แก่นเกษตร 47 (6) : 1323-1336 (2562). KHON KAEN AGR. J. 47 (6) : 1323-1336 (2019). /doi:10.14456/kaj.2019.120.

Effect of Chemical and Granular Organic Fertilizer with Hormone Mixed Formula (HO) on soil improvement and growth of Marigold (*Tagetes erecta* L.)

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ABSTRACT: In this experiment a new chemical and granular organic fertilizer with hormone mixed formula (HO) was developed and tested in combination with NPK. Fifteen treatments were arranged in Randomized Complete Block Design (RCBD). Vegetative growth variables namely: plant height plant-1 (54.47 cm), stem diameter plant^{-1} (9.55 mm), number of branches plant^{-1} (9.60), canopy spread plant^{-1} (45.40 cm), leaf chlorophyll content plant^{-1} (85.92 SPAD units) at 60 DAP, total dry matter plant^{-1} (59.67 g) and shortest days to 80% blooming plot^{-1} (72.33) were highest in T15. Percentage increment in plant height and total dry matter of T15 over the control (T1) were 25% and 86.1% respectively. Similarly, maximum improvement in soil properties via: N (0.08 %), P (26.28 ppm), K (254.43 ppm) and Ca, Mg, Fe, Mn, Cu and Zn were realized in T15. The best soil pH (6.10) was recorded in T14. Additionally, T15 again realized the most enhanced OM (1.33%), CEC (20.90 mg 100g^{-1}, EC (195 uS cm^{-1}) and water content (WC) (8.09%). Increasing fertilizer dosage from 100 kg rai-1 to 150 kg rai^{-1} did not impact marigold growth and residual soil properties much, except T15.

Keywords: HO, hormones, marigold growth, NPK, soil improvement

Received November 15, 2018
Accepted June 12, 2019

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Introduction

Marigold is an ingredient in pharmaceutical preparations for therapeutic treatment due to its active substances such as; carotenoids, flavonoids, xanthophyll, sterols, triterpene saponins, essential oil, polyacetylenes, minerals, vitamin C and carbohydrates (Hussein, 2011). The demand of marigold flowers is currently on the rise, as a result farmers are forced to use all means to boost soil fertility and productivity (Ahmad et al., 2011); in-order to improve production, farmers use either organic, chemical, EM and bio fertilizers. According to Verme et al. (2011) poor soil fertility and inappropriate nutrient management are the main factors hindering marigold productivity. This often occurs due to the high cost of chemical fertilizers, leading to imbalanced fertilization (Verme et al., 2011).

Li and Han (2016) pointed out the inability of inorganic fertilizers to condition the soil and also promote long term soil sustainability. Addtionally, Agrios (1997) suggested that excessive application of nitrogen can lead to lush growth and subsequently accelerate disease and insect damages. Therefore, standardization of production technology for the fertilization of marigold is necessary. Previous study had stated that efficient integration of chemical fertilizers, organic nutrient sources, EM and soil amendments plays a vital role in improving soil properties, promoting marigold growth and also prolong flowering period and quality (Patanwar et al., 2015). As at today there is no holistic compound organo-chemical fertilizer that contains complete balance nutrients, EM, hormones and soil conditioners, in the market. The lack of such a fertilizer has challenged the efficient implementation and adaptation of integrated nutrient management system.

As such, in our study we developed a new chemical and granular organic fertilizer with hormone mixed formula (HO), which combines inorganic nutrient sources, effective microorganism (EM), soil conditioners, extracted bio-stimulant, organic plant growth regulator (PGR), and liquid bio-fertilizer in specific formulas for marigold plant. Our objective is to investigate the effect of our HO fertilizers and in combination with NPK on soil physical and chemical properties, and on the growth of marigold.

Material and method

Formulation of HO

The HO fertilizer was developed from a mixture of chemical fertilizer, effective microorganism (EM), soil conditioners, extracted bio-stimulant, organic plant growth regulator (PGR) and liquid bio-fertilizer. These materials were separately prepared and combine in specific ratios (Table 1) for three different HO formulas (HO-A, HO-B and HO-C) depicted in (Figure 1). After the granules formation, it was air dried for 12 hr and coated to control the rate of nutrient release.

