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Original Article

Impact of soil amendments and fertilizers on maize (*Zea mays* L.) growth and yield and on physical, chemical, and biological soil properties

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Abstract

The impact of seven treatments; control (no lime and fertilizer), Ultragreen, Calcium carbonate powder ($CaCO_3$), Ultragreen + NPK (15-15-15), $CaCO_3$ + NPK, Ultragreen + Chemical and granular organic fertilizer with hormone mixed formula (HO) and $CaCO_3$ + HO were investigated on the physicochemical and biological properties of an acidic soil, as well and maize growth and yield in a two years experiment (2017-2018) at Phitsanulok province, Thailand. The results showed that the highest average plant height (272.50 cm) was produced by Ultragreen + NPK, while leaf area at flowering and total dry matter weight (273.15 dm^2 and 277.40 g, respectively) were produced by Ultragreen + HO treatment. Cob weight/plant (429.25 g), grain number/cob (584.38), grain weight/cob (268.75 g), 100 seeds weight (47.66 g) and grain yield (1681.25 kg/rai; rai = 0.16 ha) over the two years were also highest under Ultragreen + HO nourishment, followed by $CaCO_3$ + HO. The highest grain crude protein (8.15% and 8.13%, respectively) were observed in Ultragreen + HO and Ultragreen + NPK. After the trial, soil fertility and microbial population have improved, the residual soil N increased from 0.374% to 0.845% in Ultragreen + HO compared to the control, while soil pH improved from 4.3 to a range of 5.8-6.0. Our results revealed that the combination of Ultragreen + HO and $CaCO_3$ + HO produced the greatest output and are recommended.

Keywords: calcium carbonate powder, HO fertilizer, maize yield, soil properties, Ultragreen

1. Introduction

Maize is a global cereal crop (Berenguer, Santiveri, Boixadera, & Lloveras, 2008), and an important crop in the Phitsanulok province, due to its importance to the piggery, poultry, and fishery industries. However, the declining trend of soil fertility and the current rise of soil acidity in most maize growing area in the province is a matter of concern. Usually, farmer's nutrient management strategies favor inorganic fertilizers without plans for organic inputs. Several studies have reported that, the continuous application of inorganic fertilizers for intensive crop production without soil amendments has resulted in unsustainable production (Berenguer *et al.*, 2008; Li & Han, 2016). In addition to it adversely affecting agricultural sustainability, production profitability is affected as well (Li & Han, 2016). Acidic soils hinders nutrient transformation, dissolution and absorption, under a pH range of 5.5-7.0, maize can absorb most nutrients, but under strong acidity, the availability of major nutrients are limited while that of aluminum, iron, zinc and manganese are increased. Excess supply of these nutrients hinders the growth of plant root system (Matsumoto, 2000). The solution to the low soil fertility and pH is to apply soil amendments (lime) and also, integrate mineral and organic nutrient sources.

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Unfortunately, most limes are powdered and heavy. Predominantly, the cost incurred to transport and apply them deters farmers. Recently, a new high intensity liquid lime (Ultragreen) has been developed by Surint Omya Chemicals (Thailand) Ltd through pulverization of $CaCO_3$. Five liters of Ultragreen is equivalent to 500 kg of $CaCO_3$, therefore it is easy to transport at a lower cost. There are no studies on this liquid lime. Similarly, several research performed at different part of the world has reported on the interactive impact of mineral and organic fertilizers on soil properties (Khaliq, Abbasi & Hussain, 2006; Li & Han, 2016). Most of these have shown that, an optimum rate of these can sustain soil productivity and grain yield in the long term; and minimize the extensive energy used in the production of inorganic nitrogen (Blackmer, 1992).

In order to improve the fertility of these degraded soils, the Faculty of Agriculture, Naresuan University, Phitsanulok, Thailand has developed the HO fertilizer by combining mineral fertilizer, compost powder, dolomite, bio-liquid hormone and bio-liquid fertilizer, at optimum rate to address the problem. Previous studies have report on how the various components of this fertilizer affect crop growth and yield. Intanon (2013b) studied the effect of pellet compost, compost mixed bio-liquid fertilizer, compost mixed mineral formula (MF1) on rice yield and concluded that, MF1 produced the highest yield (6996.25 kg/ha) about 43.3% increase over the control in the Phitsanulok province. Additionally, Intanon (2013a) also reported that sole application HO increase maize yield by (1,305 kg) when compared to the control. In addition, Khaliq *et al.* (2006) recorded the highest seed cotton yield (2,470 kg/ha) under N170P85K60 + effective microorganisms (EM) + organic manure (OM) nourishment. However, the combined effect of HO + lime on soil properties has not been studied. Therefore, in our research, we assessed the impact of these materials on soil properties and maize yield over two growing seasons.

