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Original Article

Assessment of fertilizers for improved productivity of maize (*Zea mays* L.)

Agbesi Kwadzo Keteku[1, 4*], Pumisak Intanon[1], Suwat Terapongtanakorn[2], and Ruankwan Intanon[3]

[1] *Faculty of Agriculture, Natural Resources and Environment, Naresuan University, Mueang, Phitsanulok, 65000 Thailand*

[2] *Department of Agricultural Science, Faculty of Agriculture, Ubon Ratchathani University, Warin Chamrap, Ubon Ratchathani, 34190 Thailand*

[3] *Faculty of Business, Economics and Communication, Naresuan University, Mueang, Phitsanulok, 65000 Thailand*

[4] *CSIR - Crop Research Institute, Fumesua, Kumasi, Ghana*

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Abstract

A field experiment was conducted to evaluate the influence of five fertilization strategies on maize productivity in a randomized complete block design with four replications at Phitsanulok, Thailand in 2018. The treatments; T2 312.5 kg HO fertilizer/ha; T4 250 kg NPK + 0.5% KNO_3 at 60 days after planting (DAP); T3 250 kg NPK + micro nutrients mixture spray-0.5% at 60 DAP and T1 250 kg NPK + 12.5 tons farmyard manure (FYM)/ha, recorded a significantly high grain yield of 8,865.22 kg/ha, 8,695.22 kg/ha, 7,821.89 kg/ha and 7,240.56 kg/ha, respectively, compared to the control 312.5 kg NPK/ha (6,423.33 kg/ha). This lead to a significant ($p \leq 0.05$) yield increase of 27.5%, 26.1%, 17.9% and 11.3%, respectively over the control/ha. Plant analysis revealed that, NK uptake were greatest in T4 (116.83 and 207.32 kg/ha) and T2 (99.68 and 169.04 kg/ha). P uptake was highest in T2 (56.04 kg/ha) and T3 (52.42 kg/ha). Economic studies also showed that profit increased by 40.1%, 36.9%, 26.2% and 9.0% in T2, T4, T3 and T1 respectively, as well as the highest benefit cost ratio (B:C) (1.91) in T2. After the trial, improvement in soil properties were much more in (T2 < T1 < T3 < T4 < control). Soil organic matter and cation exchange capacity (CEC) were significantly improved by T1 and T2; this showed that the soil's health and resilience to retain and release nutrients had improved. We recommend the treatments T2, T4, T3 and T1 for high maize yield production and T2 and T1 for soil properties enhancement.

Keywords: maize yield, potassium nitrate, production economics, soil properties, HO fertilizer

1. Introduction

Maize (*Zea mays* L.) is an important global cereal crop, and ranks 3rd in production and 1st in productivity among the cereals. It accounts for about 30% of the global total energy needs in 94 developing countries of approximately 4.5 billion people (Shiferaw, Prasanna, Hellin, & Bänziger, 2011). Despite its global importance, maize productivity is still low in the developing countries due to imbalance use of chemical fertilizers (Amanullah & Khan, 2014). In Thailand, maize productivity in the medium range, however sustaining maize productivity is a major issue. This has become a challenge because most of the farmer's fertilization plans do not favor organic nor micro nutrients inputs, as such, imbalance fertilization is wide spread. The soils of most maize growing zones in the country are gradually becoming acidic as well (Intanon, Keteku, & Intanon, 2017); leading to a decrease in soil fertility. Maize is an exhaustive crop and therefore,

*Corresponding author
Email address: keteku.agbesi@yahoo.com

requires a balanced supply of essential plant nutrients (Khaliq, Abbasi, & Hussain, 2006).

Recently, farmers often practice foliar spray to boost maize yield, and is support by (Amanullah & Khan, 2014; Amanullah, Khan, Kumar, & Shah, 2015). According to these authors, foliar application of nutrients can overcome the problem of nutrient unavailability to crop and also hasten the efficiency of nutrient uptake. However, some previous studies had in contrast mentioned that, continuous application of inorganic fertilizers to intensify crop cultivation is unsustainable in a long run due to their inability to condition the soil physicochemical and biological properties (He, Zhang, & Xu, 2015; Li & Han 2016). For these reasons, the reuse of agricultural bio-products as fertilizer and their integration with inorganic fertilizers has gain popularity. Earlier studies had recommended organic + inorganic as the most practical strategy to conserve soil productivity and simultaneously improve crop growth (He *et al.*, 2015; Keteku, Intanon, Terapongtanakorn, & Intanon, 2018; Li & Han 2016). Similarly, the application of micro nutrients in cereal production has been long recommended (Salem & El-Gizawy, 2012). The Land Development Department, Thailand, has advocated the application of effective microorganisms (EM) to improve soil productivity. Khaliq *et al.* (2006) showed that, the integration of NPK + organic manure + effective microorganisms (EM) can significantly increase cotton yield and soil fertility, compared to NPK alone. These approaches seems ideal, however the cost of supplying all these components in a production system increases production cost, and therefore deter farmers.

