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Comparative Assessment of Fertilizers on Yield and Quality of Marigold (*Tagetes erecta* L.)

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ABSTRACT

Different types of fertilization strategies were investigated on marigold (*Golden King F1*) in a randomized complete block design (RCBD) with four replications at Thailand. The treatments were composed of chemical and granular organic fertilizer with hormone mixed formula (HO) and two NPK fertilizers. From the results, flower size (6.22 cm), flower yield/plot (16.05 kg) and flower yield/ha (16053.19 kg) were highest in the chemical and granular organic fertilizer with hormone mixed formula C (T15). Flower shelf-life was more prolonged in T15 (8.58 g) after 72 hr of harvest. Carotenoid content, hue angle and B value were also highest in T15 (114.32 mg/100g fresh weight, 86.80° and 121.44), respectively. Also, the nitrogen, phosphorus and potassium contents in the plants were maximum in T15 (0.15%, 0.48% and 2.38%), respectively. The treatment T15 produced the greatest yield due to its high balance nutrients and is recommended for commercial marigold production.

Key words: Effective microorganism, Fertilizers, Hormones, Marigold, Quality.

INTRODUCTION

Rising demand for marigold flower particularly in the Asian continent has awaken an urgent need for science and technology to devise new production techniques to increase marigold yield (Kumar *et al*., 2016). The use of marigold at the pharmaceutical and cosmetic industries has increased (Hussein *et al*., 2011). Government regulations have restricted the use of synthetic pigments in the poultry feed industry, as such natural sources of xanthophylls, *eg*. marigold and yellow corn are in high demand (Kumar *et al*., 2016). In Thailand, marigold seed production and consumption are approximately 12,000 Mio and 1,100 kg, respectively, on an annual production area of about 40 ha. Seed export to India, is at a minimum of 1,200 kg/year and is expected to double in the coming years in India and Southern Asia (Kumar *et al*., 2016).

Improvement in marigold yield at the farm level has been achieved either by the use of synthetic fertilizers, organic fertilizers or bio-fertilizers. Numerous studies (Mohanty *et al*. 2013; Thumar *et al*. 2013) had reported higher marigold yield and pigments in plants under organic + chemical fertilizer application. In addition, (Kumar *et al*. 2016) also did indicate the importance of plant growth regulator (gibberellic acid (GA_3) on marigold productivity. However, due to cost, farmers are unable to combine these substances in order to maximize optimum yield. Beside the material cost, the high labour cost incurred to apply these materials hinders farmer's interest. Recently, consumer awareness for safe and sustainable products have increased; market research revealed that consumers are willing to pay higher prices for environmentally safe commodities (Eaton *et al*., 2013). The way forward is to reduce the percentage of chemical usage by integrating synthetic and organic fertilizers with other yield promoting substance.

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A new chemical and granular organic fertilizer with hormone mixed formula (HO) has been developed by the Faculty of Agriculture, Naresuan University, Thailand by combining inorganic fertilizer, effective microorganisms (EM), soil conditioner, extracted bio-stimulant, plant growth regulators and bio-liquid fertilizer, at optimum rate for marigold (Keteku *et al*., 2018). Previous studies of the HO formula for other crops had shown great impact (Keteku *et al*., 2018). However, the influence of this fertilizer formula on marigold has not yet been studied. Therefore in our work, the HO marigold formula was investigated.

MATERIALS AND METHODS

Experimental fertilizers

Three HO formulas were sourced from the Faculty of Agriculture, Naresuan University, Thailand while the NPK (15-15-15) and (8-24-24) were procured from the Land Development Department, Thailand. The difference between the HO formulas is the concentration of their material component (Table 1).

Compositional analysis of HO

Total NPK contents the HO formulas were analyzed by the Kjeldahl method, Bray's No. II method and Neutral N ammonium method (Lu, 1999). Mg, Ca, Fe, Mn, Cu and Zn were analyze following the wet digestion (Nitric-perchloric digestion) method by (Lu, 1999). Soil pH was record at 1:1.5 solution ratio with electrode (H19017 Microprocessor) pH meter. The potassium dichromate oxidation method was adopted to determine organic matter. Also, CEC was determined by the ammonium acetate method while electrical conductivity (EC) was measured with the EC meter. The procedures of Lu (1999) were used to analyze bulk density and porosity. Microorganisms (bacteria, fungus and actinomyces) population were determined by the poor plate method by (Sanders, 2012). The number of microbes were calculated as in (Equation 1).