2. Materials and Methods

2.1 Location characteristics

The on farm studies was conducted at Wang Thong District in the Phitsanulok Province (16° 55′ 0″ N, 100° 30′ 0″ E), Thailand from April 2017 to November 2018. The soil was sandy clay loam in texture and low in soil fertility (Table 1). The average annual rainfall and temperature of the province were 1,339 mm and 27.8 °C, respectively. During the trial, the average monthly rainfall was 73.12 mm, while maximum and minimum temperatures were 34.1 °C and 24.6 °C.

2.2 Trial setup

The chemical and granular organic fertilizer with hormone mixed formula (HO) was obtained from the Faculty of Agriculture, Natural Resources and Environment, Naresuan University. The composition of the HO fertilizer is shown in Table 2. The Ultragreen lime was sourced from Surint Omya Chemicals (Thailand) Ltd while the calcium carbonate powder ($CaCO_3$) and NPK: 15-15-15 were sourced from the Department of Land Development, Thailand. The experiment was performed in randomized complete block design (RCBD) with seven treatments and four replications in 6 m x 5 m plot size. Treatment models were control (no lime and fertilizer), Ultragreen, $CaCO_3$, Ultragreen + NPK, $CaCO_3$ + NPK, Ultragreen + HO and $CaCO_3$ + HO.

2.3 Research procedure

According to the initial soil analysis data, soil pH was (4.28), hence 577 kg/rai (rai = 0.16 ha) of $CaCO_3$ was applied to adjust soil pH to 7.0. Therefore, 10.82 kg $CaCO_3$ and 0.11L Ultragreen were applied per plot respectively. 5L of Ultragreen is equivalent to 500 kg of $CaCO_3$. The limes were applied 25 days prior to planting to enable neutralization. The $CaCO_3$ was spread and raked into the soil while the Ultragreen was applied in solution, according to the manufacturer's instructions. The new hybrid maize (*Pacific 999 Super*) was sown at a row and intra-row spacing of 75 cm × 25 cm by drilling two seeds per hill. Thinning out was done five days after germination to maintain one plant per hill. A seed rate of 3 kg/rai was used. The fertilizer rate was 50 kg/rai (0.9 kg/plot) and were applied in two splits, 30% at 14 days after planting (DAP) and 70% at 45 DAP by side placement method. The experiment was conducted under rain fed conditions.

Table 1. Soil analysis before the experiment

N	P	K	Ca	Mg	S	Fe	Cu	Zn	Mn
	%				mg/kg				
0.381	0.003	0.005	3.561	1.292	0.246	5.862	0.134	1.397	1.903
OM %	pH 1:1	CEC cmol/kg	EC dS/m	Bulk density g/cm	Porosity %	Bacteria CFU/g (10^4)	Fungus	Actinomycetes CFU/g (10^3)	
0.531	4.28	0.174	47.317	1.571	23.172	28.45	33.43	19.10	

Table 2. Composition of HO fertilizer

N	P	K	Ca	S	Mg	Fe	Cu	Zn	Mn
	%		mg/kg			mg/kg			
8.75	7.83	7.79	6.61	1.59	0.05	11.36	0.04	1.61	1.52
OM %	pH 1:1	CEC cmol/kg	EC 25 ºC dS/m	Bacteria CFU/g (10^4)	Fungus	Actinomyces CFU/g (10^3)	IAA	GA_3 mg/kg	Cytokinins
1.13	7.5	21.84	1.57	32.90	29.36	17.22	27.11	11.23	8.59

2.4 Research data

2.4.1 Soil and fertilizer analysis

Before the trial, soil samples were collected on April 2017 for soil physicochemical and biological properties analysis from the entire research plot (30 m^2). Ten soil subsamples were randomly collected from a depth of (0–20 cm) to form a composite sample of 1,500 g. The soil was sieved with a <2 mm mesh to remove all solid debris and was air dried under room temperature for the analysis. Also, the composition of the HO fertilizer was determined. After the trial (November 2018), soil samples were again collected from each plot for analysis. Four replicates of soils and HO fertilizer were used for the analysis. Total nitrogen, phosphorus and potassium were analyzed by the alkaline permanganate method, Bray's no. II method and Neutral N ammonium method respectively (Lu, 1999). Also calcium, magnesium, sulphur, iron, copper, zinc and manganese contents were analyzed by wet digestion Nitric-perchloric digestion (Lu, 1999). Soil organic matter (OM) was determine by (Lu, 1999) method, while soil pH was determine on a 1:1 (w/v) soil and water mixture with a pH meter (Delta 320, Mettler Toledo, Switzerland). Soil pH was measured till November 2018. Cation exchange capacity (CEC) was measured by the ammonium acetate method and electrical conductivity (EC) was assessed using the EC meter. Also, soil bulk density and porosity were analyzer by the core method. Again, microorganisms (bacteria, fungus and actinomyces) population in the soils and HO were determined by the serial dilution and pour plate method (Sanders, 2012). The number of microbes was calculated as in Equation 1.

