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Influence of organo-chemical fertilizer mixed with hormones on yield of *Zea mays* (L.) and soil productivity

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Influence of organo-chemical fertilizer mixed with hormones on yield of *Zea mays* (L.) and soil productivity

Abstract: The effect of five fertilizers; NPK (15-15-15), organo-chemical hormone mixed formula 1 (HO-1), Formula 2 (HO-2), Formula 3 (HO-3) and granular organic fertilizer (GOF) were investigated on maize yield and soil properties in a Randomized Complete Block Design with 4 replications. The new hybrid maize (GT 822) was sown at 75 x 25 cm² spacing. The fertilizer rate was 300 kg ha^{-1}. Initial soil analysis showed that the soil had a lower rate of nutrients but after the second season of trial a significant ($p \leq 0.05$) improvement was observed in soil properties, the highest residual NPK of 0.875 %, 0.0275 %, and 0.0267 % were recorded in HO-3 plots. Vegetative data showed that maize height, dry matter, leaf area, and leaf chlorophyll of 270.85 cm, 282.66 g, 156.02 dm², and 56.70, respectively were also highest in HO-3 fertilizer. Plant growth indices; RGR, LAI, and dry matter use efficiency of 0.132 g g^{-1}day^{-1}, 5.90 and 34.4 %, respectively were best in HO-3. Grain yield and crude protein of 8276.68 kg ha^{-1} and 8.99 % were recorded in HO-3, followed by HO-2 and NPK. Lower yields were obtained from the control and GOF. Our finding revealed that the integration of nutrient sources in a balanced ratio produced the greatest yield output, improved soil properties, and is therefore the future approach to planning an effective fertilizer strategy. Reliance on GOF as a sole fertility package for maize production may result in significant yield losses compared to the integrated approach or use of NPK fertilizer.

Key words: fertilizers; grain yield; integrated nutrient management; soil properties; *Zea mays*

Vpliv mešanice organsko kemičnih gnojil in hormonov na pridelek koruze (*Zea mays* (L.)) in rodovitnost tal

Izvleček: V raziskavi je bil na pridelek koruze in lastnosti tal v popolnem bločnem poskusu s štirimi ponovitvami preučevan učinek mešanice petih odmerkov gnojil NPK (15-15-15) pomešanih z organskimi snovmi in hormoni v naslednjih kombinacijah: 1 (HO-1), 2 (HO-2), 3 (HO-3) ter dodatkom granularnega organskega gnojila (GOF). Novi hybrid koruze GT 822 je bil posejan v razmaku 75 x 25 cm². Odmerek gnojila je bil 300 kg ha^{-1}. Izhodiščna anliza tal je pokazala, da so bila tla slabo preskrbljena s hranili, a je bilo že po drugi sezoni trajanja poskusa opazno značilno izboljšanje ($p \leq 0,05$) v lastnostih tal, pri čemer so bile zabeležene največje vsebnosti ostankov NPK gnojil (0,875 %; 0,0275 % in 0,0267 %) na ploskvah HO-3. Tudi meritve lastnosti obravnavanega posevka koruze kot so višina rastlin, vsebnost suhe snovi, velikost listne površine in vsebnost klorofila (270,85 cm; 282,66 g; 156,02 dm² in 56,70) so imele največje vrednosti pri gnojenju HO-3. Rastlinski rastni kazalniki, RGR, LAI, in učinkovitost izrabe suhe snovi (0,132 g g^{-1} dan^{-1}; 5,90 in 34,4%) so imele največje vrednosti pri obravnavanju HO-3. Pridelek zrnja in vsebnost surovih beljakovin (8276,68 kg ha^{-1} in 8,99 %) sta bila največja pri obravnavanju HO-3, nato pri HO-2 in obravnavanju samo z NPK. Manjši pridelki so bili doseženi pri kontroli in obravnavanju z GOF. Rezultati so pokazali, da je integrirana in uravnotežena raba virov hranil dala največji pridelek in izboljšala lastnosti tal in jo zato priporočamo v bodočih programih gnojilne strategije. Vztrajanje na uporabi granuliranih organskih gnojil kot edinega gnojilnega postopka pri pridelavi koruze lahko povzroči znatne izgube pridelka v primerjavi s temi integriranimi postopki gnojenja ali uporabi NPK gnojil.