As a consequence, the Faculty of Agriculture, Naresuan University, Thailand developed a new chemical and granular organic fertilizer with hormone mixed formula (HO) by combining chemical fertilizer, compost powder, soil amendments, bio-liquid hormone and bio-liquid fertilizer (Keteku *et al.*, 2018); to improve crop yield and soil productivity. Earlier studies by Intanon *et al.* (2017) had reported that, the HO sugarcane formula increase sugarcane yield by 51.3% and soil properties; N from 0.582 to 0.86%, organic matter (OM) from 0.595 to 0.954%, EC from 56.81 to 148.72 dS/m and CEC from 0.17 to 0.87 cmol/kg when compared to the control. In addition, Jubkaew and Intanon, (2012) investigated the impact of hormones compound granular fertilizer (HOF2) on rice yield at Phitsanulok, Thailand in 2011 and reported that, HOF2 produced a significant seed weight of 784.09 kg/rai (rai = 0.16ha). Therefore in our research, we assessed the influence of the HO maize formula, integration of chemical and organic fertilizer, and foliar spray of KNO_3 and micronutrients on maize yield, soil fertility and farmers income.

2. Materials and Methods

2.1 Site description

The field experiment was conducted at Kaengsong in the Phitsanulok province of Thailand during the raining season of 2018. The site is situated on an altitude of 1,028 m above sea level at 19° 15’ 28.0440’’ N and 76° 46’ 25.4748’’ E. The average annual rainfall and temperature of the province are 1,339 mm and 27.8 °C, respectively. During the study, the mean monthly rainfall, maximum and minimum temperatures were 73.12 mm, 34.1 °C and 24.6 °C, respectively. Relative humidity was in the range of 84.33% to 79.70%, while maximum sunshine, wind speed and evaporation were 6.36 hr, 2.71 Kt and 4.76 mm, respectively. The research soil was clay loam; the properties of the soil at 0-20 cm depth are shown in Table 1.

2.2 Experimentation

The research was conducted in randomized complete block design with four replications and five treatments in a gross and net plot size of 7 m x 6 m and 6 m × 5 m, respectively. The treatments were recommended rate 312.5 kg NPK:15-15-15/ha (control); T1 250 kg NPK:15-15-15 + 12.5 tons farmyard manure (FYM)/ha; T2 312.5 kg HO fertilizer/ha; T3 250 kg NPK:15-15-15 + micro nutrients mixture spray- 0.5% at 60 days after planting (DAP); T4 250 kg NPK;15-15-15 + 0.5% KNO_3 at 60 DAP. The 312.5 kg NPK/ha was used as control because it is the standard and normal practice of maize farmers in the province (50 kg NPK/rai), so we set that as the standard for comparison in order to demonstrate the impact of other fertilization techniques to the farmers. The HO fertilizer, FYM, micro nutrient mixture and KNO_3 were sourced from the Faculty of Agriculture, Naresuan University. The composition of the HO fertilizer is shown in Table 2. The FYM was broadcasted and ploughed into the soil. The land was ploughed with a tractor drawn plough to a depth of 20 cm and harrowed twice before sowing. The seeds of hybrid maize (*Pacific 999 Super*) were sowed at a spacing of 75 cm × 25 cm, at a seed rate of 18

Table 1. Soil properties before the experiment

N g/kg	P mg/kg	K mg/kg	Fe	Zn	Cu mg/kg	Mn	B	OM%	pH 1:1	CEC cmol/kg	EC dS/m
9.8	3,500	11,600	1,033	9.21	1.07	32.55	0.18	0.94	6.51	0.175	59.83

Table 2. Composition of the HO fertilizer

N	P	K	Ca	S	Mg	Fe	Cu	Zn	Mn
	%				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 CFU/g (10^3)	Actinomyces CFU/g (10^4)	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

kg/ha. Two seeds were dibbled per hill and thinned out after 14 DAP to maintain one seedling per hill. The solid fertilizers were applied by the side placement method, 30% was applied after 14 DAP and the remaining 70% at 45 DAP.

2.3 Data collection

Twelve soil cores were randomly sampled from 12 spots on the site at a depth of (0-20 cm) using the hand auger for the assessment of soil properties before the study. 50 g of the sampled soil was oven dried at 105±5 °C for 12 hrs. The procedures of Association of Official Analytical Chemist, (1975) were adopted for the estimation of soil nutrients. Total N was estimated by the Kjeldahl method, available P by Bray's no. II method and available K, Fe, Zn, Cu, Mn and B by the inductive coupled plasma emission spectrometry 4300 Optima DV (PerkinElmer Instruments, Norwalk, CT), respectively. Soil pH was measured at 1:1 solution ratio, using the electrode (H19017 Microprocessor) pH meter. Soil organic matter (OM) was determined by the modified Walkley-Black method, while electrical conductivity (EC) and cation exchange capacity (CEC) were estimated with the EC meter and the ammonium acetate method, respectively (Association of Official Analytical Chemist, 1975).