$$\text{No. of microbes/g oven dry sample} = \frac{\text{Average plate count x dilution factor}}{\text{1 g of oven dry sample}} \quad (1)$$

In addition, phytohormones; indole-3-acetic acid (IAA), gibberellic acid (GA_3) and cytokinins contents in the HO fertilizer were analyzed by the high performance liquid chromatograph (HPLC) system (Waters 2695 Separations Module, Waters, USA) equipped with a photodiode array detector (Waters 2996 Detector, Waters, USA). The reversed-phase ProntoSil 120-5-C18-ACE-EPS column (150 × 4.6 mm, 5 μm, Bischoff analysis technology, Leonberg, Germany) was used for IAA and GA_3 analysis. The mobile phase for IAA analysis was with A) 0.1 M acetic acid and B) 0.1 M acetic acid in methanol at the flow rate of 1 ml/min. On the other hand, 30% methanol (adjusted to pH 3 with 0.1 M phosphoric acid) was used for the elution of GA_3 analysis at the flow rate of 0.8 ml/min. Cytokinins analysis was conducted with the reversed-phase C18 ProntoSil HyperSorb ODS (250×4.6 mm, 5 μm, Bischoff analysis technology, Leonberg, Germany) column. The mobile phase was with A) 0.1 M acetic acid in ultrapure water (contain 50 ml ACN, pH 3.4 triethanolamine) and B) acetronitrile at the flow rate of 1 ml/min (Szkop & Bielawski, 2012; Morris & Zaerr, 1978).

2.4.2 Vegetative growth

Ten representative sample plants were randomly selected per plot for the measurement of plant height, number of leaves and leaf area/plant. Measurements were taken after 14 DAP at 10 days interval until flowering (60 DAP). Leaf area was measure with the leaf area meter and was used to calculate leaf area/plant following the method of (Saxena & Singh, 1965) as shown in Equation 2.

$$\text{Leaf area/plant (dm}^2) = L \times D \times N \times 0.75 \quad (2)$$

where L, D and N are leaf length, leaf diameter and leaves number. 0.75 is leaf area constant for maize.

Total dry matter weight was measured after harvesting. The ten sampled plants/plot were uprooted and oven dried at 70±2 °C for 12 hrs; afterwards their weights were measures and the mean worked out as total dry matter weight/plant.

2.4.3 Yield components, yield and grain quality

There was one cob/plant in all treatments over the two seasons. Cob weight/plant, grains number/plant and grains weight/plant were measured for each plot. The entire plants in each plot were considered. 100 fully filled seeds were sampled from each plot, weighed and recorded as 100 seeds weight/plot. After that the grain yield in each plot was record and converted into grain yield/rai. Grain weight was measured at 14% moisture content, using moisture meter (FARMEX model, Delhi, India). Afterwards, the nitrogen, phosphorus and potassium contents in the grains were determined by the Kjeldahl digestion, Vanadomolybdate phosphoric acid digestion and flame atomic absorption spectrophotometry, Varian 250 plus methods, respectively (Yahya, 1996). Sriperm, Pestia, and Tillmanb (2011) maize convection factor of 5.68 was used to convert nitrogen content into crude protein content.

2.5 Data analysis

Data analysis was conducted in analysis of variance (ANOVA) using the software package SPSS 21 for Windows (SPSS Inc., Chicago, USA), and the difference between treatments means were separated by Duncan's Multiple Range Test (DMRT) at a probability of 95%.

3. Results and Discussion

3.1 Soil and HO analysis before experiment

In order to evaluate the influence of the limes and fertilizers on soil properties, the composition of the research soil was determined. The results of the soil analysis before the experiment, revealed a lower concentration of plant nutrients (Table 1). Nitrogen, phosphorus and potassium contents were 0.381%, 0.003%, and 0.005%, respectively. The OM, CEC, EC, bulk density and porosity were poor as well, while soil pH was acidic (4.28). Such soil conditions explain why farmers in the areas obtain lower yields even under the recommended NPK application rate. This might be caused by the contributive effect of the slash and burn system of farming, mostly practice by farmers and also, the sole dependence on inorganic fertilizer. Li and Han (2016) have reported from a long-term study that sole use of inorganic fertilizer does not improve the soil. From our analysis, the population of soil microbes; bacteria, fungus and actinomycetes were 28.45×10^4, 33.43×10^4 and 19.10×10^3 CFU/g, respectively.