Ključne besede: gnojila; pridelek zrnja; integrirano upravljanje z gnojili; lastnosti tal; *Zea mays*

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1 INTRODUCTION

Declining soil productivity is a major problem to sustain maize production globally (Chen et al., 2014). A balanced supply of essential plant nutrients is beneficial for maize growth (Chu et al., 2007), however, farmers' fertilization strategies often focus mainly on major nutrients and economic gains rather than a sustainable agronomic impact. This has led to decreased fertility levels and nutrient imbalances worldwide (Chu et al., 2007). The continuous application of sole inorganic fertilizer to intensify crop cultivation has resulted in unsustainable production due to its inability to condition the soil and sustainable micronutrient levels, soil pH, and soil microbial populations (Chen et al., 2014). The effect of inorganic fertilizers on soil fertility is short-term and without appropriate interventions may pose a negative threat to soil health in the long term (Keteku et. al., 2022; Yang et al., 2015; Meena et al., 2014). Organic fertilizers/amendments had long been reported to promote good soil health and fertility. Fang et al. (2021) and Wang et al. (2018) even recommended that organic fertilizers should replace inorganic fertilizers. Other works recommended a blend due to the low nutrient turnout of organic fertilizers (Voltr et al., 2021; Wang et al., 2017; Ng et al., 2016). Hence, intensive cropping systems without organic inputs are assumed to be unsustainable (Voltr et al., 2021; Ng et al., 2016; Li and Han, 2016). According to Rosegrant et al. (2014), the use of agricultural bioproducts is necessary for inorganic fertilizer conservation and the maintenance of soil productivity. Integration of organic and inorganic fertilizers has nowadays gained attention as the best and the most practical method of promoting short-term plant growth and yield while improving soil organic carbon (SOC) sustainability in the long term (Li and Han, 2016). Several previous studies have reported that combining inorganic fertilizer and organic amendments significantly increased crop yield, SOC, residual nutrients, and microbial activity (Wang et al., 2015). Khaliq et al. (2006) also demonstrated that the combined use of NPK + effective microorganisms (EM) + organic manure significantly increased the growth and yield of cotton as well as residual soil NPK compared to their sole applications. In this light, a new organo-chemical hormone mixed fertilizer (HO), developed by the Faculty of Agriculture, Naresuan University, Thailand by combining inorganic fertilizer, powder of mixed compost, soil amendments, herbal plant extracts liquid, bio-liquid hormone, and bio-liquid fertilizer at the optimum rate for each plant and coated to control nutrient release (Intanon et al., 2011), seems an interesting product. Previous studies have reported on how the various components of this fertilizer affect crop growth and yield. Intanon (2013) studied the effect of pellet compost, compost mixed bio-liquid fertilizer and compost mixed mineral formulation rice yield and concluded that compost mixed mineral formula produced the highest yield of 6996.25 kgha^{-1}, about 43.3 % increase over the unfertilized plot. In addition, Intanon et al. (2017) reported that the HO sugarcane formula increases sugarcane yield by 51.3 % and soil properties; nitrogen from 0.582 to 0.86 %, organic matter (OM) from 0.595 to 0.954 %, EC. 25 ^{o}C from 56.81 to 148.72 dS m^{-1} and CEC from 0.17 to 0.87cmol kg^{-1} when compared to the unfertilized plot. Therefore, this experiment was designed on the hypothesis that HO fertilizer can increase maize yield and improve soil properties than the basal recommended NPK fertilizer. The soil of Phitsanulok is slightly acidic and the HO fertilizer has not yet been tested in this area. Several previous researchers have reported on the integration of chemical and organic fertilizer (Voltr et al., 2021; Wang et al., 2017; Ng et al., 2016; He et al., 2015; Wang et al., 2015; Wei et al., 2016) but none have worked on a holistic combination as in HO. This formula is unique and may serve as the basis for new integrated fertilizer formulations.

2 MATERIALS AND METHODS

2.1 RESEARCH FERTILIZERS

The HO fertilizers were sourced from the Faculty of Agriculture, Naresuan University, Thailand. The differences between the formulas are the concentration of their ingredient composition (Intanon et al., 2011) as in Table 1. The NPK: 15-15-15 and GOF were procured from the Department of Land Development, Thailand. The GOF was developed from chicken manure. The compositional analysis of the fertilizers is shown in Table 3.

2.2 RESEARCH SITE

The trial was conducted in the Phitsanulok Province located at 16^{o} 55′ 0″ N and 100^{o} 30′ 0″ E in Thailand. The research soil was sandy clay loam and low in soil fertility (Table 2). The average annual rainfall and temperature in the province are 1339 mm and 27.8 ^{o}C, respectively and about 85 % of rain occurs between (June-October, 2018-2019). During the trial, the average monthly rainfall for the two seasons was 73.12 mm, while maximum and minimum temperatures were 34.1 ^{o}C and 24.6 ^{o}C, respectively. The average monthly rainfall recorded during the experimental period is in Figure 1.