Research Location

The field experiment was conducted during November 2017 to March 2018 at Phichit Province of Thailand. Phichit is situated at 16.44º N latitude, 100.35º E longitude and on 46 m elevation above sea level and soil series: Group 4

(Ban). The average weather conditions during the trial were (19.72 mm, 33.06 oC, 20.12 oC, 84.6%, 258.1 hr, 1.24 Kt, 136.92 mm) for rainfall, temperature (max and min), relative humidity, sunshine duration, wind and evaporation respectively. Water was supply by irrigation. The soil was low in fertility and sandy loam in texture.

Table 1 Material components ratio of HO fertilizer

Fertilizer	Material components for marigold (by weight, kg)						Total
	A*	B	C	D	E	F	
HO-A	30	20	30	5	5	10	100 kg
HO-B	35	15	25	5	10	10	100 kg
HO-C	40	10	20	5	10	15	100 kg

*A = chemical fertilizer (major nutrients 80%; secondary nutrients 15%; micro nutrients 5%), B = effective microorganism (EM), C = soil conditioners, D = extracted bio-stimulant, E = organic plant growth regulator (PGR), F = liquid bio-fertilizer

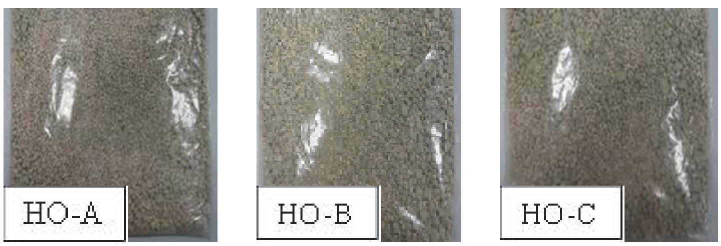

Figure 1 The HO fertilizers.

Research Design and Treatments

The trial was an experiment designed in RCBD with 15 treatments randomly distributed in three replications. Two types of chemical fertilizers, commonly used for cultivating marigold, their combinations with the HO fertilizer and sole HO fertilizers were tested. The treatments models were: T1 control, T2 =15-15-15 + 8-24-24 (1:1) = 100 kg rai-1(rai = 0.16 ha), T3 =15-15-15 + 8-24-24 (1:1) = 150 kg rai-1, T4 =15-15-15 + 8-24-24 (1:1)+ HO-A (50 kg) = 100 kg rai-1, T5 =15-15-15 + 8-24-24 (1:1)+ HO-A (50 kg) = 150 kg rai-1, T6 =15-15-15 + 8-24-24 (1:1)+ HO-B (50 kg) = 100 kg rai-1, T7 =15-15-15 + 8-24-24 (1:1) + HO-B (50 kg) = 150 kg rai-1, T8 =15-15-15 + 8-24-24 (1:1)+ HO-C (50 kg) = 100 kg rai-1, T9 =15-15-15 + 8-24-24 (1:1)+ HO-C (50 kg) = 150 kg rai-1, T10 = HO-A (100 kg rai-1), T11 =

HO-A (150 kg rai-1), T12 = HO-B (100 Kg rai-1), T13 = HO-B (150 kg rai-1), T14 = HO-C (100 kg rai-1) and T15 = HO-C (150 kg rai-1). Each plot measured 4 m × 2.5 m.

