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Economic production of maize under chemical and granular organic fertilizer with hormone mixed formula, NPK and organic fertilizer

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ABSTRACT

A new hybrid of maize (*Pacific 999 Super*) was investigated under six treatments; organic fertilizer (OF), chemical and granular organic fertilizer with hormone mixed formula A (HO-A), formula B (HO-B), formula C (HO-C), NPK-15-15-15 and control in 2017 and 2018 seasons at Phitsanulok, Thailand. The treatments were arranged in randomized complete block design (RCBD) with 3 replications. Fertilizer application rate was 300 kg/ha. Initial soil analysis had shown lower rates of NPK (0.394%, 0.013% and 0.191%). The vegetative growth data showed that, mean plant height, leaf area, leaf chlorophyll and total dry matter/plant were highest in HO-C (255.49 cm, 158.37 dm^2, 61.10 and 299.62g, respectively). A maximum grain weight (9,289.67 kg/ha), crude protein (8.99%) and profit (889.6 $/ha) were again recorded in HO-C. The results have demonstrated that the HO-C produced the greatest yield, income and is recommend for maize production.

Key words: Fertilizer, HO, Maize, Profit, Yield.

INTRODUCTION

Proper fertilization of maize is essential to secure a sustainable crop yield and soil productivity (Wei *et al.*, 2016). Low soil fertility and inappropriate nutrient management are the major factors hindering crop productivity (Koireng *et al.*, 2018). Most often smallholder farmers are unable to supply the necessary major and micro nutrients due to higher cost, resulting in imbalanced fertilization across the globe (Koireng *et al.*, 2018). Hence, there is an urgent need to seek for an alternative cheaper nutrient source, which will reduce cost and maintain good soil health (Wei *et al.*, 2016). Earlier studies by Khaliq *et al.* (2006) stated that, prudent combination of NPK, organic fertilizers and effective microorganisms (EM) improves soil properties. The low nutrient content of organic fertilizers hinders its use (Intanon *et al.*, 2017). Li and Han (2016) pointed out the inability of inorganic fertilizers to promote long term soil sustainability.

A new chemical and granular organic fertilizer with hormone mixed formula (HO) was developed by Naresuan University, by combining inorganic fertilizer, soil amendments, mixed compost, bio-liquid hormone, herbal plant extracts and bio-liquid fertilizer (Intanon *et al.*, 2017). Previous studies have reported that the various components of this fertilizer improves crop yield. The effect of hormones compound fertilizer and bio-fertilizer on rice growth and yield has been investigated (Jupkaew and Intanon, 2012). Rice yield increased by 50% compare to the control. Similarly, Intanon *et al.*, (2017) reported that the HO sugarcane formula increase sugarcane yield by (320.6 kg/ ha^{-1}) than the control. However, the benefits of OH on maize yields in Phitsanulok still remain to be tested. Therefore in our study the HO maize formula was investigated on maize productivity.

MATERIALS AND METHODS

Experimental fertilizers: The NPK-15-15-15 and OF were procured from the Land Development Department of Thailand. OF was produce from chicken and pig manure. The material components of the HO fertilizers are shown in (Table 1).

Research location: The trial was conducted during 2017 and 2018 seasons at Phitsanulok, Thailand. Phitsanuluk is situated on (16° 55′ 0″ N / 100° 30′ 0″ E, respectively). The soil of the site was sandy loam, under the Ultisols classification and poor in plant nutrients (0.394% N, 0.013% P, 0.191% K, 4.40 mg/kg Ca, 1.28mg/kg Mg, 0.22mg/kg S, 0.536% OM, 5.3 pH. The average monthly rainfall, maximum and minimum temperatures were during the trial were 73.12mm, 34.1°C and 24.6°C, respectively.

Research plan: The investigation was designed in RCBD with 3 replications. The treatment were; organic fertilizer (OF), chemical and granular organic fertilizer with hormone mixed formula A (HO-A), formula B (HO-B), formula C

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Table 1: Material components of HO.