The composition of the HO fertilizer in Table 2 showed that, HO contained 10 essential plant nutrients. The NPK contents of HO were 8.75%, 7.83% and 7.79%, respectively. Moreover, secondary major nutrients and micro nutrients elements such as Fe, Zn, Cu and Mn were present. Again, OM, pH (7.5), CEC, and EC of HO were well pronounced. Also, microbes such as bacteria (32.90×10^4 CFU/g), fungus (29.36×10^4 CFU/g) and actinmycetes (11.22×10^3 CFU/g) were present. The hormonal analysis also indicated the availability of IAA, GA_3 and cytokinins contents of 27.11, 17.23 and 8.59 mg/kg, respectively. The balanced nutrient status of HO might be due to the materials used for its production. It is said that the fertilizer was developed by combing mineral fertilizer, compost powder, dolomite, bio-liquid hormone and bio-liquid fertilizer at optimum rate. Chemical properties of a fertilizer are a major determinate of its ability to supply nutrients, therefore a fertilizer which contain a balance of major and minor nutrients stands a better chance of promoting crop yield (Sharma, Choudhary & Jat, 2017). Moreover, the micronutrients (Fe + Mn + Zn) have been reported by Salem and El-Gizawy, (2012) to be the best combination for maize. The availability of secondary and micronutrients accounts for the good CEC (21.84 cmol/kg) detected, which is an indication of available nutrient ions.

3.2 Maize growth after treatment application

It was apparent from our results in Table 3 that the treatments had the capacity to enhance vegetative growth. Compared to the control, maize height increased significantly ($p\leq0.05$) under all the lime and fertilizer treatments. The highest height of 257.50 and 287.40 cm in 2017 and 2018 seasons, respectively, were found in the Ultragreen + NPK treatment, which lead to a maximum average height of 272.50 cm. The performance might be due to its high level of NPK. Nitrogen is a principal constituent of protein, chlorophyll and hormones which causes cell elongation and an increase in vegetative apparatus in plant (Nsoanya & Nweke, 2015). However, we did not find any notable changes in the number of leaves/plant. From our results, leaf area/plant was significantly influenced. Although the number of leaves/plant did not vary, differences were noticed in leaf length and diameter, as we measured with the leaf area meter. The largest leaf area/plant were observed among the plots under combined lime and fertilizer nourishment, however the greatest leaf area/plant during the 2017 and 2018 seasons of 249.4 and 296.9 dm^2, respectively were realized in Ultragreen + HO treatment. The effect of Ultragreen and $CaCO_3$ on maize growth was not significant ($p\leq0.05$) apart, however the combination of Ultragreen with NPK or HO, produced the highest growth. The result showed that HO played a more significant role on maize growth than Ultragreen. The Ultragreen is in nano particle size (0.1-0.5 micon) and in solution state; hence it can react with the soil faster. Maize growth was in accordance with the balance nutrient status of the fertilizers. We observed that in spite of the high NPK content of the mineral fertilizer, leaf area/plant were highest under HO. This may be the resultant effect of balance fertilization and the hormones contained in HO (Table 2). Our results are consistent with Timothy and Joe (2003) statement that nitrogen interacts with gibberellin and cytokinins to increase plant growth. A slight increase in maize growth was notice in 2018 over the 2017 season, and this we relate to residual effects (Li and Han, 2016). Probably, when the soil pH got improved, plants could absorb enough nutrients for better growth. However, a decreasing trend of growth were observed in the control, and sole Ultragreen and $CaCO_3$ plots, which can be attributed to lack of nutrients.

3.3 Dry matter production, grain yield and quality

Lima *et al.* (2017) mentioned that, the sink capacity of a plant is mainly dependent on vigorous vegetative growth. Therefore at maximum leaf area/plant, as indicated in the Table 3, there was more green area for the interception of active radiation (photosynthesis) in the plants (Azarpour, Moraditochaee & Bozorgi, 2014). Hence total dry matter production and accumulation, as well as grain yield components were significantly ($p\leq0.05$) influenced by treatments in comparison to the control. The greatest total dry matter was found in the combined application of limes and HO (Table 4). Again the Ultragreen interacted well with the fertilizers than $CaCO_3$. Although the average total dry matter produced, during the 2017 and 2018 seasons were not significant between the limes and fertilizers combination but the highest 277.4 g was again noticed in the Ultragreen + HO treatment. Likewise was cob weight and grain number/plant. Grain number and grain weight/cob are the key determinants of grain yield (Uhart and Andrade, 1995). In our results, grain number/cob was maximum (584.38) in the Ultragreen + HO