For the HO fertilizer, total nitrogen was determine by the Kjeldahl analysis, while the determination of other nutrients concentration were done by the inductive coupled plasma emission spectrometry 4300 Optima DV (PerkinElmer Instruments, Norwalk, CT) and the results shown in (Table 2). The microbial properties (bacterial, fungus and actinomycetes) in the HO fertilizer were estimated by the serial dilution and poor plate method (Sanders, 2012). The microbial abundance was worked out as Equation 1.

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

Hormones (indole-3-acetic acid (IAA), gibberellic acid (GA_3) and cytokinins) in the HO were estimated 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. 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. Cytokinins 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 (contain 50 ml ACN, pH 3.4 triethanolamine) and B) acetonitrile at the flow rate of 1 ml/min (Szkop & Bielawski, 2012).

Fifteen representative plants were randomly selected in each plot and tagged for the measurement of vegetative growth. Plant height, number of leaves, leaf length, leaf width, and leaf area per plant were measured after 14 DAP at 10 days interval. On harvest day (120 DAP), the 15 sample plants were uprooted, oven dried at 72±2 °C for 12 hrs for total dry matter weight measurement. Leaves were grouped into three class viz., small, medium and big. The maximum length and width of three leaves from each group were measured using the hand held laser leaf area meter (CID Bio-Science, Inc.) and the method of Saxena and Singh (1965) was used to calculate the leaf area/plant Equation 2.

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

where; L, D and N are leaf length, leaf width and number of leaves, respectively. 0.75 is leaf area constant for maize. Only the final values were reported here. Leaf area index was calculated as Equation 3.

$$\text{Leaf area index (LAI)} = \frac{\text{Leaf area / plant (cm}^2)}{\text{Planting (cm}^2)} \quad (3)$$

Yield components viz; cob weight/plant, grain number/cob, grain weight/cob and 1000 seeds weight were measured from the 15 sampled plants. After harvesting, grain weight/plot and straw weight/plot were measured, all the plants in the net plots were consider and the amounts converted into ha. The grains were measured at 13% moisture using the moisture meter (FARMEX model, Delhi, India). The biological yield produce was determined as the summation of cob weight/plot and straw weight/plot and converted into ha. Harvest index (HI) was estimated as Equation 4.

$$\text{HI} = \frac{\text{Grain yield / ha (kg)}}{\text{Biological yield (kg)}} \text{ X 100} \quad (4)$$

Also, dry matter accumulation efficiency in the grain (DMAE), shelling % and percentage yield increase were calculated as Equations 5 to 7.

$$\text{DMAE (\%/day)} = \frac{\text{Grain yield / plant (g)}}{\text{Total dry matter / plant (g)}} \text{ X } \frac{100}{\text{Crop duration}} \quad (5)$$

$$\text{Shelling \%} = \frac{\text{Grain yield / plant (g)}}{\text{Cob weight / plant (g)}} \text{ X 100} \quad (6)$$

$$\text{Yield increase \%/ha} = \frac{\text{Increase}}{\text{Original value}} \text{ X 100} \quad (7)$$

where increase = new value – original value. This similar formula was used to calculate percentage profit increase/ha.

The 15 sampled plant/plot were grounded (cob + straw) per treatment for the estimation of nitrogen, phosphorus and potassium contents, for quality assessment, following the methods; Kjeldahl digestion method and it content quantified by an auto analyzer and Vanadomolybdate phosphoric acid digestion methods (Yahya, 1996). The nutrient uptake by plants was calculated as Equation 8.

$$\text{Nutrient uptake (kg/ha)} = \frac{\text{Nutrient content in plant (\%) X Dry matter weight (kg/ha)}}{100} \quad (8)$$

The economic assessment of the fertilizers was done according to the procedures of (Byerlee, 1988). The cost incurred and the revenue obtain were considered. The standard prices of the inputs, wages, selling price of maize and total cost of production were calculated by the Accounting Department, Naresuan University. Profit was calculated by subtracting the total production cost of each treatment from the revenue realized. The benefit cost ratio (B: C) of each treatment was estimated by Equation 9.

$$\text{B: C ratio} = \frac{\text{Revenue (baht/ha)}}{\text{Production cost (baht/ha)}} \quad (9)$$

2.4 Statistical analysis

The data recorded were subjected to Analysis of Variance (ANOVA) and comparison of treatment means (Duncan's Multiple Range Test (DMRT) were performed using SPSS version 17.0. and presented in tables, in alphabets with 'a' depicting highest value. Correlation analyses were performed to depict the relationship between some variables.