Research Procedure and Data

The N, P, K Ca, S, Mg, Cu, Fe, Mn, Zn, pH, OM, EC and CEC content of the fertilizers used in this studies were analyzed. Ten soil samples were initially collected from the whole experimental field, mixture together and a composite sample taken for soil physical and chemical properties analysis. N and P content were analyzed following Kjeldahl method and Bray's no. II method (Lu, 1999) respectively. Lu (1999) method of wet digestion (Nitric – perchloric digestion), Atomic Absorption Spectrophotometry was adopted to determine K, Ca, Mg, Cu, Fe, Mn and Zn. Ashing, titrate with silver nitrate method was followed in Cl analysis (Lu, 1999). The soil pH was measure with pH meter at a soil: water fraction of 1:1. Electrical conductivity (EC) was assessed with the EC meter. Organic matter (OM) was determined by the method of (Walker and Black, 1934) while cation exchange capacity (CEC) was measured following the ammonium acetate saturation method. Marigold, Golden King F1 cultivar seeds were nursed in a tray and transplanted after 14 days at a row spacing of 0.5 m and an inter row space of 0.5 m to each plot. 500 kg rai-1 (4.7 kg plot-1) cow dung was applied as basal treatment to all plots before transplanting. Seedlings vigor and height were uniform for all plot. Each plot had 40 seedlings. Fertilizer application was in four splits, 25% of each fertilizer were applied at 14, 34, 54 and 74 DAP (days after transplanting) respectively. The fertilizers were side placed and rates of application were as per treatment.

Five representative sample plants were randomly selected in each plot and tagged for periodic vegetative growth variables recordings. Plant height plant-1, stem diameter plant-1, number of branches plant-1, canopy spread plant-1 and leaf chlorophyll content were recorded at 10 days interval after 40 DAP. Leaf chlorophyll content was measured with SPAD-502 Chlorophyll Meter (Minolta Camera Co., Ramsey, NJ). For each plant, five new fully expanded leaves were randomly chosen for SPAD measurement and the average recorded. Also, days to 80% blooming for each plot was recorded. The total dry matter produced per plant were recorded from the five sample plants. Plant parts were oven dried at 70 ºC for 24 hr. A month after the trial, soil samples were collected from each replicate to assess the impact of the fertilizers on residual soil physical and chemical properties. All laboratory analysis were conducted at the Faculty of Agriculture, Khon Kaen University, Thailand.

Data Analysis

The data recorded were analyzed in analysis of variance (ANOVA) using SPSS 17 statistical package to quantify the variation between treatments means at a critical difference of 0.05% probability level. Duncan's multiple range test (DMRT) analysis was performed and presented in tables, in alphabets with 'a' depicting highest value.

Results

Composition of the HO Fertilizers

Average relative chemical contents of the HO fertilizers are shown in **Table 2**. From the results, all three HO fertilizers contained major and micro nutrients. HO-C contained the highest major nutrient elements. NPK of 10.66%, 10.71% and 9.83%, respectively) and Ca, S of 7.70% and 1.03%, respectively) were significantly ($p<0.05$) highest in HO-C. Mg content did not differ significantly between the HO fertilizers. However, HO-C contained maximum1.93% compared to HO-B and HO-A with 1.89% and 1.86%, respectively. Micronutrients (Fe, Mn, Zn, Cu and Cl) were maximum in HO-C except Mn which was at par between HO-C and HO-B. Highest pH of 6.69 and 6.53 were recorded in HO-B and HO-A respectively. HO-C again contained a significant more OM and EC of1.32% and 38. 15 uS cm-1 respectively than HO-B and HO-A (1.10%; 35.10 uS cm-1 and 0.91%; 33.75 uS cm-1 respectively).

Table 2 Composition of HO fertilizers

Soil properties	HO-A	HO-B	HO-C	CD (5%)
Major nutrients				
Total N (%)	9.15[c*]	9.47[b]	10.66[a]	0.09
Total P (%)	9.57[b]	9.82[b]	10.71[a]	0.65
Total K (%)	9.43[b]	9.58[b]	9.83[a]	0.17
Ca (%)	4.17[c]	6.02[b]	7.70[a]	0.24
Mg (%)	1.89	1.86	1.93	NS
S (%)	0.13[c]	0.71[b]	1.03[a]	0.03
Minor nutrients				
Fe (mg kg^{-1})	2.12[b]	2.47[a]	2.51[a]	0.18
Mn (mg kg^{-1})	219.00[b]	222.00[a]	222.00[a]	1.31
Zn (mg kg^{-1})	95.00[b]	175.00[a]	181.00[a]	6.54
Cu (mg kg^{-1})	21.00[c]	23.00[b]	27.00[a]	1.31
Cl (mg kg^{-1})	2.30[b]	2.37[b]	3.00[a]	0.29
OM (%)	0.91[c]	1.10[b]	1.32[a]	0.14
pH (1:1)	6.53[ab]	6.69[a]	6.39[b]	0.19
EC (1:5, uS cm^{-1})	33.75[b]	35.10[b]	38.15[a]	1.70
C/N ratio	0.23	0.22	0.22	NS

*mean values with different superscript letter within each column denotes significance ($p<0.05$) between different groups. CD = critical difference between means; NS = non-significant.