Material components for maize	Kg		
	HO-A	HO-B	HO-C
Inorganic fertilizer (70% NPK; 20% Ca Mg S; 10% Fe Zn Cu Mn)	25	30	40
Soil amendments	20	20	15
Mixed compost	25	25	20
Bio-liquid hormone	10	10	10
Herbal plant extracts	5	5	5
Bio-liquid fertilizer	15	11	10
Total	**100**	**100**	**100**

(HO-C), NPK-15-15-15 and control (no fertilizer). The treatments were randomly allocated to plots of 6m × 5m. The hybrid corn (*Pacific 999 Super*) was planted at a seed rate and spacing of 18 kg/ha and 75cm x 25cm, respectively. A fertilizer dose of 300 kg/ha was used and 0.9 kg fertilizer was applied per plot. The fertilizer application was in two splits; 30% at 14 DAP and 70% at 45 DAP.

Fertilizer nutrient analysis: Total NPK contents were determined by the Kjeldahl method, Bray's no. II method and Neutral N ammonium method (Lu, 1999). Ca, Mg, Fe, Mn, Cu and Zn were determined by wet digestion (Nitric-perchloric digestion) method (Lu, 1999). Fertilizer pH was measured with electrode (H19017 Microprocessor) pH meter at a fertilizer water ratio of 1:1.5. The potassium dichromate oxidation method was adopted to determine organic matter (OM), while cation exchange capacity (CEC) was determined by the ammonium acetate method (Lu, 1999).

Vegetative data: Ten representative sample plants were randomly selected per plot for vegetative data collection. Observations on plant height, leaf area, leaf chlorophyll were collected after 14 DAP at 10 days interval till flowering 54 DAP. One representative plant was uprooted from each plot at after 14DAP at 20 days interval to investigate dry matter accumulation till harvesting. The plants were oven dried at 72 ± 2°C for 24 hr before weighing. The SPAD-502Plus meter was used to measure leaf chlorophyll content. Saxena and Singh (1965) formula was used to calculate leaf area plant^{-1}.

$$\text{Leaf area/plant}^{-1}\ (\text{dm}^2) = (L \times D \times N \times 0.75) \qquad \text{(Eqn 1)}$$

Where; L, D and N are leaf length, leaf diameter and leaves number/plant respectively. 0.75 is leaf area constant for maize.

Yield and grain quality: Grain weight/plant was measured from the ten sample plants. The grains on each cobs/plot were individually weighed, summed up and recorded as grain weight/plot and converted to grain yield/ha. 100 seeds were randomly sampled from each plot, weighed and recorded as 100 seeds weight. The grains were measured at 13% moisture content using the moisture meter (FARMEX model, Delhi, India). Grain nitrogen content was analyzed by Kjeldahl digestion method (Yahya, 1996). The average N content of the two seasons was converted into crude protein content by the convection factor 5.68 (Sriperm *et al.*, 2011).

Economics of production: Byerlee (1988) method was adopted for the economics studies. The average grain yield of the two seasons was use for the assessment. The cost incurred and the revenue obtain were considered. The prices were based on the standard market price given by the Ministry of Agriculture, Thailand. Benefit cost ratio (B: C) of each treatment was calculated as;

$$\text{B:C} = \frac{\text{Total revenue}}{\text{Production cost}} \qquad \text{(Eqn 2)}$$

Statistical analysis: The data recorded were subjected to Analysis of Variance (ANOVA) using the software package SPSS 17.0 for Windows (SPSS Inc., Chicago, USA). Difference between treatments means were separated by Duncan's multiple range test (DMRT) at a probability of 5%.

RESULTS AND DISCUSSION

Analysis of the experimental fertilizers: The nutrient contents to the fertilizers varied statistically ($p<0.05$) as shown in (Table 2). From the results OF, HO-A, HO-B and HO-C, contained (N P K Ca Mg S Fe Zn Cu and Mn). Nitrogen, phosphorus and potassium contents were highest in the NPK15-15-15 and HO-C treatments (10.920, 9.272 and 9.175%, respectively). Similarly, the secondary and micro nutrients, pH and CEC were maximum in HO-C. OM was highest in OF (7.50%). According to Wei *et al*. (2016) fertilization is one of the most important and manageable factor influencing crop growth. He stated that the type and value of fertilizer directly influence the release of nutrients. Therefore, balanced and optimum nutrients are of immense significance. The pH of all the fertilizers were at good level and would not hinder the release of nutrients.