Table 1: Material components of HO maize formula

Fertilizer	Materials (by mass, kg) A	B	C	D	E	F	Total
HO-1	25	30	20	5	10	10	100 kg
HO-2	30	25	20	5	10	10	100 kg
HO-3	36	20	15	5	12	12	100 kg

Note: A = inorganic fertilizer (7:2:1 major, secondary and micronutrients), B = compost powder (OM), C = soil amendment, D = herbal plant extract liquid, E = bio-liquid hormone, F = Bio-liquid fertilizer

2.3 EXPERIMENTAL PLAN

The trial was performed in Randomize Complete Block Design (RCBD) with 6 treatments and 4 replications. The treatments were; T1 control (no fertilizer), T2 NPK: 15-15-15, T3 organo-chemical hormone mixed fertilizer formula 1 (HO-1), T4 formula 2 (HO-2), T5 formula 3 (HO-3), T6 granular organic fertilizer (GOF). The new hybrid maize (GT 822) was sown at an inter-row and intra-row spacing of 75 cm × 25 cm in a 6 m x 5 m plot size. A seed rate of 18 kg ha^{-1} was used with one plant maintained per hill. The fertilizer rate was 300 kg ha^{-1} (0.9 kg plot^{-1}) and was applied in two splits, 30 % at 14 days after planting (DAP) and 70 % at 45 DAP by side placement method.

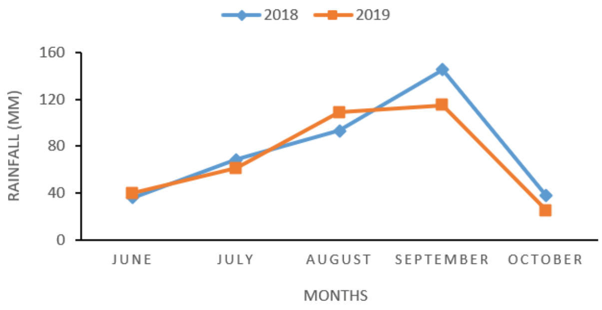

Figure 1: Average monthly rainfall during the experimental period (Source: Phitsanulok weather station)

2.4 RESEARCH DATA

2.4.1 Soil and fertilizer analysis

Soil cores were randomly sampled from the experimental plot before and after the experiment at a depth of (0-20 cm) with a hand auger for soil physical, chemical, and biological properties analysis. The physical and chemical analysis of the fertilizers and soil were determined by the routine methods of (A.O.A.C., 1975). Total N was estimated by the Kjeldahl method, available P by Bray's no. II method and available K, Fe, Zn, Cu, and Mn by the inductively coupled plasma emission spectrometry 4300 Optima DV (PerkinElmer Instruments, Norwalk, CT). Soil pH was recorded at a 1:1 solution ratio with the electrode (H19017 Microprocessor) pH meter. The potassium dichromate oxidation method was adopted to determine organic matter content. Also, cation exchange capacity (CEC) was determined by the ammonium acetate method while electrical conductivity (EC) was measured with the EC meter. The procedures of A.O.A.C. (1975) were again adopted to analyze soil bulk density and porosity. For the fertilizers, total nitrogen was determined by the Kjeldahl analysis, while the determination of other nutrients concentration was done by the inductively coupled plasma emission spectrometry 4300 Optima DV (PerkinElmer Instruments, Norwalk, CT). Also, soil microorganisms (bacteria, fungi, and actinomyces) population in the fertilizers and soil before and after the trial were analyzed by the serial dilution and pour plate method by (Sanders, 2012). The number of microbes was calculated as in Equation 1.

$$\text{No. of microbes g}^{-1}\text{ oven dry sample} = \frac{Average\ plate\ count \times dilution\ factor}{1\ g\ of\ oven\ dry\ sample} \qquad \text{(Eqn 1)}$$

The hormones (indole-3-acetic acid (IAA), gibberellic acid (GA_3) and cytokinins) in the HO were estimated by the high-performance liquid chromatography (HPLC) system (Waters 2695 Separations Module,

Table 2: Compositional analysis of the soil before trial

N	P	K	Ca	Mg	S	Fe	Cu	Zn	Mn
	%					mg kg^{-1}			
0.394	0.013	0.015	4.400	1.274	0.216	5.867	0.023	1.355	1.864
OM %	pH 1.1	CEC Cmol kg^{-1}	EC. 25° dS m^{-1}	Bulk density g cm^{-1}	Porosity %	Bacteria	Fungi	Actinomyces	
						CFU g^{-1} (10^4)		CFU g^{-1} (10^3)	
0.536	5.1	0.183	46.713	1.553	23.093	34.0	39.0	17.0	

Note: sample size (n) = 4

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^{-1}. Conversely, 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^{-1}. Cytokinin analysis was performed 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 (containing 50 ml ACN, pH 3.4 triethanolamine) and B) acetonitrile at the flow rate of 1 ml min^{-1} (Szkop and Bielawski, 2012).

2.4.2 Vegetative growth analysis

Twenty representative sample plants were randomly selected per plot for the assessment of maize height, number of leaves, leaf chlorophyll, and leaf area per plant. Measurements were taken at 10 days interval after 14 DAP until flowering. The SPAD-502 Plus meter was used to measure leaf chlorophyll content (surrogate chlorophyll) on the first five fully open leaves from the plant

tip. Leaf area per plant was also measured following the method of (Saxena and Singh 1965) as in Equation 2.