3. Results and Discussion

3.1 Maize growth

Maize growth variables viz; leaf length, leaf area/plant, leaf area index and total dry matter produced per plant were significantly ($p \leq 0.05$) affected by fertilizer. Plant height, number of leaves and leaf width/plant did not vary among the fertilizers (Table 3). The maize plants exhibited a fixed number of nodes but foliar KNO_3 application (T4) increased the intermodal length much more and produced the highest height of 264.18 cm, followed by T2 (250.64 cm). Leaf length, leaf area/plant and leaf area index were similarly highest in T2 and T4 with 59.20 cm and 59.63 cm; 7,273.92 cm^2 and 7,013.12 cm^2; 3.88 and 3.7, respectively. The greatest leaf width of T2 (10.24 cm) influenced its higher leaf area/plant. The control also produced a higher plant height and leaf length of 253.97 cm and 51.40 cm compared to T1 and T3. However, due to the greater leaf width (9.13 cm) produced by T3, its leaf area/plant of 5,466.56 cm^2 and leaf area index of 2.92 were higher than the control. The sink capacity of a crop is mainly dependent on vigorous vegetative growth (Khaliq *et al.*, 2006). At higher leaf area/plant, more green areas were available for the interception of active radiation for photosynthesis in the crop, leading to greater dry matter production (Azarpour, Moraditochaee, & Bozorgi, 2014). LAI is an important indicator of photosynthesis system, higher LAI relates to higher photosynthesis rate and greater yield (Azarpour *et al.*, 2014). The total dry matter accumulated were highest in the order T4 < T2 < T3 < T1 < control with 269.33, 258.38, 247.77, 236.40, and 223.20 g, respectively. The highest vegetative growth observed under T4 can be attributed to the functions of NPK. The KNO_3 sprayed supplied more nitrogen and potassium to the crops; nitrogen is a principal constituent of protein, chlorophyll and the hormones which causes cell elongation; while potassium enhances the availability of nitrogen to crops, accelerates water uptake and activation enzymes for greater dry matter production (Keteku *et al.*, 2018). Previous studies had reported the influence on KNO_3 on maize growth (Amanullah *et al.*, 2016); wheat (Amal, Tawfik, & Hassanein, 2011) and soybean (Raj & Mallick, 2017).

Besides having NPK in the fertilizers, secondary and micronutrients do also influence cell division, chlorophyll construction and photosynthesis (Intanon, 2013); this may probably explains why T2 and T3 produced a comparable dry matter to T4. It is important to state that, when NPK levels were reduced to 40 kg and combined with either micronutrient spray (T3) or FYM (T1), the dry matter produced were greater. In the (Table 2), the NPK levels of the HO fertilizer were lower but it promoted highest vegetative growth, compared to the other fertilizers except (T4). This can be related to the presence of the hormones (IAA, GA_3 and Cytokinins). Nitrogen interacts with gibberellin and cytokinins to increase plant grow (Timothy & Joe, 2003). A linear correlation coefficient of (R^2=0.7615) was noticed between leaf area/plant and dry matter/plant, indicating that dry matter production responded positively to an increase in leaf area/plant (Figure 1). This result can be correlated to previous findings of Amal *et al.* (2011). According to Raj and Mallick, (2017) the application of 80 kg N/ha + 0.203% Ca $(NO_3)^2$ + 0.25% KNO_3 produced the maximum leaf area index of 1.748 and 1.592, and dry matter mass of 1404.3 and 1288.8 g/m^2 in soybean.

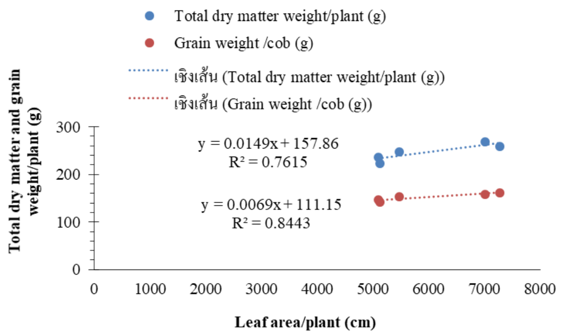

Figure 1. Correlation coefficient of leaf area/plant to total dry matter weight/plant and grain weight/cob

Table 3. Effect of fertilizers of maize growth

Treatments	Plant height (cm)	Number of Leaves/plant	Leaf length /plant	Leaf width /plant	Leaf area /plant (cm^2)	Leaf area index (LAI)	Total dry matter weight/plant (g)
Control	253.97	16	51.40[b]	8.30	5,130.72[b]	2.74[c]	223.20[c]
T1	226.87	16	48.63[b]	8.77	5,097.56[b]	2.72[c]	236.40[bc]
T2	250.64	16	59.20[a]	10.20	7,273.92[a]	3.88[a]	258.38[ab]
T3	217.95	16	49.90[b]	9.13	5,466.56[b]	2.92[bc]	247.77[ab]
T4	264.18	16	59.63[a]	9.83	7,013.12[a]	3.74[ab]	269.33[a]
CD (5%)	NS	NS	6.16	NS	1530.12	0.82	28.22

Note: mean values with different superscript letter within each column indicates significance ($p<0.05$) between different treatments. NS = Non-significant, CD = Critical difference (n = 15)