Table 3. Impact of treatments on vegetative growth

Treatments	Plant height/plant (cm)			Leaves number/plant			Leaf area/plant (dm^2)		
	2017	2018	mean	2017	2018	mean	2017	2018	mean
Control	158.20^d	145.70^b	151.95^c	15.75	16.0	15.88	93.70^c	80.20^d	86.95^d
Ultragreen	241.90^{bc}	271.70^a	256.90^{ab}	16.00	15.9	15.95	193.48^b	210.97^c	202.22^{bc}
$CaCO_3$	230.40^c	255.60^a	242.90^b	15.75	16.0	15.88	171.12^b	178.62^c	174.87^c
Ultragreen+NPK	257.50^a	287.40^a	272.50^a	15.75	16.0	15.88	234.04^a	281.54^{ab}	257.79^a
$CaCO_3$+NPK	247.60^{ab}	285.10^a	266.35^{ab}	16.00	16.0	16.00	226.85^a	251.85^b	239.35^{ab}
Ultragreen+HO	256.20^a	281.30^a	268.70^{ab}	16.00	16.0	16.00	249.40^a	296.90^a	273.15^a
$CaCO_3$+HO	255.60^{ab}	280.60^a	268.10^{ab}	16.00	16.0	16.00	238.87^a	263.98^{ab}	251.42^a
CD (5%)	14.20	38.84	28.08	NS	NS	NS	29.22	34.20	37.44

Note: mean values with different superscript letter within each column denotes significance ($p<0.05$) between different groups. NS = Non-significant, CD = Critical difference at 95%

Table 4. Impact of treatments on dry matter and yield components

Treatments	Total dry matter weight (g)			Cob weight/plant (g)			Grain no./cob		
	2017	2018	mean	2017	2018	mean	2017	2018	mean
Control	125.76^{c}	106.55^{c}	116.16^{c}	167.00^{e}	152.00^{d}	159.50^{e}	267.50^{c}	265.00^{c}	266.25^{c}
Ultragreen	192.87^{b}	199.88^{b}	196.38^{b}	308.00^{cd}	301.50^{c}	304.75^{d}	390.00^{b}	380.00^{b}	385.00^{b}
$CaCO_3$	189.75^{b}	194.80^{b}	192.28^{b}	305.00^{d}	295.00^{c}	300.00^{d}	381.00^{b}	345.75^{b}	363.38^{b}
Ultragreen+NPK	252.95^{a}	273.99^{a}	263.47^{a}	348.00^{b}	390.50^{b}	369.25^{bc}	545.00^{a}	575.00^{a}	560.00^{a}
$CaCO_3$+NPK	236.70^{a}	258.65^{a}	247.68^{a}	339.00^{bc}	386.50^{b}	362.75^{c}	530.00^{a}	555.00^{a}	542.50^{a}
Ultragreen+HO	261.81^{a}	292.99^{a}	277.40^{a}	413.00^{a}	445.50^{a}	429.25^{a}	575.00^{a}	593.75^{a}	584.38^{a}
$CaCO_3$+HO	254.45^{a}	289.60^{a}	272.03^{a}	393.00^{a}	440.50^{a}	416.75^{ab}	560.00^{a}	585.00^{a}	572.50^{a}
CD (5%)	33.53	38.33	32.25	32.41	36.49	49.96	46.13	66.76	41.66

Note: mean values with different superscript letter within each column denotes significance ($p<0.05$) between different groups. CD = Critical difference at 95%

treatment, though it was not significant from $CaCO_3$ + HO (572.50), Ultragreen + NPK (560.0) and $CaCO_3$ + NPK (542.50) treatments. But specifically, grain weight/cob was significantly heavier in 2017 and 2018 with 265.0 and 272.5 g, respectively in Ultragreen + HO, compared to all other treatments (Table 5). The yield increment was mainly caused by the greater seeds number/cob, associated with higher cob weight, as well as a greater 100 seeds weight. The nutrients; N, Fe, Cu, Zn, S and Mg are important elements in the synthesis of organic compounds (carbohydrate) in crops. When there is an adequate balance of these nutrients under favorable conditions, carbohydrate production will be enhanced (Intanon, 2013a). As a result, maize grain yield were greater in the order (Ultragreen + HO > $CaCO_3$ + HO > Ultragreen + NPK > $CaCO_3$ + NPK > Ultragreen > $CaCO_3$ > control) with average values of (1681.25, 1590.0, 1450.0, 1385.0, 929.68, 865.0 and 600.50 kg/rai, respectively). Our finding are also in line with Berenguer *et al.* (2008) who opined that integration of organic and inorganic fertilizers promotes synergistic and complementary effect on crop yield.