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

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

One representative plant was uprooted at 20 days interval intervals after 14 DAP for dry matter measurement, and after harvesting (120 DAP), the 20 sampled plants were oven-dried at 65 ± 2 °C for 24 h for total dry matter measurement. Plant growth indices; relative growth rate (RGR), leaf area index (LAI), and dry matter use efficiency (DMAE) were calculated by the method of Fisher (1921) shown in (Equation 3, 4, and 5). RGR was calculated at 20 days interval.

$$RGR\ (\mathrm{g\ g^{-1}\ day^{-1}}) = \frac{(Log_e W_2 - Log_e W_1)}{t_2 - t_1} \qquad \text{(Eqn 3)}$$

$$LAI = \frac{Leaf\ area\ per\ plant\,(\mathrm{dm^2})}{Ground\ area\ per\ plant\ (\mathrm{dm^2})} \qquad \text{(Eqn 4)}$$

$$DMAE\ (\%/\mathrm{day}) = \\ = \frac{\text{Grain mass/plant (g)}}{\text{Total dry matter/plant (g)}} \times \frac{100}{\text{Duration of crop}} \qquad \text{(Eqn 5)}$$

W_1 and W_2 represents total dry matter $plant^{-1}$ at time t_1 and t_2 respectively. Log_e is the natural logarithm (e = 2.3026).

2.4.3 Yield and yield quality

Grains mass was measured on a plot-wise basis, all the entire grains per plot were taken into consideration. Gain mass measurement was done at 13 % moisture content, measured with a moisture meter (FARMEX model, Delhi, India) and later converted into grain mass ha^{-1}. The average mass of the two seasons is reported here. Afterward, grain NPK contents were determined for quality assessment by the methods; Kjeldahl digestion and its content quantified by an auto-analyzer and vanadomolybdate phosphoric acid digestion methods, respectively (A.O.A.C., 1975). Sriperm et al. (2011) maize convection factor (5.68) was used to convert percent grain nitrogen into crude protein content. Also, the IAA, GA_3, and cytokinins content in the maize shoot were analyzed by the procedure mentioned above.

2.5 DATA ANALYSIS

All growth, yield, and soil analyses results are averages of two season data. Data analysis was conducted with the Analysis of Variance (ANOVA) using the statistical software SPSS version 21 for Windows (SPSS Inc., Chicago, USA). A comparison of treatment means was done by Tukey's test at a 95 % significance level.

3 RESULTS AND DISCUSSION

3.1 COMPOSITIONAL ANALYSIS OF FERTILIZERS

The compositional analysis of the experimental fertilizers is shown in Table 3. The chemical properties of the fertilizers are a major determinate factor of their inherent capacity to supply nutrients. The contents of NPK elements were the highest in NPK: 15-15-15 and HO-3 fertilizers. Secondary nutrients; Ca, Mg, and S were all present in the HO fertilizers and GOF, however, the HO-3 formula contained the highest of 7.97, 1.628, and 0.055 mg kg^{-1}, respectively. Similarly, the micronutrients Fe, Zn, Cu, and Mn contents followed the same trend. The fertilizer with a balance of major and minor nutrients stands a better chance of promoting optimum crop yield (Sharma et al., 2017). The micronutrients Fe + Mn + Zn were reported by Salem and El-Gizawy, (2012) to be the best combination for maize growth as they enhance the utilization of major nutrient elements. In addition, other properties such as pH, EC, CEC, and OM were well expressed in the HO formulas and GOF. The highest CEC of 21.97 cmol kg^{-1} was noted in the HO-3 and is an indication of available nutrient cations ready to be released. This is due to the presence of high secondary and micronutrient elements. The pH of all the fertilizers was ideal to facilitate the release and uptake of nutrients. The hormone quantification showed that IAA and gibberellic acid (GA_3) were more pronounced in the HO-3 formula with 32.44 mg kg^{-1} and 17.22 mg kg^{-1}, respectively than HO-2 and HO-1, but were absent from NPK fertilizer and GOF. Also, bacteria, fungi, and actinomycetes cell count were similarly present in the HO fertilizers and GOF as well. It is therefore evident from Table 3 that, the NPK fertilizer lacks micronutrients, hormones, and microorganisms, which are important requirements for promoting higher crop yield.