No. of microbes/g oven dry sample =

$$\frac{\text{Average plate count} \times \text{dilution factor}}{\text{1 g of oven dry sample}} \quad \text{(Eqn 1)}$$

Also, plant growth hormones such as indole-3-acetic acid (IAA), gibberellic acid (GA_3) and cytokinins contents in the fertilizer were determined 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 compositional analysis of the HO fertilizers are given in (Table 2).

Study site and treatments

This on-farm study was carried out during November 2017 to March 2018 at Phichit Province (situated on 16.44° N latitude and 100.35° E longitude), Thailand. The research soil was loamy clay in texture and low in fertility; NPK content of 0.04%, 9.43 ppm and 144.23 ppm, respectively and pH 5.9. The study was a three factorial (two chemical fertilizer and HO) designed in RCBD with three replications. The treatments were as given in Table 3. Each plot measured 4 m x 2.5 m.

Research procedure

The Golden King F1 marigold seedlings of uniform height and size were transplanted to the various plots at 14 days after nursing, in a row and inter-row spacing of 0.5 m x 0.5 m. Each plot contained 40 seedlings and was irrigated after transplanting. Fertilizer applications were in four splits, each 25% was applied at 14, 34, 54 and 74 days after transplanting (DAP) by the side placement method.

Research data

Ten representative sample plants were randomly selected per plot for the measurement of bulb flower height and size, harvested flowers number at 80% blooming/plot and flower number/plant after 40 DAP at 10 days interval. After harvesting, flower number/plot, flower yield/plot, and flower yield/ha were measured. All the matured flowers in each plot were collected at each data collection, their fresh weights were recorded and dry weights taken after oven drying at 70°C for 24 hr. After 110 DAP the final flower collection was carried out. The flower weights recorded at each observation were sum up as total yield/plot and converted into yield/ha. Quality characteristics such as; flower shelf-life, carotenoid, hue angle and B value were measured using the flowers from the 10 sample plants. Afterwards, the 10 sample plants were grounded with a Wiley mill (40 mesh) for shoot nutrient analysis. Nitrogen content was determined by Kjeldahl digestion method and it content quantified by an auto analyzer (Yahya, 1996). Ahmad (1993) method of hydrochloric and nitric acid treatment and spectrometry techniques were followed to determine P, K, Mg and Ca. Carotenoid content in the flower was analyzed by Witham *et al*. 1971 method, and calculated following the formula (Equation 2-5). Flower colour (Hue angle and B value) were measure with (Chroma Meter CR-400).

Chlorophyll a (µg/mL) =

$$(12.64 \text{ x O.D. } 664) - (2.99 \text{ x O.D. } 647) \quad \text{(Eqn 2)}$$

Chlorophyll b (µg/mL) =

$$(-5.6 \text{ x O.D. } 664) + (23.26 \text{ x O.D. } 647) \quad \text{(Eqn 3)}$$

Carotenoid (µg/mL) =

$$\frac{[(1000 \text{ O.D. } 470) - (327 \text{ x Chl a}) - (104 \text{ x Chl b})]}{229} \quad \text{(Eqn 4)}$$

To convert to mg/100g FW

Carotenoid (mg/100g FW) =

$$(\text{Carotenoid (g/mL) x } 20.5 \text{ x } 100 \text{ x } 1) \quad \text{(Eqn 5)}$$

Where; FW = fresh weight, chl a = Chlorophyll a, chl b = Chlorophyll b

Table 1: Material components of the HO formulas.

Materials	Kg		
	HO-A	HO-B	HO-C
Chemical fertilizer (8:1.5:0.5 major nutrients: secondary nutrients: micro nutrients)	30	35	40
Effective microorganism (EM)	20	15	10
Soil conditioners	30	25	20
Extracted bio-stimulant	5	5	5
Plant growth regulator (PGR)	5	10	10
Bio-liquid fertilizer	10	10	15
Total	100 kg	100 kg	100

Data analysis

Statistical analysis was performed by Analysis of Variance (ANOVA) using 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% when detected.