3.2 Maize yield

The maize yields produced were in accordance with the balanced and high nutrient status of the fertilizers (Table 4). Maize yield components viz; cob weight/plant, grain number/cob, grain weight/cob and 1000 seeds weight were on a par in T2, T4 and T3. Similarly, no significant differences were observed between T1 and control, however the combination of NPK and FYM (T1) produced greater yield components than NKP alone (control). Nevertheless, the highest yield components of 179.87 g, 545.90, 162.10 g and 324.76 g, respectively were record under T2. The performance of T2 might be due to the supply of balanced nutrients, as well as hormonal effect. Hormones can increase the endosperm cell number and size of grains for heavier grains (Cai *et al.*, 2014). The nutrients; N, Fe, Cu, Zn, S and Mg are also important elements in the synthesis of organic compounds (carbo hydrate) in crops (Intanon, 2013); as such, the fertilizers which contained higher amount of these nutrients produced the greatest yield. In our study, foliar application of KNO_3 and micro nutrient mixture produced higher yield than the use of FYM and sole NPK application. The greatest grain yield of 26.60 kg/plot and 8,865.22 kg/ha were recorded in T2. The straw yield/ha, biological yield/ha and HI did not vary significantly ($p \leq 0.05$) among the fertilizers. A significant increase of 27.5%, 26.1%, 17.9% and 11.3% in the grain yield of T2, T4, T3 and T1, respectively were found, compared to the control. From our results, DMAE was also not significantly impacted by the fertilizers; however the highest (0.53%/day) was notice in the control. This is a measure of efficiency, not the amount produced. Probably, the greater dry matter translocated to the cobs and straws of the other treatments, might had decrease the rate of the other treatments. A similar observation was made in shelling %, the fertilizers that produced the greatest cob weight, recorded a lower shelling percentage of 85.28, 85.89% and 86.28% in T3, T2 and T4, respectively. This indicates that the husk and spindle of these treatments were heavier as well. A positive relationship (R^2=0.8443) was again noticed between leaf area/plant and grain weight/plant (Figure 1). Our findings are in line with Intanon *et al.* (2017) and Intanon (2013). Consistent to our results also, Amanullah *et al.* (2016) reported that the application of 1 to 3% foliar K and 0.1 to 0.2% foliar Zn were found most beneficial for maize yield. Raj and Mallick (2017) also reported a 10.7% increase in soybean yield when 0.25% KNO_3 spray proceeded 80 kg N/ha.

3.3 Plant nutrient content and uptake

Analysis of the maize plants, revealed a significant ($p \leq 0.05$) variations in the percentage nitrogen and phosphorus contents and uptakes (Figures 2 and 3). Potassium content and uptake were not significantly influenced by the fertilizers, probably due to the initial medium K level in the soil. However, the highest NK contents were realized in T4 with 0.81% and 1.44%, respectively and was followed by T2 with 0.72% and 1.23%, respectively, due to their high uptake of 116.83 kg/ha and 201.32 kg/ha in T4 and 99.67 kg/ha and 169.04 kg/ha in T2. The KNO_3 applied in T4 made available more N and K to the plants. In T2, T3 and T1 the high NPK contents recorded in the plants may be due to the positive synergy between micro and macro nutrients; as well as the microorganisms in the HO fertilizer. Microorganism play important role in making nutrients available to plant roots (Keteku *et al.*, 2018). The T1 and T2 contained some amount of organic matter, which can interact with soil microbes to increase nutrient availability. This lead to a high P content in T2 (0.41%) and T1 (0.36%) compared to T4 (0.33%) and control (0.32%). Our work concurs with those of (Zilic *et al.*, 2011). The least nutrient content and uptake were observed in the control. Figure 4 shows that grain yield increased with an increase in nutrient uptake. A linear correlation of (R^2=0.8714; 0.6720; 0.7021) were noticed between NPK uptake and grain yield.

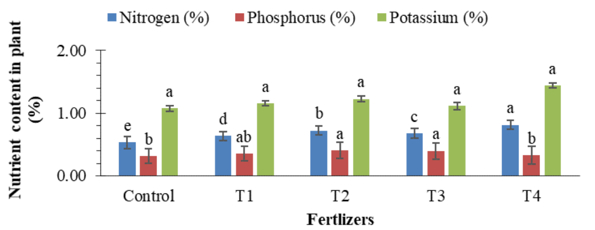

Figure 2. Effect of fertilizers on maize nutrient content (bars = standard deviation values)

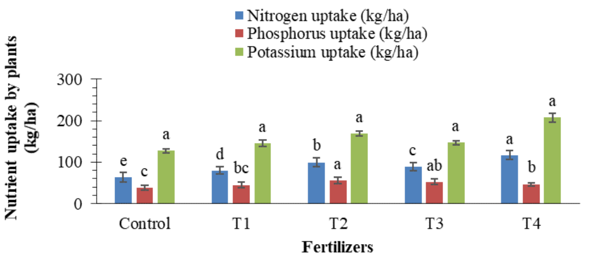

Figure 3. Effect of fertilizers on maize nutrient uptake (bars = standard deviation values)