3.2 VEGETATIVE GROWTH

Maize growth was in accordance with the balance nutrient status of the fertilizers (Table 4). Maize height and leaf numbers were comparable between HO-3, NPK, and HO-2. Leaf area/plant was clearly significant ($p \leq 0.05$) with 156.02 dm^2 in HO-3 and was followed closely by NPK and HO-2 (Table 4). Besides the fertilizers having nitrogen which is an important factor for cell division, secondary and micronutrients also significantly affect cell division, chlorophyll construction, and photosynthesis (Kadam et al., 2020). This might have accounted for the higher and comparable maize height and

Table 3: Compositional analysis of fertilizers

			Fertilizer treatments					
Fertilizer properties			T2 (NPK)	T3 (HO-1)	T4 (HO-2)	T5 (HO-3)	T6 (GOF)	CD 5 %
Primary nutrients	N	%	15^{a}	7.061^{d}	8.754^{c}	10.96^{b}	4.92^{e}	0.82
	P	%	15^{a}	6.547^{d}	7.832^{c}	9.302^{b}	4.68^{e}	0.82
	K	%	15^{a}	6.451^{d}	7.795^{c}	9.215^{b}	4.84^{e}	0.15
Secondary nutrients	Ca	Mg kg^{-1}	0	6.54^{b}	6.61^{b}	7.97^{a}	2.35^{c}	0.03
	Mg	Mg kg^{-1}	0	1.526^{c}	1.587^{b}	1.628^{a}	0.960^{d}	0.04
	S	mg kg^{-1}	0	0.050^{a}	0.050^{a}	0.055^{a}	0.021^{b}	0.01
Supplementary nutrients	Fe	mg kg^{-1}	0	9.74^{c}	11.36^{b}	14.24^{a}	2.55^{d}	2.55
	Cu	mg kg^{-1}	0	0.034^{a}	0.035^{a}	0.043^{a}	0.011^{b}	NS
	Zn	mg kg^{-1}	0	1.523^{a}	1.612^{a}	1.679^{a}	0.517^{b}	NS
	Mn	mg kg^{-1}	0	1.325^{c}	1.522^{b}	1.750^{a}	0.761^{d}	0.04
Organic matter (OM) %			0	1.05^{c}	1.13^{c}	1.25^{b}	1.37^{a}	0.07
(pH) = 1:1			6.2^{d}	7.2^{b}	7.5^{a}	7.6^{a}	6.9^{c}	1.18
CEC (cmol kg^{-1})			10.54^{d}	18.62^{b}	21.84^{a}	21.97^{a}	10.78^{c}	0.76
EC. 25º (dS m^{-1})			1.44	1.55	1.57	1.58	1.46	NS
Bacteria CFU g^{-1} (×10^{4})			0	32.36^{a}	29.60^{a}	32.90^{a}	22.33^{b}	3.49
Fungus CFU g^{-1} (×10^{4})			0	48.90^{b}	39.40^{c}	53.93^{a}	40.17^{d}	4.28
Actinomycetes CFU g^{-1} (×10^{3})			0	19.52^{b}	16.68^{c}	23.42^{a}	14.17^{d}	1.93
IAA mg kg^{-1}			0	23.26	24.17	27.11	0	NS
GA_3 mg kg^{-1}			0	11.17^{c}	13.25^{b}	17.22^{a}	0	0.92
Cytokinins mg kg^{-1}			0	8.58	7.05	8.59	0	NS

Note: Mean values with identical superscript letters (a,b,c,d.e) are not significantly different at ($p \leq 0.05$), (n = 4); NS = Non significant, CD = Critical difference leaf area/plant of HO-3 and HO-2 fertilizers to that of NPK, respectively. HO-3 and HO-2 produced the highest dry matter as well because the sink capacity of a crop is mostly dependent on vigorous vegetative growth (Lima et al., 2017). At maximum leaf area, there was more green area for the interception of active radiation for photosynthesis. In addition, leaf chlorophyll, an important factor in photosynthesis was also the highest (56.7 SPAD units) in the HO-3 fertilizer. As a result, the maximum total dry matter of 282.66 g/plant was recorded in HO-3 (Table 5). A similar finding was reported by Azarpour et al. (2014). Probably plants under this treatment could absorb enough nutrients for better growth leading to the higher RGR of 0.132 g g^{-1} day^{-1}, LAI of 5.90 and DMAE of 34.4 %day^{-1} expressed in HO-3, HO-2, and NPK fertilizers (Table 4 and 5). LAI is an important indicator of the photosynthesis system, it relates to economic yield, and its increment results in high yield (Azarpour et al., 2014). The high growth and growth indices recorded could also be attributed to the IAA, GA$_3$, and cytokinins contained in HO fertilizers as these hormones are well known to promote crop growth. Our results agree with Timothy and Joe (2003) who reported that nitrogen interacts with GA$_3$ and cytokinins to increase plant growth. All the fertilized plots outperformed the control plot significantly.