Table 3 Influence of treatments on marigold growth

Treatments	Height (cm)	Stem diameter (mm)	No. of branches	Canopy spread (cm)			Leaf chlorophyll (SPAD units)			Days to 80% blooming
				40 DAP	50 DAP	60 DAP	40 DAP	50 DAP	60 DAP	
T1	40.87^{d}	6.48^{c}	6.10^{e}	17.11^{e}	25.43^{c}	31.20^{e}	46.95^{c}	44.73^{d}	42.72^{e}	77.33^{a}
T2	45.03^{bcd}	5.94^{d}	7.07^{d}	22.75^{ab}	27.33^{bc}	37.21^{bc}	48.88^{bc}	52.93^{cd}	47.13^{de}	76.33^{ab}
T3	46.93^{bc}	7.33^{bc}	7.40^{cd}	22.49^{ab}	33.33^{a}	40.93^{abc}	48.48^{bc}	53.51^{cd}	45.78^{de}	76.33^{ab}
T4	46.47^{bc}	7.33^{bc}	7.93^{bcd}	18.74^{de}	26.61^{bc}	33.88^{de}	48.88^{bc}	56.74^{bc}	46.02^{de}	76.00^{abc}
T5	47.66^{b}	7.99^{b}	7.33^{cd}	19.25^{cde}	33.40^{a}	44.67^{a}	50.08^{bc}	60.54^{bc}	47.14^{de}	75.67^{bc}
T6	44.49^{bcd}	7.17^{bcd}	7.87^{bcd}	19.49^{bcde}	29.61^{abc}	39.03^{bc}	47.65^{c}	58.33^{bc}	53.88^{d}	75.33^{bcd}
T7	48.46^{b}	7.60^{bc}	7.07^{d}	22.29^{abc}	32.65^{a}	40.33^{abc}	57.98^{a}	55.98^{bc}	53.98^{d}	75.00^{bcd}
T8	48.18^{b}	7.73^{bc}	7.07^{d}	19.02^{cde}	26.68^{bc}	38.93^{bcd}	56.34^{a}	61.74^{bc}	49.70^{de}	75.33^{bcd}
T9	47.7^{b}	7.47^{bc}	7.07^{d}	19.49^{bcde}	30.09^{ab}	41.80^{ab}	48.45^{bc}	58.45^{bc}	50.63^{de}	75.33^{bcd}
T10	44.73^{bcd}	7.42^{bc}	7.60^{bcd}	19.24^{cde}	29.97^{abc}	35.83^{cde}	47.57^{c}	64.84^{b}	51.22^{de}	74.67^{cd}
T11	45.00^{bcd}	6.87^{bcd}	8.67^{ab}	21.11^{abcd}	30.62^{a}	41.53^{ab}	47.51^{c}	57.8^{bc}	52.76^{d}	73.67^{de}
T12	42.33^{bcd}	7.93^{b}	7.13^{cde}	23.77^{a}	28.44^{abc}	36.00^{cd}	47.01^{c}	57.54^{bc}	68.48^{bc}	75.00^{bc}
T13	47.10^{b}	7.81^{b}	6.40^{e}	20.24^{bcde}	29.81^{abc}	38.60^{bcd}	48.14^{c}	56.93^{bc}	66.44^{c}	72.67^{e}
T14	43.43^{bcd}	6.83^{bcd}	8.27^{bc}	22.83^{a}	28.62^{abc}	40.87^{abc}	48.08^{c}	56.63^{bc}	77.41^{ab}	72.67^{e}
T15	54.47^{a}	9.55^{a}	9.60^{a}	23.78^{a}	32.27^{a}	45.40^{a}	52.00^{b}	82.58^{a}	85.92^{a}	72.33^{e}
CD (5%)	5.26	1.31	1.2	3.34	4.45	5.09	3.66	10.52	9.11	1.39

*mean values with different superscript letter within each column denotes significance ($P<0.05$) between different groups ($n = 15$). CD = critical difference between means.