Vegetative growth: Significant ($p<0.05$) variations in maize growth were observed over the two seasons (Table 3). Maize height was significantly higher in all the treated plots compared to the control. The average highest height (255.49cm) and leaf area/plant (158.37dm^2) were noticed in HO-C. In the 2018 season, leaf area was not significant between HO-C (156.99dm^2) and NPK-15-15-15 (148.09dm^2). Mean leaf chlorophyll contents were similar

Table 2: Chemical analysis of the fertilizers.

Soil properties			Fertilizer treatments OF	NPK-15-15-15	HO-A	HO-B	HO-C	CD (P ≤ 0.05)
Primary nutrients	N	%	4.886	15.00	7.023	8.715	10.92	0.82*
	P	%	4.650	15.00	6.518	7.802	9.272	0.82*
	K	%	4.801	15.00	6.412	7.755	9.175	0.15*
Secondary nutrients	Ca	mg/kg	2.371	0.00	6.561	6.631	7.990	0.30*
	Mg	mg/kg	0.982	0.00	1.548	1.611	1.650	0.04*
	S	mg/kg	0.024	0.00	0.051	0.051	0.055	0.01*
Supplementary nutrients	Zn	mg/kg	0.498	0.00	1.504	1.593	1.658	3.86*
	Cu	mg/kg	0.024	0.00	0.047	0.048	0.056	NS
	Fe	mg/kg	2.42	0.00	9.61	11.23	14.11	NS
	Mn	mg/kg	0.75	0.00	1.32	1.51	1.74	0.04*
(pH) = 1:1.5			6.9	6.4	7.10	7.40	7.50	0.18*
Organic matter %			1.39	0.00	1.08	1.16	1.27	0.07*
CEC (cmol/kg)			12.82	12.54	20.66	23.88	24.01	0.76*

*Significant at P ≤ 0.05; NS- Non Significant at P > 0.05.

Table 3: Vegetative growth.

Treatments	Plant height (cm)			Leaf area/plant (dm^2)			Leaf chlorophyll (SPAD unit)			Total dry matter (g)		
	2017	2018	mean	2017	2018	mean	2017	2018	mean	2017	2018	mean
OF	205.45	215.89	210.67	94.65	95.21	94.93	47.76	49.49	48.62	174.81	176.77	175.79
HO-A	220.36	235.12	227.74	126.05	126.61	126.33	56.89	58.62	57.75	227.32	229.29	228.30
HO-B	222.85	239.26	231.05	134.97	135.54	135.25	60.45	62.18	61.31	271.56	273.52	272.54
HO-C	250.94	260.04	255.49	159.76	156.99	158.37	61.24	60.97	61.10	298.64	300.61	299.62
NPK 15-15-15	226.22	259.99	243.10	147.81	148.38	148.09	60.22	61.95	61.08	263.30	265.27	264.28
Control	156.69	153.46	155.08	76.20	66.43[d]	71.31	20.03	19.43	19.73	149.19	127.82	138.51
CD (P ≤ 0.05)	47.89	48.59	21.97*	10.52	16.18	7.57*	4.46	4.14	2.04*	21.4	30.76	17.31*

*Significant at P ≤ 0.05.

in HO-B, HO-C, NPK-15-15-15 and HO-A (61.31, 61.10, 61.08 and 57.75, respectively) due to their high N content. In addition, total dry matter weights were highest (298.64 and 300.61g) in HO-C in both seasons. A slight increase in growth was noticed in 2018. Similarly, the OF treatment also showed superior growth compared to the control. According to Sreedevi *et al.* (2018) the effect of fertilizers on nutrient availability to crop can be observed from their impact on vegetative growth. In our work, vegetative growth was in accordance with the nutrient status of the treatments. Besides having N, an important element in cell division in the fertilizers, secondary and minor nutrients also relates to cell division, the construction of chlorophyll and photosynthesis (Sreedevi *et al*., 2018; Intanon *et al*. 2017). The greater dry matter produced by HO-C, HO-B and NPK-15-15-15 may be due to the availability of more green area for photosynthesis, due to their high plant height and leaf area/ plant. Again, the presence of OM in OF and HO group may had increased nutrients availability. It is noteworthy to mention that, vegetative growth was greater under the NPK treatment compared to OF and as well, produced greater dry matter weight (264.28 g) over HO-A (228.30 g) owing to its higher levels of NPK. Our results concur with that of Zerihun *et al.* (2013) who reported a maize height of 232.9cm under 110/46 NP + 16 t/ha farmyard manure (FYM) and 236.2cm under 110/46 NP + 4 t/ha.