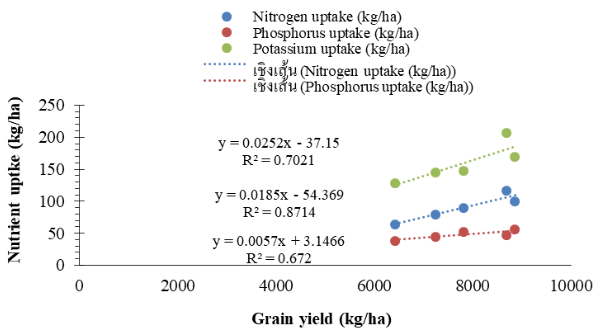

Figure 4. Correlation coefficient of nutrients uptake to grain yield

3.4 Soil properties after the study

The results in the Table 5 show that soil fertility got improved after the trial. Improvement in N and P were significant among the fertilizers but not K. Residual N and P were much improved under T2 (153 g/kg and 4,900 mg/kg) and T1 (15 g/kg and 4500 mg/kg) compare to the initial soil status. Although not significant ($p \leq 0.05$), the highest (K, Fe and Cu) contents were greatest in T2 and T1 as well. Again,

Table 4. Effect of fertilizers on maize yield

Treatments	ɫCob weight /plant (g)	ɫGrains number /cob	ɫGrain weight /cob (g)	1000 seeds weight (g)	Grain weight/ plot (kg)	Grain weight /ha (kg)	Straw weight /ha (kg)	Biological yield/ha (kg)	Harvest index (%)	DMAE (%/day)	Shelling %
Control	157.07^{c}	446.90^{c}	142.47^{c}	284.83^{c}	19.27^{c}	6423.33^{c}	10,400.00	18,589.89	0.35	0.53	90.70
T1	162.50^{bc}	474.33^{bc}	147.13^{bc}	294.19^{c}	21.72^{bc}	7240.56^{bc}	9,800.00	18,291.67	0.40	0.52	90.54
T2	188.73^{a}	545.90^{a}	162.10^{a}	324.76^{a}	26.60^{a}	8865.22^{a}	10,966.67	20,568.78	0.43	0.52	85.89
T3	179.87^{ab}	521.10^{ab}	153.40^{abc}	306.91^{b}	23.47^{ab}	7821.89^{ab}	10,355.56	19,304.22	0.41	0.52	85.28
T4	183.47^{ab}	529.93^{a} b	158.30^{ab}	317.50^{ab}	26.09^{a}	8695.22^{a}	11,055.56	20,361.89	0.43	0.49	86.28
CD (5%)	22.74	68.07	12.99	11.85	3.97	1,321.81	NS	NS	NS	NS	NS

Note: mean values with different superscript letter within each row indicates significance ($p<0.05$) between different treatments. NS = Non-significant, CD = Critical difference. ɫ(n = 15)

Table 5. Soil properties after experiment

Soil properties			Control	T1	T2	T3	T4	CD (5%)
Primary nutrients	N	g/kg	12^{b}	15^{a}	15.3^{a}	10.6^{b}	13.5^{ab}	3.20
	P	mg/kg	$4{,}200^{b}$	$4{,}500^{ab}$	$4{,}900^{a}$	$3{,}800^{b}$	$4{,}400^{ab}$	600
	K	mg/kg	12,500	13,600	14,600	12,500	1,4800	NS
Micro nutrients	Fe	mg/kg	1,010.0	1,243.0	1,281.3	1,183.3	10,14.0	NS
	Cu	mg/kg	1.02	1.14	1.95	1.02	0.98	NS
	Zn	mg/kg	9.89^{c}	17.31^{a}	19.75^{a}	15.63^{ab}	10.78^{bc}	5.63
	Mn	mg/kg	32.81^{b}	42.40^{ab}	52.27^{a}	36.29^{b}	32.13^{b}	11.67
	B	mg/kg	0.17^{b}	1.16^{b}	1.38^{a}	0.65^{c}	0.18^{b}	0.15
Organic Matter (OM) %			0.95^{b}	3.96^{a}	1.15^{b}	0.94^{b}	0.96^{b}	0.22
pH (1:1)			6.48	6.53	6.57	6.43	6.47	NS
EC. 25 °C (dS/m)			67.25^{c}	90.97^{a}	87.15^{ab}	73.17^{bc}	69.34^{c}	16.20
CEC (cmol/kg)			0.17^{bc}	0.29^{a}	0.25^{ab}	0.18^{bc}	0.16^{c}	0.08

Note: mean values with different superscript letter within each row indicates significance ($p<0.05$) between different treatments. NS = Non-significant, CD = Critical difference. (n = 3)

Zn, Mn and B contents were also substantially improved under the T2, T1 and T3 treatments. Most notably, B was significantly improve by T2 (1.38 mg/kg) compared to the other fertilizers. It was obvious from the data that, the compound fertilizer (HO) and T1 had proved that, the combination of organic and chemical fertilizer can improve soil fertility better than chemical fertilizer alone. Additionally, OM, EC, and CEC were much improved by T1 (3.96%, 90.97 dS/m and 0.29 cmol/kg) and T2 (1.15%, 87.15 dS/m and 0.25 cmol/kg, respectively). OM was tremendously improved by T1 compared to all other fertilizers. In contrast, pH decreased under the sole chemical fertilizers (control, T3 and T4), while OM and CEC remained almost the same as the initial. However slight improvement in EC was found under the chemical applications. Nevertheless, the variations between the fertilizers on soil pH were not significant. The improvement observed in T1 was due to the beneficial effect of FYM (He *et al.*, 2015; Li & Han 2016) while that of T2 was down to the presence of Ca, Mg, OM, dolomite and EM in the HO fertilizer. Several previous studies have reported that OM and EM interrelates to improve soil properties (Amanullah *et al.*, 2016; Khaliq *et al.*, 2006). The significant ($p \leq 0.05$) improvement of OM and CEC by T1 and T2 does indicate that the soil's health and resilience to retain and release nutrients had improved and may intend enhance soil quality through soil aggregation.