Marigold Growth

To evaluate the impact of the various fertilizers, marigold growth variables via: plant height plant-1, stem diameter plant-1, branch number plant-1, canopy spread plant-1, leaf chlorophyll content plant-1, dry matter plant-1 and days to 80% flower blooming plot-1 were measured. From the results in **Table 3**, height plant-1 54.47 cm, stem diameter plant-1 9.55 mm and branch number plant-1 9.60 were significantly (P<0.05) highest in T15 compared to the other treatments. Canopy spread increased gradually with plant growth, maximum canopy spread was record at 60 DAP. Among the treatments, T15 again record the highest canopy spread of 45.40 cm at 60 DAP. In addition, the results showed that highest leaf chlorophyll content, 85.92 SPAD units was generally at 50 DAP in most treatments. However, the maximum chlorophyll content was realized in T15 at 60 DAP and was highly significant over all other treatments except T14 with 77.41 SPAD units. In the control (T1), chlorophyll content showed a decreasing trend as growth progresses. It is evident from Table 4 that, dry matter production and accumulation was more efficient in T15. This correspondingly led to a maximum total dry matter of 59.67 g. The results also revealed that, increasing the fertilizer rates from 100 to 150 kg rai-1 affected dry matter production and accumulation significantly. The shortest duration to 80% flower blooming plot-1 of 72.33 days, showcased in **Table 3** was found in T15 and the highest 77.33 days in T1. In all the measured growth parameters, T1 recorded the lowest performance.

Table 4 Influence of treatments dry matter accumulation

Treatment	Flower weight plant^{-1} (g)	Leaves weight plant^{-1} (g)	Stem & shoot plant^{-1} (g)	Root weight plant^{-1} (g)	Total dry matter plant^{-1} (g)
T1	2.08^{h}	2.94^{j}	3.04^{k}	0.23^{i}	8.29^{k}
T2	5.62^{g}	3.48^{j}	5.98^{i}	0.38^{h}	14.46^{j}
T3	6.23^{fg}	4.98^{hi}	12.20^{g}	0.57^{g}	23.98^{h}
T4	4.94^{g}	4.55^{i}	6.92^{i}	0.66^{ef}	17.07^{ij}
T5	6.72^{fg}	6.18^{gh}	14.54^{e}	0.68^{e}	28.12^{fg}
T6	4.33^{g}	8.12^{cd}	6.28^{ij}	0.59^{fg}	19.32^{i}
T7	9.20^{e}	7.16^{ef}	17.35^{d}	0.87^{b}	34.58^{cd}
T8	10.89^{d}	6.73^{fg}	10.45^{h}	0.75^{cd}	28.82^{ef}
T9	12.63^{c}	7.37^{def}	17.21^{d}	0.76^{cd}	37.97^{c}
T10	7.60^{f}	5.67^{h}	10.85^{gh}	0.72^{de}	24.84^{gh}
T11	9.45^{de}	8.51^{c}	13.78^{ef}	0.85^{b}	32.59^{de}
T12	9.36^{e}	7.73^{cde}	12.31^{fg}	0.81^{bc}	30.21^{ef}
T13	16.28^{b}	10.70^{b}	21.64^{b}	1.11^{a}	49.73^{b}
T14	17.72^{b}	7.92^{cde}	19.38^{c}	0.87^{b}	45.89^{b}
T15	20.94^{a}	11.78^{a}	25.83^{a}	1.12^{a}	59.67^{a}
CD (5%)	1.46	0.92	1.53	0.07	4.15

*mean values with different superscript letter within each column denotes significance (P<0.05) between different groups (n = 3). CD = critical difference between means.