Yield and grain quality: Grain weight and 100 seeds weight increased slightly in 2018 under all fertilizers. In contrast, a decrease was noticed in the control plot (Table 4). The mean highest grains and 100 seeds weight/plant (166.23g and 37.90g, respectively) were observed in HO-C. This lead to a greater average grain yield/ha of (9289.67kg), followed by HO-B and NPK treatments in (Table 5). The performance of the HO-C might be due to the higher vegetative growth resulting from optimum balanced nutrients supply (Wei *et al*., 2016); which might have resulted in higher nutrients uptake and better translocation of assimilates from source to sink for greater yield. In our results, the treatments with higher P content and a balance of other nutrients (Table 2) produced the greatest yield. Although the NPK treatment had no secondary and minor nutrients, because of its high P content (15%), grain yield was higher. Also, (N S Mg Fe Cu and Zn) are major factors in the synthesis of carbohydrate and sugar, hence under their adequate supply more organic compound were produced in HO-C and HO-B. As a result, there were weight gains in terms of grain weight plant^{-1}. The average grain nitrogen contents (1.58 and 1.53%) and crude protein (8.99 and 8.67%) were highest in HO-C and NPK-15-15-15 (Table 5). The HO and NPK influenced higher grain weight than OF. Grain weight/plot between HO-A (24.29 kg) and OF (22.12 kg) were not significant. Our findings are in agreement with Kumar *et al.* (2010) report

Table 4: Maize yield and yield components.

Treatments	Grain weight/plant (g)			100 seeds weight (g)			Grain weight/plot (kg)		
	2017	2018	mean	2017	2018	mean	2017	2017	mean
GF	125.93	127.27	126.60^{b}	31.20	34.40	32.80	21.46	22.79	22.12
HO-A	155.60	156.93	156.27^{a}	33.50	37.57	35.53	23.80	24.79	24.29
HO-B	159.57	160.90	160.23	35.27	38.37	36.82	26.34	27.00	26.67
HO-C	165.57	166.90	166.23	36.00	39.80	37.90	27.21	28.53	27.87
NPK 15-15-15	156.41	157.74	157.08	34.77	38.23	36.50	25.88	26.20	26.04
Control	98.50	92.17	95.33	29.87	27.17	28.52	16.74	11.40	14.07
CD ($P \leq 0.05$)	20.59	19.52	19.66*	2.70	5.02	3.36*	2.76	2.97	2.39*

*Significant at $P \leq 0.05$.

Table 5: Maize yield and grain quality.

Treatments (50 kg/ha^{-1})	Grain yield/ha kg			Grain nitrogen %			Crude protein content %
	2017	2018	mean	2017	2018	mean	
OF	7153.00	7595.22	7374.11	1.02	1.23	1.12	6.38
HO-A	7931.67	8262.78	8097.22	1.03	1.22	1.13	6.40
HO-B	8778.56	8998.56	8888.56	1.24	1.58	1.41	8.03
HO-C	9068.56	9510.78	9289.67	1.54	1.63	1.58	8.99
NPK 15-15-15	8625.56	8734.44	8680.00	1.44	1.61	1.53	8.67
Control	5580.22	3800.22	4690.22	0.92	0.90	0.91	5.17
CD ($P \leq 0.05$)	921.20	989.47	1567.88*	0.24	0.23	0.22*	1.23*

*Significant at $P \leq 0.05$.

Table 6: Research expenditure.

Expenditure	Cost				
	Price/unit $	Quantity	$/ha		$/ton
Materials costs					
Basic material costs:-					
Seed cost	47.6	3.6 bags	171.4		
Allacore weed control pill	4.8	6 box	28.6	200.0	
Fertilizer cost:-					
Control	-			-	
NPK:15-15-15	27.9	6bags		167.6	
HO-A	21.6	6bags		129.5	
HO-B	24.8	6bags		148.6	
HO-C	27.9	6bags		167.6	
OF	14.3	6bags		85.7	
Labour cost					
Basic labour costs:-					
Labor cost for ploughing	79.4		158.7		
Labour cost for spraying herbicide			50.8		
Labour cost for planting			131.7	341.2	
Labour cost for fertilizer application				63.5	
Labour cost for harvesting					20.6
Labour cost for transporting yield					15.9
Other costs					
Basic cost for pumps and spraying				9.5	
Fertilizer transportation cost				9.5	
Maize threshing cost					11.1
Cost of storage sacks (1.3 $ /sack)					25.4

Table 7: Production cost and profit.