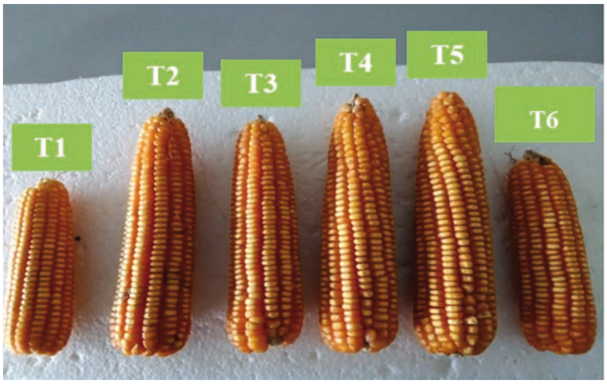

Figure 2: Average cob size under various fertilizers

3.3 YIELD AND GRAIN QUALITY

Maize grain mass varied significantly among the fertilizers (Table 5). The nutrients (N, Fe, Cu, Zn, S, and Mg) are important elements in the synthesis of organic compounds (carbohydrates) in crops (Keteku et al., 2019). Under favourable soil conditions, the production of organic compounds is enhanced by these nutrients. The HO-3 formula contained a higher amount of these nutrients except N, producing the maximum average grain mass over the two seasons (24.83 kg/plot and 8276.68 kg ha^{-1}, respectively). This was followed by HO-2 and NPK fertilizers. The mean cob size of the various fertilizers is depicted in Figure 2. According to Cai et al. (2014), the endosperm makes up about 80 % of the total grain mass, therefore hormones that affect cell proliferation can accelerate greater grain sink capacity and endosperm cell number for greater grain yield. In their study, a significant 6.2 - 40.4 % rise in endosperm cells was promoted by GA$_3$, which intern accelerated grain filling rate and grain weight by 2.9 - 16.0 % when compared to the control. Our findings support their statement because even though the HO-3 and HO-2 fertilizers contained less NPK nutrients compared to T2, they produced a greater grain mass. Previous investigation by Wei et al. (2016) concluded that organic + inorganic fertilizers treatment significantly increased maize yield by 29 % relative to sole organics and by 8 % compared to inorganic fertilizer alone. Consistent with their result, in our work, HO-3 significantly increased maize yield by 30 % relative to GOF and 12.2 % compared to the NPK fertilizer. Khaliq et al. (2006) also similarly, recorded the

Table 4: Influence of fertilizers on vegetative growth

			Leaf area plant^{-1} (dm^2)			Leaf area index		
			DAP			DAP		
Treatments	Height plant^{-1} (cm)	Leaves no. plant^{-1}	34	44	54	34	44	54
T1 (control)	165.67^{e}	14.70^{d}	31.12^{d}	55.23^{e}	75.80^{e}	1.04^{e}	1.84^{f}	2.53^{d}
T2 (NPK)	247.31^{ab}	18.13^{a}	71.63^{b}	116.4^{b}	147.41^{b}	2.39^{b}	3.88^{b}	4.91^{b}
T3 (HO-1)	217.95^{cd}	16.90^{b}	57.37^{c}	94.94^{c}	125.65^{c}	1.91^{c}	3.16^{d}	4.19^{b}
T4 (HO-2)	230.64^{bc}	18.10^{a}	70.52^{b}	110.1^{b}	134.57^{bc}	2.35^{b}	3.67^{c}	4.49^{b}
T5 (HO-3)	270.85^{a}	18.50^{a}	76.73^{a}	129.26^{a}	156.02^{a}	2.56^{a}	4.11^{a}	5.90^{a}
T6 (GOF)	193.54^{de}	16.07^{c}	42.17^{d}	74.09^{d}	94.25^{d}	1.41^{d}	2.47^{e}	3.14^{c}
CD @ 5 %	27.98	0.43	4.44	10.76	18.93	0.14	0.10	0.98

Note: Mean values with identical superscript letters (a,b,c,d.e) are not significantly different at ($p \leq 0.05$), (n = 4); CD = Critical difference

Table 5: Influence of fertilizers on growth and yield

	Leaf chlorophyll (SPAD unit)			Relative growth rate (g g^{-1} day^{-1})		Total dry matter $plant^{-1}$ (g)	Dry matter accumulation efficiency % day^{-1}	Grain mass $plot^{-1}$ (kg)	Grain mass ha^{-1} (kg)
	DAP			DAP					
Treatments	34	44	54	34	54				
T1 (control)	18.48^{d}	15.42^{d}	11.76^{d}	0.113	0.051^{c}	134.20^{e}	15.9^{d}	12.67^{d}	4223.31^{d}
T2 (NPK)	33.84^{a}	55.36^{a}	51.95^{a}	0.136	0.068^{b}	248.20^{b}	32.8^{a}	21.80^{b}	7266.69^{b}
T3 (HO-1)	28.81^{b}	52.08^{b}	48.62^{b}	0.130	0.063^{bc}	212.38^{c}	26.9^{b}	19.72^{bc}	6573.31^{bc}
T4 (HO-2)	35.15^{a}	56.04^{a}	52.18^{a}	0.138	0.067^{b}	255.77^{b}	33.7^{a}	22.26^{ab}	7420.00^{ab}
T5 (HO-3)	35.73^{a}	56.70^{a}	52.97^{a}	0.147	0.132^{a}	282.66^{a}	34.4^{a}	24.83^{a}	8276.67^{a}
T6 (GOF)	23.02^{c}	46.22^{c}	39.49^{c}	0.121	0.061^{bc}	159.73^{d}	21.1^{c}	17.39^{c}	5796.67^{c}
CD @ 5 %	4.67	2.35	2.29	NS	0.07	15.34	2.17	2.76	859.69