RESULTS AND DISCUSSION

Flower yield and yield components

The different fertilizers significantly ($p<0.05$) increased yield and yield components, when compared to the control. Application of HO-C produced better results on bulb flower height (5.97 cm), flower size (6.22 cm), flower number/plant (43.49), seed number/flower (518.67) and seed weight/plot (10.08 g), as shown in Table 4. A similar trend was noticed in harvested flower number @ 80% blooming/plot, total flower number/plot, flower yield/plot and flower yield/ha, as T15 produced the highest of 1071.67, 1739.67, 16.05 kg and 16053.19 kg, respectively compared to other treatments. The treatment T15 was particularly significant with regards to flower number/plant, total flower number/plot and seeds number/flower. The flower yield recorded by T5 was comparable to T15. There were no significant effect on the flower diameter between (T8, T9, T10, T11, T12, T13, T14 and T15). However, some tendency of increased flower size were realized. T1 recorded the lowest in all the variables measured. A rise in fertilizer dosage from (625 kg to 937 kg/ha) increased flower height and diameter but the increase were not significant. Similar results with respect to nitrogen fertilization were obtained by Hussein *et al*. (2011). The sole HO fertilizers and their combination with NPK gave the most outstanding outputs on flower number/plant, harvested flower number at 80% blooming, total flower number/plot, seed number/plant, seed weight/plot, flower yield/plot and flower yield/ha. The performance of the HO fertilizers is due to their optimum balanced nutrient supply (Keteku *et al*., 2018; Intanon 2013) as indicated in (Table 2). This might had resulted in higher nutrients uptake and better translocation of assimilates from source to sink for increased flower yield.

In general, the number of flowers harvested from a single plant in our study was higher, compared to the 21.5 harvested by Pacheco *et al*. (2013) under nitrogen and magnesium nourishment. Similar to our findings, Król, (2011) collected 60 and 45.6 flowers/plant in two successive years. Biesiada *et al*. (2006) mentioned that, higher nitrogen is not ideal for marigold, he recommended 30-50 kg/ha as the optimum. Similarly, higher dose of chemical fertilizer was not observed to enhance flower production. The greater flower weights recorded in the fertilized plots, compared to the control was due to the marginal increase in bulb flower height, diameter, seeds number and seed weight. Improvement in vegetative character (canopy spread and leaf chlorophyll) correlated positively (R^2 = 0.6445 and 0.3361) to yield (Fig 1a and b), respectively. This is an indication of increased photosynthetic activity and assimilation rate. Probably, the PGR included in the HO fertilizers influenced the endogenous auxin (Kim *et al*., 2009). Our findings are in agreement with Kumar *et al*. (2010) who reported that 7% N + 60 kg P_2O_5/ha + 60 kg K_2O/ha + Azotobacter 5L/ha + enriched banana pseudo stem Sap 1%, produced the greatest marigold yield attributes.

The nutrients; N, Fe, Cu, Zn, S and Mg are important elements in the synthesis of carbohydrate, under favorable soil conditions, the production of carbohydrate is enhanced by these nutrients. T15 increased flower and seed yield/plot

Table 2: Compositional analysis of the HO formulas.

Soil properties	HO-A	HO-B	HO-C	CD ($P \leq 0.05$)
Major nutrients				
N (%)	9.14	9.46	10.65	0.09*
P (%)	9.59	9.84	10.73	0.65*
K (%)	9.41	9.56	9.81	0.17*
Ca (%)	4.16	6.01	7.70	0.24*
Mg (%)	1.88	1.85	1.94	NS
S (%)	0.15	0.73	1.05	0.03*
Minor nutrients				
Fe (mg/kg)	2.14	2.49	2.53	0.18*
Mn (mg/kg)	218.00	221.00	221.00	1.31*
Zn (mg/kg)	93.00	172.00	179.00	6.54*
Cu (mg/kg)	22.00	23.00	26.00	1.31*
Cl (mg/kg)	2.31	2.37	3.01	0.29*
OM (%)	0.92	1.12	1.34	0.14*
pH (1:1)	6.52	6.67	6.38	0.19*
EC (1:10; uS/cm)	33.73	35.80	38.13	1.70*
Bacteria (CFU/g $\times 10^4$)	20.83	18.54	15.64	3.03*
Fungus (CFU/g $\times 10^4$)	24.25	18.61	13.80	1.58*
Actinomyces (CFU/g $\times 10^3$)	40.13	33.45	25.80	NS
IAA (mg/kg)	23.26	24.17	32.44	1.33*
GA_3 (mg/kg)	11.17	13.25	17.22	0.92*
Cytokinins (mg/kg)	5.91	7.05	8.26	0.75*

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

Table 3: Experimental Treatments.

No.	Treatments
T1	Control
T2	NPK: 15-15-15 + 8-24-24 (1:1) at 625 kg/ha
T3	15-15-15 + 8-24-24 (1:1) at 937 kg/ha
T4	15-15-15 + 8-24-24 (1:1)+ HO-A (312 kg) at 625 kg/ha
T5	15-15-15 + 8-24-24 (1:1)+ HO-A (312 kg) at 937 kg/ha
T6	15-15-15 + 8-24-24 (1:1)+ HO-B (312 kg) at 625 kg/ha
T7	15-15-15 + 8-24-24 (1:1) + HO-B (312 kg) at 937 kg/ha
T8	15-15-15 + 8-24-24 (1:1)+ HO-C (312 kg) at 625 kg/ha
T9	15-15-15 + 8-24-24 (1:1)+ HO-C (312 kg) at 937 kg/ha
T10	HO-A (625 kg/ha)
T11	HO-A (937 kg/ha)
T12	HO-B (625 kg/ha)
T13	HO-B (937 kg/ha)
T14	HO-C (625 kg/ha)
T15	HO-C (937 kg/ha)

by 49.5% and 23.3%, respectively when compared to the control.