According to Cai *et al.* (2014) the endosperm makes up about 80% of the total grain weight, therefore hormones that affect cell proliferation can accelerate greater grain sink capacity and endosperm cells number for greater grain yield. In their study, a significant (6.2-40.4%) rise in endosperm cells were promoted by growth hormones, which intern accelerated kernel filling rate and grain weight by 2.9-16.0% when compared to the control. Our findings support their statement because the HO which contains hormones produced the greatest grain weight. It is evident from our results that, the combination of Ultragreen with HO or NPK produced the greatest grain weight/cob than combining $CaCO_3$ with the fertilizers. Also, the use of amendments alone resulted in lower yield. Consistent to our work, Khaliq *et al.* (2006) recorded the highest seed cotton yield of 2470 kg/ha under $N_{170}P_{85}K_{60}$ + EM + OM fertilization. Additionally, Wei *et al.* (2016) also demonstrated that organics + inorganic fertilizers significantly increased maize yield on an average by 29% relative to sole organic and by 8% to inorganic fertilizer only. The mean percentage increase in grain yield caused by Ultragreen + HO was 13.8% greater than Ultragreen + NPK, and 5.4% greater than $CaCO_3$ + HO over the two seasons. Also, among the limes, Ultragreen increases the mean maize yield by 6.9% compare to $CaCO_3$. Moreover the grain quality factors: nitrogen, phosphorus, potassium and crude protein contents of the plants nourished with HO were slightly better, though not significant from the NPK fertilizer. The increase in grain quality could be related to the balanced nutrients and effect of the microorganisms in HO; microorganisms are known to create favorable environment for nutrient uptake by plant roots (Li and Han, 2016). The mean kernel nitrogen content of maize ranged from 1.24 to 1.64% (Berenguer *et al.*, 2008); values that can be considered as standard for maize (Watson & Ramstad, 1987).

3.4 Soil properties after the experiment

Several works have indicated that the long-term combination of mineral and organic fertilizers with soil amendments can sustain higher crop yields (Khaliq *et al.*, 2006; Wei *et al.*, 2016) and improve soil fertility (Wei *et al.*, 2016). Consistent with other studies (Li & Han, 2016); the application of HO with either Ultragreen or $CaCO_3$ produce the most improved the soil properties at the end of the two years trial in comparison to the other treatments (Table 7). The residual N Ca Mg S Fe Zn and Cu were significantly ($p \leq 0.05$) enhanced by Ultragreen + HO and $CaCO_3$ + HO. Nitrogen content of the soil rise by 55.7% (from 0.374% to 0.845%) under the Ultragreen + HO treatment when compared to the control. An increase was observed in the residual K content, however, the change was not significant. Similarly, no significant variations in soil P content was noticed between HO or NPK fertilizers combination with lime, nevertheless, their combinations gave the highest improved values. All the micronutrient elements except Mn were significantly improve by the HO compared to the NKP fertilizer; this may be due to the composition of HO in Table 2. Also, other soil properties; OM, EC, CEC, bulk density and porosity were significantly improved by the limes alone or their combination with the fertilizers, when compared to the control. The HO fertilizer contains some additional dolomite and compost; these may have also influenced its performance. The improvement in soil physical properties can also be related to the beneficial effects OM and effective microorganisms in the HO. From our results, bacteria, fungus and actinomycetes population in the soil after the trail were highest in $CaCO_3$ + HO and Ultragreen + HO treatments, with values of 51.10×10^4, 56.05×10^4, 26.18×10^3, and 50.47×10^4, 56.73×10^4, 25.43×10^3 CFU/g, respectively. An increase in OM content can stimulates soil microorganism's rapid growth (Li, & Han, 2016). This could intend enhance soil quality through soil aggregation, because OM and EM are the key factors for soil aggregate formation