3.5 Economic implications

The production economics of the fertilizers (Table 6) illustrates that, total production cost/fertilizer was highest in T4 and T2 with 37,538.88 and 37,196.78 baht/ha, respectively. The total production cost of T1 was higher (35,717.50 baht/ha) compared to the control (31,185.88 baht/ha) due to the price and transportation cost of the FYM. After the sale of the produce, the greatest revenue of 70,921.76 baht/ha was recorded by T2 and was followed by T4 < T3 < T1 < control. Nevertheless, after the deductions, the profit realized and the B: C ratios of the fertilizers were not significant, but T2; T4; T3 and T1 recorded more profit of 33,724.98; 32,022.88; 27,362.54 and 22,206.98 baht/ha, respectively than the control. The B: C ratios of T1 (1.62) was lesser, compared to the control (1.65) due to its higher production cost. Our economics studies showed that the integration of chemical and organic fertilizers (T1 and T2); foliar spray of KNO_3 (T4) and micro nutrients (T3) produced better result than the application of NPK alone (Jubkaew & Intanon, 2012). The treatments T2, T4, T3 and T1 increase the profit by 40.1%, 36.9%, 26.2% and 9.0% compared to the control. Our findings are consistent with those of Intanon (2013).

Table 6. Production economics of the fertilizers

Details	Control	T1	T2	T3	T4	CD (5%)
Material Cost						
Total basic material cost (seed & Allacore weed control pill, Baht/ha)	4,620.00	4,620.00	4,620.00	4,620.00	4,620.00	
Fertilizer cost (Baht/ha)	3,900.00	5,120.00	4,200.00	3,520.00	3,750.00	
Labor Cost						
Basic labor cost (ploughing, harrowing & spraying of herbicide Baht/ha)	4,500.00	4,500.00	4,500.00	4,500.00	4,500.00	
Fertilizer application cost (Baht/ha)	2,000.00	2,500.00	2,000.00	3,200.00	3,200.00	
Harvesting cost (500 Baht/ton)	3,861.57	4,120.43	4,932.86	4,410.99	4,847.96	
Other cost						
Fertilizer transportation cost (Baht/ha)	100.00	1100.00	100.00	100.00	100.00	
Maize threshing cost (300 Baht/ton)	1,926.99	2,172.17	2,659.57	2,346.57	2,608.57	
Maize storage sacks (50 kg/bag; 30 Baht/bag; 600 Baht/ton)	3,853.99	4,344.34	5,319.13	4,693.13	5,217.13	
Total production cost (Baht/ha)	31,185.88	35,717.5	37,196.78	35,212.58	3,7538.88	
Grain yield (kg/ha)	6423.33	7240.56	8865.22	7821.89	8695.22	
Total revenue (8 Baht/kg)	51,386.64[c]	57,924.48[bc]	70,921.76[a]	62,575.12[ab]	69,561.76[a]	10,574.45
Profit (Baht/ha)	20,200.76	22,206.98	33,724.98	27,362.54	32,022.88	NS
Benefit: Cost ratio (B:C)	1.65	1.62	1.91	1.78	1.85	NS
Ranking base on profit (1 = best, 5 = last)	5	4	1	3	2	

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

4. Conclusions

Our work has demonstrated that, the HO fertilizer with balanced nutrients, hormones and EM promoted the highest maize growth, yield, nutrient uptake and income. Spraying KNO_3 and micronutrients at the grain filling stage (60 DAP) improved nutrient uptake and maize yield greater than sole NPK application. A significant 27.5%, 26.1%, 17.9%, and 11.3% increase in grain yield were observed in T2, T4, T3 and T1, respectively compared to the control. Similarly, the treatments T2, T4, T3 and T1 increase the profit gained by 40.1%, 36.9%, 26.2% and 9.0% compared to the control. The significant increase in soil organic matter and CEC by T1 and T2 does indicate that the soil's health and resilience to retain and release nutrients had improved and may intend enhance soil quality through soil aggregation. We recommend the treatments T2, T4, T3 and T1 for high yield production and T2 and T1 for soil properties enhancement.

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References

Amal, G. A., Tawfik, M. M., & Hassanein, M. S. (2011). Foliar feeding of potassium and urea for maximizing wheat productivity in sandy soil. *Australian Journal of Basic and Applied Sciences, 5*, 1197-1203.

Amanullah, A. I., Khan, H. I., Kumar, M., & Shah, A. (2015). Foliar nitrogen management for improving growth and yield of dryland wheat. *Cercetări Agronomice în Moldova*, *48*, 23-31.