Flower quality

The data presented in Table 5 and Fig 2 showed a significant (p<0.05) influence of fertilization on flower quality. Flower shelf-life (weight) decreased in all treatments from 24, 48 and 72 hr after harvest. Among the treatments, T15 maintain the heaviest flower weights of 9.53, 9.44 and 8.58 g, respectively after those hr. Biesiada *et al*. (2006) mentioned that flower longevity decreases with higher nitrogen dose, in our study also, flower longevity decreased more in the

Table 4: Effect of fertilizers on marigold yield and yield components.

Treatments	Bulb flower height† (cm)	Bulb flower size† (cm)	Seed no./ flower†	Seed weight/ plot (g)	Flower no./ plant†	Harvested flower no. @ 80% blooming	Flower yield plot(kg)	Flower yield/ ha (kg)
T1	5.03	5.11	261.33	7.73	26.16	684.00	8.11	8114.31
T2	5.07	5.21	352.33	8.79	33.52	771.67	11.63	11629.31
T3	5.15	5.22	372.00	9.16	36.62	929.67	13.40	13402.69
T4	5.10	5.23	361.33	9.02	33.74	830.00	12.00	11997.69
T5	5.18	5.29	374.33	9.06	39.82	990.00	14.05	14054.81
T6	5.10	5.32	344.33	8.92	35.63	716.67	11.22	11219.00
T7	5.18	5.35	398.00	8.86	39.73	888.33	13.77	13767.00
T8	5.13	6.05	372.00	9.13	35.12	886.00	11.03	11027.31
T9	5.65	6.08	423.67	9.20	37.08	949.67	13.53	13525.69
T10	5.60	6.07	372.33	9.10	31.48	745.67	11.60	11599.25
T11	5.68	6.18	428.00	9.17	35.86	885.67	12.47	12470.81
T12	5.66	6.09	393.00	9.23	34.47	785.33	12.80	12795.19
T13	5.84	6.18	456.00	9.65	38.40	910.00	13.50	13502.81
T14	5.75	6.10	438.00	9.24	35.70	730.67	12.85	12845.81
T15	5.97	6.22	518.67	10.08	43.49	1071.67	16.05	16053.19
CD (P ≤ 0.05)	0.25*	0.22*	72.80*	0.83*	2.96*	152.62*	2.09*	2088.31*

*Significant at P ≤ 0.05.

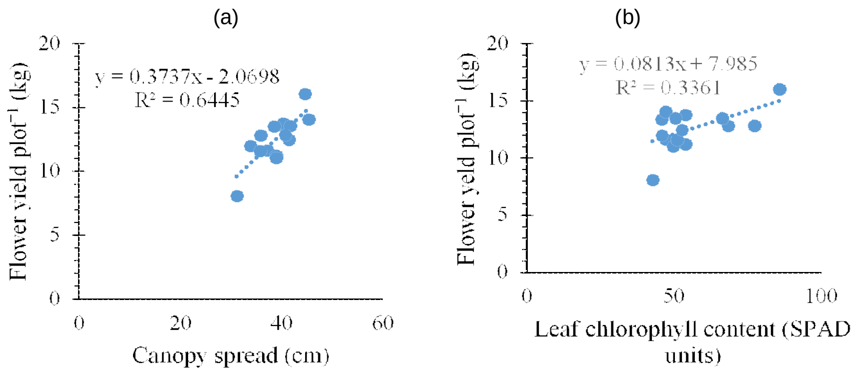

Fig 1: Correlation coefficient (a) canopy spread and flower yield (b) leaf chlorophyll content and flower yield.