Note: Mean values with identical superscript letters (a,b,c,d.e) are not significantly different at ($p \leq 0.05$), (n = 4); NS = Non significant, CD = Critical difference

highest seed cotton yield of 2470 kg ha^{-1} under $N_{170}P_{85}K_{60}$ + EM + OM fertilization. With regards to grain quality, nitrogen, phosphorus, potassium and crude protein contents were comparable between HO-3 and NPK with average values of 1.58, 0.54, 0.86, 8.99 % and 1.53, 0.53, 0.85, 8.67 %, respectively as shown in Figure 3. Analysis of the maize shoots also revealed higher concentrations of IAA, GA_3, and cytokinins in the HO-3 treated plot, most particularly IAA (0.03 mg kg^{-1}), which may justify Cai et al. (2014) results in figure 4.

3.4 SOIL IMPROVEMENT

After the second growing season, fertilization caused a significant ($p \leq 0.05$) improvement in soil properties (Table 6). When compared to the initial soil properties in Table 2, all the fertilizers improved soil physical, chemical, and biological properties. The HO-3, HO-2 and NPK fertilizers, significantly increased N levels to 0.875, 0.865 and 0.654 %, respectively compared to the control. This increase represents 57.4 %, 56.9 %, and 42.9 %, respectively. Similarly, secondary and micronutrients were also much improved by the HO fertilizers and GOF, when compared to NPK fertilizer. The best improvement in OM and CEC of 0.785 % and 0.8815 cmol kg^{-1}, respectively were observed in GOF, while EC, bulk density, and porosity of 134.75 dS m^{-1}, 1.445 g cm^{-3}, and 33.32 %, respectively were also found in the plots under HO-3 nourishment. The result in Figure 5 showed a rise and drop pattern in the mean soil pH values in all plots, nevertheless, a significant ($p \leq 0.05$) improvement of 6.0 was observed in HO-1 at the end of the second trial compared to the control. The improvement in soil physicochemical properties might be due to the minerals, compost, and soil amendment (dolomite) contained in these fertilizers (He et al., 2015). The HO-1 contained more soil amendments in its formula than the other HO formulas, there-

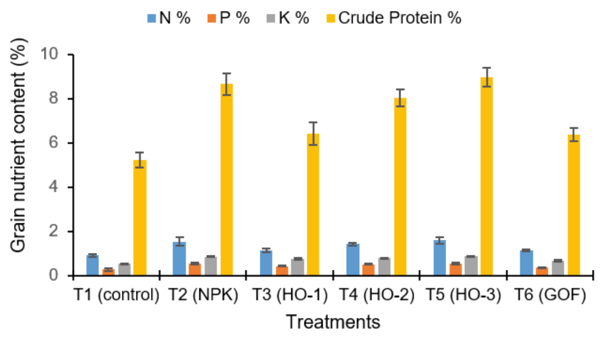

Figure 3: Grain nutrient composition

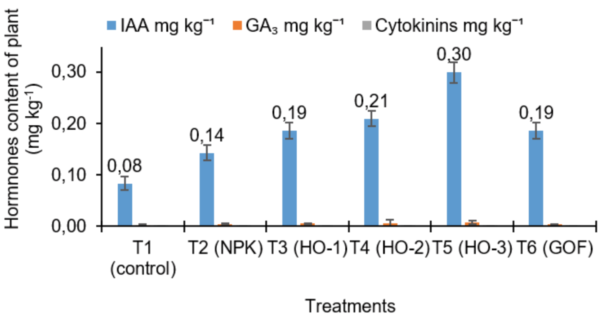

Figure 4: Phytohormones content of maize shoot

fore the calcium might have reacted with water to form CO$_3^-$, which binds to H$^+$ ion to adjust soil acidity (Intanon et al., 2011). The effect of the fertilizers on soil pH may also be due to the initial pH of the fertilizers which relates to the materials used in their formulation (Lehmann et al., 2011). The improvement in OM correspondingly decreased soil bulk density and increase porosity (Li and Han, 2016), for good aeration and easy penetration of maize roots. Significant increases in bacteria, fungi, and actinomycetes abundance were also noticed in the HO fertilizers and GOF (Figure 6). An increase in OM due to the addition of organic materials could also increase soil microbial activity (Khaliq et al., 2006). Several previous studies have reported that OM and EM interrelate to improve soil properties (Khaliq et al., 2006; Abujabhah et al., 2016). Abujabhah et al. (2016) reported significant ($p \leq 0.009$) differences in fungi and bacterial abundance in compost amended plots. Our findings support the argument that soil amendments can improve OM and can potentially assist in improving soil physiochemical and biological properties. The significant increase in OM by the HO fertilizers and GOF does indicate that the soil's health and resilience to retain and release nutrients has been improved (Li and Han, 2016) and may intend enhance soil quality through soil aggregation.