Details	OF	HO-A	HO-B	HO-C	NPK (15-15-15)	Control	CD($P \leq 0.05$)
Material Cost							
Basic material cost $/ha	200.0	200.0	200.0	200.0	200.0	200.0	
Fertilizer cost $/ha	85.7	129.5	148.6	167.6	167.6	0.0	
Labour Cost							
Basic labour cost $/ha	341.3	341.3	341.3	341.3	341.3	341.3	
Fertilizer application cost $/ha	63.5	63.5	63.5	63.5	63.5	0.0	
Harvesting cost $/ton	152.2	167.1	183.4	191.7	179.1	96.8	
Yield transportation cost $/ton	117.1	128.5	141.1	147.5	137.8	74.4	
Other cost							
Total basic other costs $/ha	9.5	9.5	9.5	9.5	9.5	9.5	
Fertilizer transportation cost $/ha	9.5	9.5	9.5	9.5	9.5	0.0	
Maize threshing cost $/ton	81.9	90.0	98.8	103.2	96.4	52.1	
Maize storage sacks $/ton	187.3	205.6	225.7	235.9	220.4	119.1	
Total production cost $/ha	1248.0	1344.6	1421.4	1469.7	1425.2	893.2	
Revenue							
Sale of Grain 0.254 $/kg	1872.8	2056.4	2257.4	2359.3	2204.4	1191.2	
Profit $/ha	**624.8**	**711.9**	**836.0**	**889.6**	**779.2**	**298.0**	**126.5***
Benefit: Cost ratio (B:C)	**1.50**	**1.53**	**1.59**	**1.61**	**1.55**	**1.33**	**NS**

*Significant at $P \leq 0.05$; NS- Non Significant at $P > 0.05$.

that 75% N/ha + 60 kg P_2O_5/ha + 60 kg K_2O/ha + 5L Azotobacter/ha + 1% enriched banana sap, produced the highest yield. Khaliq *et al.* (2006) recorded the highest seed cotton yield (2470 kg/ha) under $N_{170}P_{85}K_{60}$ + EM + OM fertilization. Consistently, Agegnehu *et al*. (2016) also recorded (8.08 t/ha) of maize seed yield in a trail of $N_{150}P_{41}K_{120}S_3$ kg/ha + 10 t/ha biochar + 25 t/ha compost.

Economic impact: From the (Tables 6 and 7), cost of production and revenue were highest (1469.7 and 2359.3 $/ha) in HO-C followed in cost by NPK (1425.2 $/ha) and HO-B (1421.4 and 2257.4 $/ha) According to our findings, the maximum profit (889.6 $/ha) was again realized under HO-C due to its higher yield. The profit of HO-B (836.0 $/ha) and NPK (779.2 $/ha) were on a par. The percentage increase in profit of HO-C, HO-B and NPK were (66.5%, 64.4% and 61.8%, respectively) compared to the control. The B: C ratio of the treatments were not significant, however the best (1.61) was in HO-C, followed by HO-B (1.59), NPK (1.55), HO-A (1.53), OF (1.50) and control (1.53).

CONCLUSION

Our findings have shown that, HO-C, HO-B and NPK-15-15-15 produced the highest maize growth, yield (9289.67, 8888.56 and 8680.00 kg/ha, respectively) and profit (889.6, 836.0 and 779.2 $/ha, respectively). It was evident from the results that, balance supply of major and micro nutrients promotes maximum maize yield and farmer income. In addition, the combination of inorganic and organic nutrient sources as in HO can build up the soil organic matter content and help increase nutrients availability to crop for greater yield. The control produced the lowest maize yield and profit. The B: C ratios of the fertilizers showed a positive economic implication. Agriculture policies should therefore encourage the inclusion of micro nutrients in fertilizer plans. We recommend the HO-C formula for maize production.

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