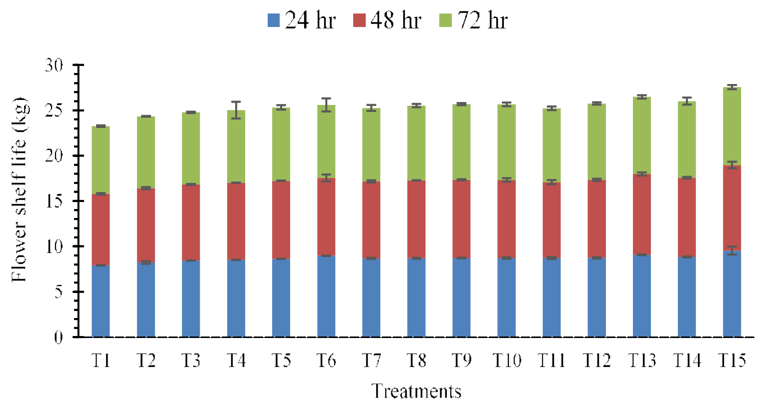

Fig 2: Shelf-life of flowers after harvesting.

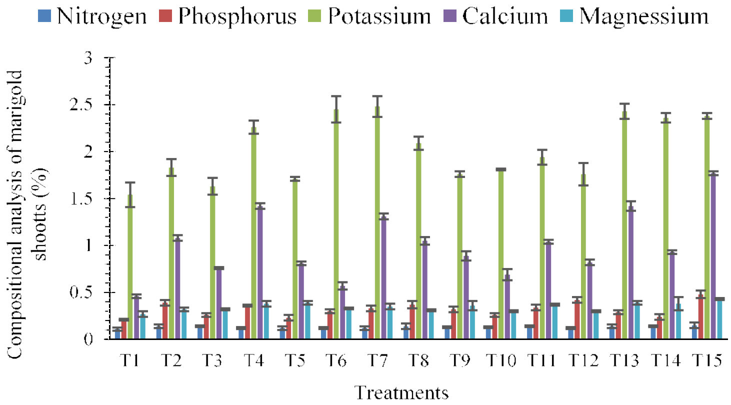

Fig 3: Compositional analysis of marigold shoots.

Table 5: Effect of fertilizers on flower quality.

Treatments	Carotenoid (mg/100g FW)	Hue value (°)	B value
T1	87.48	83.89	100.41
T2	88.26	85.30	103.13
T3	89.97	85.20	105.14
T4	91.28	84.44	105.36
T5	92.41	84.66	106.51
T6	101.09	86.03	107.75
T7	94.73	85.06	107.84
T8	96.04	85.64	107.87
T9	105.29	85.39	107.92
T10	106.37	86.20	112.65
T11	111.47	85.73	114.10
T12	104.26	85.13	112.95
T13	106.61	86.01	113.44
T14	110.01	86.26	117.50
T15	114.32	86.80	121.44
CD ($P \leq 0.05$)	13.46*	1.30*	10.34*

*Significant at $P \leq 0.05$.

treatments with higher nitrogen content after 72 hr, in contrast to T15, which is evident that moderate nitrogen rate enhance flower longevity. With regard to flower quality, the carotenoid content, hue angle and B value were more evident among the sole HO nourished plants. The highest of 114.32 mg/ 100g FW, 86.80° and 121.44, respectively were again recorded in T15, followed by T14. T1 recorded the lowest values. According to Heaton (2001), fertilization indirectly affects the biosynthesis of secondary metabolites such as carotenoid. The fertilizer treatment with the most balanced nutrients (T15) produced the greatest carotenoid (114.32 mg 100/g FW), and plant nutrient contents of N, P, K, Ca, Mg (0.15%, 0.48%, 2.38%, 1.77% and 0.43%), respectively (Table 5 and Fig 3). This occurrence might be due to the interaction of nutrients and hormones (Jubkaew and Intanon, 2012); auxins, cytokinin and gibberellic acid (GA_3) are known to enhance enzyme activities for greater biosynthesis of carotenoid. Similarly, Zaredost *et al*. (2014) measured highest carotenoid (3.903 mg/g dry weight) in marigold under biological and moderate chemical fertilization. The high hue angle and + b value are an indication of a bright yellow colour, this trait affects the marketability of the flowers as consumers reference favour a yellow gold colour. In our results in Table 5, hue angle was closer to + b zone (bright yellow). Among the treatments, T15 again produced a significant hue angle (86.80°) and +b value (121.44) over the control (83.89° and 100.41), respectively. Carotenoid content might have influence flower colour, as suchthe hue angle and b value were well expressed in (T10, T11 T12, T13, T14 and T15).

CONCLUSION

In summary, sole application of T15 (HO-C) produced the best marigold yield and quality. Integration of NPK with HO fertilizers also gave a better account on yield. Increasing fertilizer rates from (100 to 150 kg did not generally lead to a significant improvement in flower weight however, it did increase flower number/plot. Marigold flower quality traits (shelf-life, carotenoid, hue angle and B value) were better expressed in the plants nourished.

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