Table 5 Influence of fertilizers on soil chemical properties

Treatments	N (%)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	Fe (ppm)	Mn (ppm)	Cu (ppm)
Soil properties before experiment								
	N (%)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	Fe (ppm)	Mn (ppm)	Cu (ppm)
	0.04	9.431	144.23	912.64	236.75	103.75	86.53	2.17
Soil properties after experiment								
T1	0.04^{e*}	7.11^{g}	118.22^{f}	1007.14^{c}	248.55^{d}	98.80^{g}	79.53^{i}	2.03^{f}
T2	0.06^{cd}	23.20^{bc}	197.07^{d}	1425.38^{b}	335.05^{c}	108.53^{fg}	101.67^{h}	2.71^{e}
T3	0.07^{bc}	31.74^{a}	270.68^{b}	1544.57^{ab}	332.45^{c}	116.13^{ef}	107.33^{gh}	2.74^{de}
T4	0.08^{ab}	21.50^{c}	215.41^{d}	1557.88^{ab}	357.37^{bc}	120.73^{def}	119.67^{bcdef}	2.73^{de}
T5	0.07^{bc}	27.85^{b}	244.86^{c}	1508.27^{ab}	323.37^{c}	121.80^{de}	112.33^{fg}	2.52^{e}
T6	0.07^{bc}	18.29^{de}	208.45^{d}	1443.53^{b}	352.29^{bc}	122.67^{de}	113.33^{efg}	2.68^{e}
T7	0.09^{a}	32.85^{a}	298.60^{a}	1599.62^{ab}	340.62^{bc}	125.93^{de}	115.00^{defg}	2.66^{e}
T8	0.06^{d}	13.94^{f}	125.29^{ef}	1592.36^{ab}	349.87^{bc}	129.93^{cd}	105.67^{gh}	2.67^{e}
T9	0.07^{ab}	19.14^{d}	198.45^{d}	1516.74^{ab}	329.18^{cc}	140.87^{bc}	116.33^{cdefg}	3.04^{bc}
T10	0.06^{cd}	16.81^{ef}	144.05^{e}	1577.84^{ab}	350.54^{bc}	148.47^{ab}	128.34^{ab}	3.06^{bc}
T11	0.06^{cd}	21.61^{cd}	195.14^{d}	1641.58^{a}	346.48^{bc}	149.47^{ab}	126.00^{abc}	2.93^{c}
T12	0.07^{bc}	19.38^{d}	200.70^{d}	1557.88^{ab}	352.35^{bc}	151.93^{ab}	124.00^{bcde}	3.01^{bcd}
T13	0.07^{bc}	22.11^{c}	251.63^{bc}	1588.73^{ab}	352.53^{bc}	153.53^{a}	125.00^{bcd}	3.79^{a}
T14	0.07^{bc}	17.06^{ef}	194.10^{d}	1632.90^{a}	358.46^{ab}	152.00^{ab}	127.33^{ab}	3.21^{b}
T15	0.08^{ab}	26.28^{b}	254.43^{bc}	1652.01^{a}	380.91^{a}	156.13^{a}	136.67^{a}	3.96^{a}
CD (5%)	0.01	3.71	23.10	186.94	23.46	12.29	10.81	0.25

*mean values with different superscript letter within each column denotes significance ($P<0.05$) between different groups ($n = 3$).
CD = critical difference between means.

