other yield parameter of barley as affected by integrated use of lime, Vermicompost and inorganic fertilizer at Ilfata site during 2020

Treatment number	Treatment	Grain yield	Number of seed/spikes	Thousand seed weight	Harvest index
11	100%(lime+NP+VC)	5238.1ab	41.87	47.0	52.60
14	50% (lime, + VC) +100%NP	4239.6abc	40.33	45.0	51.02
4	100% NP	4831.9abc	42.6	45.0	54.97
6	100% (lime + NP)	4826.5abc	41.33	45.0	49.66
7	100% (VC + NP)	5590.3a	41.20	46.33	54.16
12	100% lime +50%VC+50%NP	4255.4abc	40.80	45.33	52.62
5	100% (VC + lime)	3926.8bcd	39.53	44.67	44.77
9	50% (Lime + VC)	3511.2cd	40.47	43.33	48.03
3	100% lime only	3577.4cd	36.53	45.33	47.32
8	50% (lime + NP)	3733.3cd	39.33	42.33	49.90
13	50% (lime + VC + NP)	4394.7abc	40.13	43.67	51.92
10	50% (VC + NP)	3594.8cd	39.0	44.67	48.52
2	100%VC only	2725.2d	37.73	45.33	47.46
1	Control (no input)	2581.5d	39.53	40.67	50.47
CV (%)		21.11	9.75	8.26	9.86
LSD		1443.2	NS	NS	NS
Mean		4073.32	40.02	44.54	50.24

CV= Co-efficient of variation; LSD= List significant different; Means with the same letters are statistically not significant ($p > 0.05$) different from each other.

Table 4: plant height, spike length and above ground dry biomass of barley as affected by integrated use of lime, Vermicompost and inorganic fertilizer at Jibat site during 2020

Treatment number	Treatments	PHT	SL	DBM
14	50% (lime, + VC) +100%NP	107.27ab	5.70	7.55cd
12	100% lime +50%VC+50%NP	106.27ab	6.07	8.11bcd
11	100%(lime+NP+VC)	110.73a	6.07	8.87ab
6	100% (lime + NP)	106.53ab	6.00	6.92de
7	100% (VC + NP)	106.47ab	6.00	9.03ab
8	50% (lime + NP)	101.20bcd	5.87	7.37cd
9	50% (Lime + VC)	102.33bcd	5.87	7.03de
5	100% (VC + lime)	104.33abc	5.73	7.77bcd
13	50% (lime + VC + NP)	99.87bcd	5.67	5.89ef
3	100% lime only	101.33bcd	5.60	9.41a
1	Control (no input)	95.40d	4.47	5.63f
4	100% NP	106.60ab	5.53	8.44abc
10	50% (VC + NP)	99.73bcd	5.40	7.22cd
2	100%VC only	96.53cd	4.73	5.89ef
CV		4.57	10.74	10.15
LSD		7.91	NS	1.28
MEAN		103.18	5.62	7.51

CV= Co-efficient of variation; LSD= List significant different; SL=Spike length; DBM= Dry biomass; PHT= Plant height; Means with the same letters are statistically not significant ($p > 0.05$) different from each other.

For both test crops at all site yields, Above ground dry biomass and plant height was greater with all combined lime, organic and mineral fertilizer than sole applications of either vermicompost or lime or inorganic/mineral fertilizer. The highest Dry biomass (9926 kg ha^{-1}) and (9.17a kg ha^{-1}) of food barley at Ilfata site and wheat were obtained from the application of 100% lime+100% NP+100% VC respectively. Compared to application of full dose of lime, organic and inorganic fertilizer, statistically similar dry biomass (8481abc kg ha^{-1}) and (6.9a-d ton ha^{-1}) were obtained from the application of 50% (lime + VC + NP) for food barley and wheat respectively. This implied that the integrated use of lime, organic and inorganic/mineral fertilizers resulted in yield benefits greater than using them alone. Similar results were also reported on barley (Agegnehu *et al*., 2016a) and wheat (Demelash *et al*., 2014). The improved yields of food barley and wheat due to combined application of lime, organic and inorganic/ mineral amendments resulted from positive changes to the soil, including increased soil pH, available P and total N, and possibly other macro- and micronutrients. The lowest yield and yield components were obtained from the control treatment.

Table 5: Grain yield and other yield parameter of barley as affected by integrated use of lime, Vermicompost and inorganic fertilizer at Jibat site during 2020

Treatment number	Treatments	GY	TT	PT	NSPS
14	50% (lime, + VC) +100%NP	3153.1bc	3.87	3.73	40.33
12	100% lime +50%VC+50%NP	3833ab	4.53	4.40	40.80
11	100%(lime+NP+VC)	4118.1a	4.07	4.00	41.87
6	100% (lime + NP)	3100c	3.87	3.73	41.33
7	100% (VC + NP)	4205.6a	4.33	4.20	41.20
8	50% (lime + NP)	2925.7c	3.87	3.67	39.33
9	50% (Lime + VC)	2750.6c	4.20	4.13	40.47
5	100% (VC + lime)	3910.8a	4.07	4.00	39.53
13	50% (lime + VC + NP)	2523.7c	3.67	3.40	40.13
3	100% lime only	3785.9ab	4.40	4.27	36.53
1	Control (no input)	2690.2c	4.33	4.27	39.53
4	100% NP	3804.3ab	4.20	4.13	42.60
10	50% (VC + NP)	2832c	3.80	3.67	39.00
2	100%VC only	2640.2c	3.53	3.40	37.73
CV		12.31	15.31	15.16	9.75
LSD		683.15	NS	NS	NS
MEAN		3305.22	4.05	3.92	40.02

CV= Co-efficient of variation; LSD= List significant different; Means with the same letters are statistically not significant ($p > 0.05$) different from each other.