Table 5. Impact of treatments on yield components and yield

Treatments	Grain weight/cob (g)			100 seeds weight (g)			Grain yield/rai (kg)		
	2017	2018	mean	2017	2018	mean	2017	2018	mean
Control	105.00^{e}	98.75^{d}	101.88^{d}	28.96^{c}	26.79^{c}	27.88^{d}	628.00^{d}	573.00^{d}	600.50^{d}
Ultragreen	205.00^{d}	201.75^{c}	203.38^{c}	35.21^{b}	32.71^{b}	33.96^{c}	967.75^{c}	891.61^{c}	929.68^{c}
$CaCO_3$	198.00^{d}	193.75^{c}	195.88^{c}	34.06^{b}	32.56^{b}	33.31^{c}	880.00^{c}	850.00^{c}	865.00^{c}
Ultragreen+NPK	239.00^{b}	244.00^{b}	241.50^{b}	46.20^{a}	46.95^{a}	46.58^{ab}	1400.00^{b}	1500.00^{b}	1450.00^{b}
$CaCO_3$+NPK	228.00^{c}	238.00^{b}	233.00^{b}	44.51^{a}	44.69^{a}	44.60^{b}	1310.00^{b}	1460.00^{b}	1385.00^{b}
Ultragreen+HO	265.00^{a}	272.50^{a}	268.75^{a}	47.41^{a}	47.91^{a}	47.66^{a}	1637.50^{a}	1725.00^{a}	1681.25^{a}
$CaCO_3$+HO	244.00^{b}	251.50^{b}	247.75^{b}	46.56^{a}	47.06^{a}	46.81^{ab}	1575.00^{a}	1605.00^{ab}	1590.00^{ab}
CD (5%)	8.96	16.14	11.55	4.01	3.84	2.42	164.54	200.12	149.33

Note: mean values with different superscript letter within each column denotes significance ($p<0.05$) between different groups. CD = Critical difference at 95%

Table 6. Impact of treatments on grain nutrients content

Treatments	Nitrogen (%)			Phosphorus (%)			Potassium (%)			Crude protein %
	2017	2018	mean	2017	2018	mean	2017	2018	mean	
Control	0.72^{e}	0.44^{d}	0.58^{d}	0.22^{d}	0.17^{e}	0.19^{d}	0.48^{d}	0.35^{e}	0.42^{e}	3.30^{d}
Ultragreen	0.93^{d}	0.88^{c}	0.90^{c}	0.32^{c}	0.36^{d}	0.34^{b}	0.65^{bc}	0.59^{c}	0.62^{cd}	5.13^{c}
$CaCO_3$	0.85^{de}	0.82^{c}	0.83^{cd}	0.40^{b}	0.37^{d}	0.39^{b}	0.60^{c}	0.50^{d}	0.55^{de}	4.73^{cd}
Ultragreen+NPK	1.39^{a}	1.47^{a}	1.43^{a}	0.50^{a}	0.53^{bc}	0.51^{a}	0.79^{a}	0.81^{a}	0.80^{ab}	8.13^{a}
$CaCO_3$+NPK	1.12^{c}	1.22^{b}	1.17^{b}	0.48^{a}	0.50^{c}	0.49^{a}	0.70^{b}	0.72^{b}	0.71^{bc}	6.63^{b}
Ultragreen+HO	1.41^{a}	1.46^{a}	1.44^{a}	0.51^{a}	0.60^{a}	0.56^{a}	0.82^{a}	0.83^{a}	0.83^{a}	8.15^{a}
$CaCO_3$+HO	1.23^{b}	1.40^{a}	1.32^{ab}	0.51^{a}	0.56^{ab}	0.53^{a}	0.79^{a}	0.82^{a}	0.80^{ab}	7.47^{ab}
CD (5%)	0.14	0.14	0.25	0.05	0.05	0.08	0.06	0.05	0.11	1.43

Note: mean values with different superscript letter within each column denotes significance ($p<0.05$) between different groups. CD = Critical difference at 95%

Table 7. Soil properties after the experiment (November 2018)