Soil Analysis

In **Tables 5 and 6** shows the chemical and physical properties of the experimental soil before and after the trial. Soil fertility, notably NPK Ca, Mg, S contents were low with 0.04%, 9.431-, 144.23-, 912.64-, 236.75 ppm and 0.75%, respectively. Fe, 103.75 ppm and Mn, 86.53 ppm were in medium concentration while Cu, 2.17 ppm and Zn, 2.19 ppm were low. Similarly, OM, CEC, EC and water content (WC) of 0.62%, 12.65 mg 100 g-1, 83.79 uS cm-1 and 6.31%, respectively were also low. However, after the trail, a significant ($p<0.05$) improvement in soil properties were noticed except for pH. The highest residual soil NPK of 0.09%, 32.85 ppm, 298.60 ppm; 31.74 ppm, 270.68 ppm and 0.08%, 26.28 ppm, 254.43 ppm were observed in the treatments T7, T3 and T15, respectively. The plots under T15 nourishment again recorded the highest improved residual Ca, 1652.01 ppm and Mg, 380.91 ppm. The best improvement in soil micronutrients (Fe, Mn, Cu and Zn) were noted in T15 with averages of 156.13 ppm, 136.67 ppm, 3.96 ppm and 3.83 ppm, respectively. Moreover, OM, CEC, EC and WC were all highest in the plots under T15 fertilization with average recordings of 1.33%, 20.90 mg 100g-1, 195 uS cm-1 and 8.09%, respectively. Although soil pH was not significantly affected by fertilization, the best enhancement, 6.10 was evident in T14. At 40 and 90 DAP, as shown in Figure 2, there was a general drop in pH across all treatments except for T14 with 5.98 at 90 DAP compared to the initial pH. The results also showed that increasing fertilizer rate from 100 kg to 150 kg rai-1 did not significantly affected most soil properties except from T14 to T15.

Table 6 Influence of treatments on residual soil physical and chemical properties

Soil analysis before experiment						
	Zn (ppm)	OM (%)	pH (1:1)	CEC (mg $100g^{-1}$)	EC 1.5 (uS cm^{-1})	WC(%)
	2.19	0.62	5.90	12.65	83.79	6.31
Soil analysis after experiment						
Treatments	Zn (ppm)	OM (%)	pH (1:1)	CEC (mg $100g^{-1}$)	EC (uS cm^{-1})	WC (%)
T1	2.17^{f}	0.69^{e}	5.80	13.43^{e}	82.85^{f}	6.58^{d}
T2	2.87^{cd}	1.14^{bc}	5.50	16.55^{d}	133.20^{d}	7.93^{a}
T3	2.93^{cd}	1.02^{bcd}	5.20	20.28^{a}	174.95^{b}	7.73^{a}
T4	3.07^{c}	1.09^{bc}	5.80	17.03^{cd}	122.60^{de}	7.16^{bcd}
T5	2.50^{e}	1.02^{bcd}	5.30	18.30^{bc}	179.50^{ab}	7.53^{abc}
T6	2.70^{de}	1.13^{ac}	5.80	16.30^{d}	114.85^{e}	7.76^{ab}
T7	2.87^{cd}	0.99^{cd}	5.10	19.90^{ab}	181.60^{ab}	7.27^{bc}
T8	2.70^{de}	0.89^{d}	6.00	17.33^{cd}	133.40^{d}	7.29^{bc}
T9	3.43^{b}	1.14^{bc}	5.20	20.25^{a}	188.80^{ab}	7.79^{a}
T10	3.77^{a}	0.89^{d}	5.60	17.28^{cd}	113.05^{e}	7.05^{cd}
T11	3.67^{ab}	0.99^{cd}	5.80	18.48^{bc}	126.45^{de}	7.26^{bc}
T12	3.44^{b}	1.13^{bc}	5.90	17.83^{c}	102.95^{e}	7.99^{a}
T13	3.73^{ab}	1.18^{ab}	5.40	18.73^{bc}	154.10^{c}	7.86^{a}
T14	3.73^{ab}	1.04^{bcd}	6.10	17.23^{cd}	134.95^{d}	7.93^{a}
T15	3.83^{a}	1.33^{a}	5.80	20.90^{a}	195.00^{a}	8.09^{a}
CD (5%)	0.30	0.17	NS	1.49	16.80	0.58

*mean values with different superscript letter within each column denotes significance ($p<0.05$) between different groups (n = 3). WC = water content; CD = critical difference between means.