Similar to barley, wheat plant height was significantly (P< 0.05) influenced by the integrated application of lime, VC, and inorganic fertilizer either alone or combined compared to the control (Table 6). The maximum (68 cm) plant height was recorded from the application of 50% (lime, + VC) +100%NP while the minimum plant height was recorded from control.

Table 6: Wheat growth parameter (PHT) and Dry biomass response to applied treatments at Jibat during 2020.

Treatment number	Treatments	PHT	DBM	PT	NSPS
14	50% (lime, + VC) +100%NP	68a	8.95a	3.13	41.40
12	100% lime +50%VC+50%NP	66.87ab	8.44ab	3.47	41.07
11	100%(lime+NP+VC)	66.33abc	9.17a	3.93	43.20
6	100% (lime + NP)	64.73abc	7.76abc	3.60	43.53
7	100% (VC + NP)	64.27abc	8.97a	3.33	43.33
8	50% (lime + NP)	63.47abc	6.87a-d	3.53	37.07
9	50% (Lime + VC)	63.27abc	7.16a-d	3.47	39.40
5	100% (VC + lime)	61.67abc	6.73a-d	3.87	43.07
13	50% (lime + VC + NP)	61.13bcd	6.9a-d	3.53	41.47
3	100% lime only	60.8bcd	5.9b-e	3.33	32.73
1	Control (no input)	60.07cd	4.33de	3.27	30.27
4	100% NP	59.93cd	6.39a-d	3.60	41.20
10	50% (VC + NP)	59.67cd	4.97c-e	3.40	32.67
2	100%VC only	54.87d	3.21e	3.33	34.53
CV		6.45	26.38	18.23	17.29
LSD		6.7679	3.0293	NS	NS
MEAN		62.50	6.84	3.48	38.92

CV= Co-efficient of variation; LSD= List significant different; Means with the same letters are statistically not significant (p > 0.05) different from each other.

Table 7: Wheat yield and yield parameter response to applied treatments at Jibat during 2020.

Treatment number	Treatments	SL	GY	TT	NSPS
14	50% (lime, + VC) +100%NP	6.4a	3714.3a	3.13	41.40
12	100% lime +50%VC+50%NP	5.8abc	3349.2abc	3.60	41.07
11	100%(lime+NP+VC)	6ab	3690.5a	4.07	43.20
6	100% (lime + NP)	5.2bcd	3039.7bcd	3.67	43.53
7	100% (VC + NP)	5.67abc	3547.6ab	3.33	43.33
8	50% (lime + NP)	5.07cde	2674.6d	3.80	37.07
9	50% (Lime + VC)	6ab	2833.3cd	3.53	39.40
5	100% (VC + lime)	5.33bcd	2515.9d	3.93	43.07
13	50% (lime + VC + NP)	5.47bc	2682.5d	3.53	41.47
3	100% lime only	5.03cde	1595.2e	3.40	32.73
1	Control (no input)	5.27bcd	1595.2e	3.33	30.27
4	100% NP	5.13cd	3047.6bcd	3.60	41.20
10	50% (VC + NP)	4.53de	1857.1e	3.40	32.67
2	100%VC only	4.3e	1452.4e	3.60	34.53
	CV	9.13	13.11	16.78	17.29
	LSD	0.8236	590.8	NS	NS
	MEAN	5.37	2685.37	3.56	38.92

CV= Co-efficient of variation; LSD= List significant different; Means with the same letters are statistically not significant (p > 0.05) different from each other.

Conflict of Interest: Author declares that there are no conflicts of interest.

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CONCLUSION AND RECOMMENDATION

Results of the study showed that productivity of food barley and wheat could be more sustainable with integration of lime, organic amendments and inorganic/mineral fertilizers than with the use of either lime or organic amendments or mineral fertilizers alone. Therefore, farmers of the study area and other similar agroecologies are advised to apply 50% of recommended lime + 50% recommended (VC) + 50% recommended inorganic fertilizer for optimum wheat and barley production. To counteract the decline in soil fertility on the one hand, to decrease soil acidity and to cope with the increasing price of the imported mineral fertilizers on the other hand, the integrated use of lime, organic and mineral fertilizers is found to be very important. However, to draw a conclusive recommendation, the study has to be repeated over several seasons as lime and vermicompost have long-term effects on improving soil properties.

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