Soil properties			Control	Ultragreen	$CaCO_3$	Ultragreen+ NPK	$CaCO_3$+ NPK	Ultragreen+ HO	$CaCO_3$+ HO	CD (5%)
Primary nutrients	N	%	0.374^{d}	0.585^{c}	0.585^{c}	0.702^{b}	0.646^{bc}	0.845^{a}	0.840^{a}	0.078
	P	%	0.003^{b}	0.004^{b}	0.004^{b}	0.005^{a}	0.005^{a}	0.007^{a}	0.007^{a}	0.002
	K	%	0.005	0.005	0.005	0.006	0.006	0.007	0.007	NS
Secondary nutrients	Ca	mg/kg	3.462^{d}	5.507^{c}	5.272^{c}	6.442^{b}	6.244^{b}	9.191^{a}	8.644^{a}	0.570
	Mg	mg/kg	1.284^{d}	2.985^{c}	2.953^{c}	4.665^{b}	4.564^{b}	7.015^{a}	6.997^{a}	0.894
	S	mg/kg	0.203^{c}	0.295^{c}	0.294^{c}	1.158^{b}	1.157^{b}	1.696^{a}	1.694^{a}	0.255
Micro nutrients	Fe	mg/kg	5.554^{b}	6.336^{b}	6.244^{b}	6.935^{b}	6.957^{b}	14.180^{a}	13.859^{a}	3.177
	Cu	mg/kg	0.011^{d}	0.034^{c}	0.035^{c}	0.047^{b}	0.046^{b}	0.065^{a}	0.064^{a}	0.005
	Zn	mg/kg	1.351^{d}	2.167^{c}	2.161^{c}	5.768^{b}	5.760^{b}	9.753^{a}	9.749^{a}	0.551
	Mn	mg/kg	1.855^{b}	2.492^{b}	2.465^{b}	3.787^{a}	3.774^{a}	4.376^{a}	4.374^{a}	0.816
Organic Matter (OM) %			0.485^{b}	0.574^{b}	0.572^{b}	0.626^{ab}	0.635^{a}	0.766^{a}	0.764^{a}	0.149
EC. 25 ºC (dS/m)			46.080^{d}	80.870^{c}	80.770^{c}	118.350^{b}	114.750^{b}	133.980^{a}	131.680^{a}	7.587
CEC (cmol/kg)			0.171^{c}	0.270^{bc}	0.275^{bc}	0.375^{b}	0.365^{b}	0.818^{a}	0.810^{a}	0.105
Bulk Density (Db) g/cm^3			1.575^{a}	1.555^{a}	1.555^{a}	1.515^{a}	1.515^{a}	1.445^{b}	1.440^{b}	0.051
Porosity (E) %			23.209^{c}	27.830^{b}	27.770^{b}	29.720^{ab}	29.350^{ab}	33.050^{a}	33.010^{a}	4.268
Bacteria CFU/g of soil (10^4)			27.67^{d}	39.06^{c}	38.46^{c}	46.80^{abc}	41.78^{bc}	50.47^{ab}	51.10^{a}	9.03
Fungus CFU/g of soil (10^4)			31.77^{b}	39.64^{b}	35.26^{b}	39.65^{b}	40.30^{b}	56.73^{a}	56.05^{a}	13.79
Actinomycetes CFU/g of soil (10^3)			19.76	20.27	19.95	23.58	20.44	25.43	26.18	NS

Note: mean values with different superscript letter within each row denotes significance ($p<0.05$) between different groups. NS = Non-significant, CD = Critical difference at 95%

(Mayer, Scheid, Widmer, Fließbach, & Oberholzer, 2010). The increase in soil microbial population after the trial is an indication of good soil health. Improvement in OM can correspondingly decrease soil bulk density and increase soil porosity (Li & Han, 2016). In our studies, soil bulk density decreased to (1.440 and 1.445 g/cm^3) in CaCO3 + HO and Ultra green + HO treatments, respectively. Similarly, Rivenshield and Bassuk (2007) reported a decrease in bulk density from 1.5 g/m^3 to 1.2 g/m^3 (a 20% change) using organic amendments. The application of Ultragreen and $CaCO_3$ alone or in combination with the fertilizers raised the soil pH significantly to weak acidity (5.8 to 6.0), respectively in Figure 1. The addition of lime increased the available alkaline elements; Ca, P, and K in the soil. Ca reacts with water to form CO_3^+, which binds to H^+ ion to adjust soil acidity (Intanon, 2013a). A change in pH from 5.0 to 5.6 owing to soil amendments application has been reported by (Agegnehu, Nelson, & Bird, 2016). Generally, the HO fertilizer interacted well with both limes compared to the NPK fertilizer, to improve the soil properties. When the soil properties got improved, plant could absorb more nutrients for maximum growth and yield, as shown by the nutrient content in the grains (Table 6).

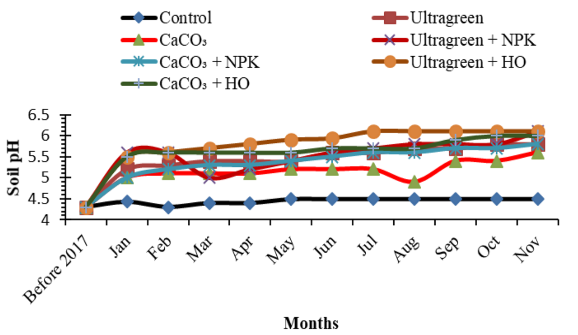

Figure 1. Changing soil pH during the trial (Jan –Nov 2018)

4. Conclusions

The results support our hypothesis that, a combination of soil amendments and the chemical and granular organic fertilizer with hormone mixed formula (HO) and chemical fertilizer can better improve soil properties and enhance maize growth and yield. Maize grain weight/cob, yield/rai and soil properties were highest in Ultragreen + HO and $CaCO_3$ + HO. The significant increase in soil organic matter content and microbial abundance does indicate that the soil's health and resilience to retain and release nutrients has been improved and may intends enhance soil quality through soil aggregation.

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