Amanullah, Iqbal, A., Irfanullah, & Hidayat, Z. (2016). Potassium management for improving growth and grain yield of maize (*Zea mays* L.) under moisture stress condition. *Scientific Reports, 6*, 34627. doi:10.1038/srep34627.

Amanullah, K. K. M., & Khan, A. (2014). Growth and yield response of maize (*Zea mays* L.) to foliar NPK-fertilizers under moisture stress condition. *Soil & Environment, 33*, 116-123.

Association of Official Analytical Chemists (1975). *Official and tentative methods of the Analysis*. Washington, DC: Author.

Azarpour, E., Moraditochaee, M., & Bozorgi, H. R. (2014). Effect of nitrogen fertilizer management on growth analysis of rice cultivars. *International Journal of Biosciences, 4*, 35-47. doi:10.12692/ijb/4.5.35-47

Byerlee, D. (1988). *An economics training manual, Agronomic data to farmer's recommendation*. Mexico: CIMMYT.

Cai, T., Xu, H., Peng, D., Yin, Y., Yang, W., & Ni, Y. (2014). Exogenous hormonal application improves grain yield of wheat by optimizing tiller productivity. *Field Crops Research, 155*, 172-183.

He, Y. T., Zhang, W. J., & Xu, M. G. (2015). Long-term combined chemical and manure fertilizations increase soil organic carbon and total nitrogen in aggregate fractions at three typical cropland soils in China. *Science of the Total Environment, 532*, 635-644.

Intanon, P. (2013). The influence of different types of fertilizers on productivity and quality of maize in the area of Kwaew Noi Bamrungdan Dam, Phitsanulok Province, Thailand. *International Journal of Environmental and Rural Development, 4*, 15-20.

Intanon, P., Keteku, A. K., & Intanon, R. (2017). Effect of different materials on soil pH improvement, soil properties, growth, yield and quality of sugarcane. *Proceeding of the East and Southeast Asia Federation of Soil Science Societies, 13*, 50-59.

Jubkaew, S., & Intanon, P. (2012). Effect of hormones compound granular fertilizer on growth and yield of rice. *Khon Kaen Agriculture Journal, 40*, 105-109.

Keteku, A.K., Intanon, P., Terapongtanakorn, S., Intanon, R. (2018). Evaluation of fertilizer management on yield and yield components and production economics of "*Pacific 999 Super*" maize cultivar. *World Research Journal of Agricultural Science, 5*, 147-156.

Khaliq, A., Abbasi, M. K., & Hussain, T. (2006). Effects of integrated use of organic and inorganic nutrient sources with effective microorganisms (EM) on seed cotton yield in Pakistan. *Bioresource Technology, 97,* 967-972. doi:10.1016/j.biortech. 2005.05.002

Li, L. J., & Han, X. Z. (2016). Changes of soil properties and carbon fractions after long-term application of organic amendments in Mollisols. *CATENA, 143*, 140-144. doi:10.1016/j.catena.2016.04.007

Raj, A., & Mallick, R. B. (2017). Effect of nitrogen and foliar spray of potassium nitrate and calcium nitrate on growth and productivity of yellow sarson (*Brassica campestris* L. var yellow sarson) crop under irrigated condition. *Journal of Applied and Natural Science, 9,* 888 -892.

Salem, H. M., & El-Gizawy, N. K. B. (2012). Importance of micronutrients and its application methods for improving maize (*Zea mays* L.) yield grown in clayey soil. *American-Eurasian Journal of Agricultural and Environmental Sciences, 12*, 954-959. doi:10.5829/idosi.aejaes.2012.12.07.1759

Sanders, E. R. (2012). Aseptic laboratory techniques: plating methods. *Journal of Visualized Experiments, 63,* 3064. doi:10.3791/3064

Saxena, M. C., & Singh, Y. (1965). A note on area estimation of intact maize leaves. *Indian Journal of Agronomy*, 10, 437-439.

Shiferaw, B., Prasanna, B. M., Hellin, J., & Bänziger, M. (2011). Crops that feed the world 6. Past successes and future challenges to the role played by maize in global food security. *Food Security, 3*, 307. doi:10.1007/s12571-011-0140-5

Szkop, M., & Bielawski, W. A. (2012). Simple method for simultaneous RP-HPLC determination of indolic compounds related to bacterial biosynthesis of indole-3-acetic acid. *Antonie Van Leeuwenhoek, 103*, 683-91.

Timothy, W., & Joe, E. (2003). Rice fertilization. *Mississippi Agricultural and Forestry Experiment Station, 13,* 1-4.

Yahya, A. (1996). Effects of fertilizer rate on leaf nutrient composition, growth, flowering and quality of marigold plants. *MARDI Research Journal*, *24*, 13-18.

Zilic, S., Milasinovic, M., Terzic, D., Barac, M., & Ignjatovic-Micicet, D. (2011). Grain characteristics and composition of maize specialty hybrids. *Spanish Journal of Agricultural Research, 9*, 230-241.