4 CONCLUSION

Our findings support the hypothesis that the organo-chemical hormone mixed fertilizer (HO) can increase maize yield and improve soil properties more than NPK fertilizer. Our findings suggest that (i) an optimum combination of inorganic fertilizer, powder of mixed compost, soil amendments, bio-liquid hormone and bio-liquid fertilizer at an optimum rate as in HO-3 can improve soil properties and lead to a maximum maize growth and yield. (ii) the incorporation of growth hormones into fertilization strategies is useful. (iii) grain quality with regards to nitrogen and crude protein contents can be improved by balanced nutrition. This work will serve as a basis for such holistic fertilizer formulation and promote the concept of integrated nutrient management.

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Table 6: Soil properties after the experiment

Soil properties			T1 (Control)	T2 (NPK)	T3 (HO-1)	T4 (HO-2)	T5 (HO-3)	T6 (GOF)	CD @ 5%
Primary nutrients	N	%	0.373^f	0.654^c	0.707^b	0.865^a	0.875^a	0.597^d	0.01
	P	%	0.0126	0.0172	0.0194	0.0204	0.0275	0.01541	NS
	K	%	0.0113	0.0177	0.0188	0.0196	0.0267	0.01552	NS
Secondary nutrients	Ca	mg kg^{-1}	3.452^d	3.557^d	5.527^b	9.257^a	9.461^a	5.287^b	0.35
	Mg	mg kg^{-1}	1.274^d	1.576^c	3.007^b	7.776^a	7.785^a	2.967^b	0.07
	S	mg kg^{-1}	0.193^d	1.170^b	0.318^c	1.707^a	1.716^a	0.309^c	0.01
Supplementary nutrients	Fe	mg kg^{-1}	5.846^b	5.972^b	6.364^b	15.872^a	16.200^a	6.336^b	1.42
	Cu	mg kg^{-1}	0.001^d	0.059^b	0.057^b	0.077^a	0.085^a	0.050^b	0.01
	Zn	mg kg^{-1}	1.343^d	1.475^d	7.192^b	9.777^a	9.788^a	2.178^c	0.68
	Mn	mg kg^{-1}	1.846^f	1.787^g	3.515^c	4.388^b	4.401^a	2.505^d	0.01
Organic Matter (OM) %			0.514^c	0.523^c	0.616^b	0.611^b	0.606^b	0.785^a	0.02
(pH) = 1:1			5.20^e	5.25^e	6.00^a	5.90^b	5.80^c	5.41^d	0.06
EC. 25°(dS m^{-1})			46.843^e	115.513^c	121.643^b	132.44^a	134.75^a	81.535^d	3.97
C.E.C. (cmol kg^{-1})			0.183^d	0.373^c	0.763^b	0.783^b	0.800^a	0.815^a	0.02
Bulk Density (Db) g cm^{-3}			1.573^a	1.533^c	1.473^e	1.453^f	1.445^f	1.495^d	0.01
Porosity (E) %			23.113^c	25.613^c	29.103^b	33.273^a	33.32^a	26.035^b	3.49

Note: Mean values with identical superscript letters (a,b,c,d.e) are not significantly different at ($p \leq 0.05$). (n = 4); NS = Non significant, CD = Critical difference

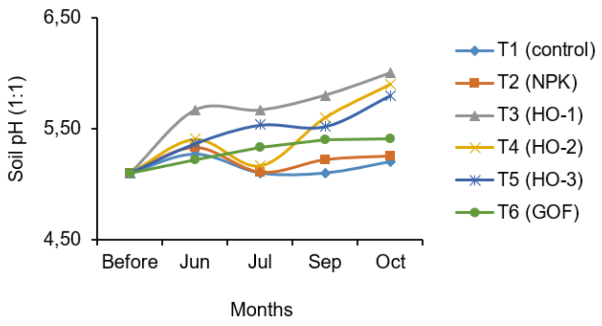

Figure 5: Soil pH during the second cropping season

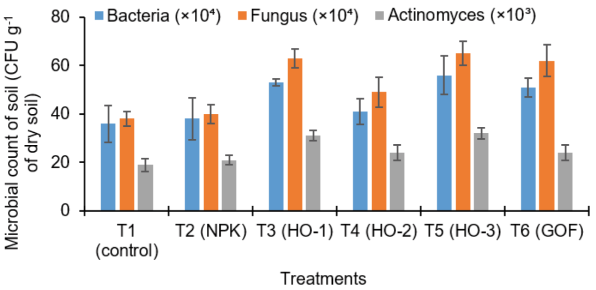

Figure 6: Soil microbial abundance after the trial

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