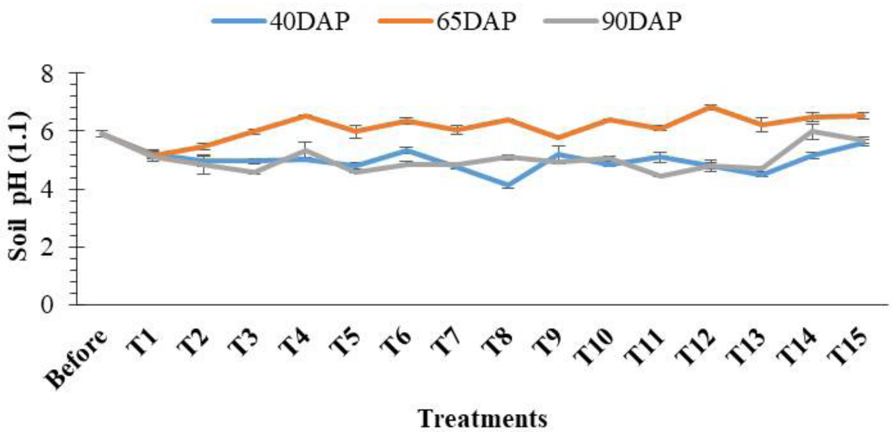

Figure 2 Effect of treatments on soil pH. Error bar are standard deviation of means.

Discussions

Fertilization plays a major role on plant growth and in replenishing lost soil nutrients (Ahmad et al., 2011). The HO fertilizers developed contained a good balance of essential nutrients needed for marigold growth, **Table 2**. Balance and optimum availability of nutrients is of immense importance for marigold (Sharma et al., 2017). Previous study by Agrios (1997) stated that excess nitrogen in a fertilizer may promote lush growth, accelerate disease and insect damages. Therefore the N contents 10.66%, 9.47% and 9.15% in the HO-C, HO-B and HO-A respectively, added to the phosphorus, potassium, and other secondary and micro nutrients were adequate for marigold growth. The OM content and the carbon to nitrogen ratios (C/N) of the HO fertilizers were ideal. The presence of a high OM, 1.32% and C/N ratio 0.22 in the HO-C makes it a very promising fertilizer. Although all the HO fertilizer had balanced sources of nutrients, **Table 2**, HO-C gave the best EC content of 3.15 uS cm-1 which can be explained by the higher secondary and minor nutrient elements it contained. According to Robbins and Evans, (2010) a high EC implies the availability of ions to be released and may enhance the cation exchange capacity of the fertilizer. The pH 6.69 and 6.53 recorded in HO-B and HO-A respectively, might be due to their higher soil conditioner composition of 25- and 30 kg respectively, depicted in **Table 1**. Similar balanced nutrients levels were reported by Intanon, 2013a in his HO maize formula.

Fertilization enhanced marigold growth and dry matter production, however in excess amount, crop growth may be compromised. The overall effect of increasing nutrient availability on marigold growth was clearly indicated by increased vegetative growth as seen in plant height, stem diameter, number of branches, canopy spread, leaf chlorophyll content, days to 80% flower blooming and dry matter weight (Sharma et al., 2017). In the **Tables 3** and **4** showed a significant ($P<0.05$) variations in marigold height. Significantly higher plant height 54.47cm was noted in T15 followed by T7 48.46 cm and T8 48.18 cm. Plant height is usually associated with higher and balanced nutrients level and might suggest an increased efficiency in whole plant assimilation rate (Sharma et al., 2017). Gomaa and Youssef (2007) stated that, NPK fertilizers plays an important physiological and biochemical functions in carbohydrate metabolism, protein synthesis and structure of photosynthetic pigments, these effects might had caused a significant increase in plant height. Ganjali et al. (2010) results claimed that under 50 and 100 kg N ha-1, differences in height were not significant. A similar phenomenon was observed in our work, increase in fertilizer rate from 100 to 150 kg rai-1 did not resulted in a significant increase in height except for T15. Our results are in accordance with the findings of Hassan et al. (2014) who obtained a marigold height of (66.02 cm) under N120 P80 K40. The maximum stem diameter plant-1 9.55 mm, branches plant-1 9.60, canopy spread plant-1 45.40 cm, leaf chlorophyll content plant-1 85.92 SPAD units and shortest days to 80% blooming plot-1 72.33 days were obtained in the treatment T15. From the Table 3, it was noticed that the HO fertilizers alone or its combination with chemical fertilizer gave the best growth parameters. It can therefore be stated that, the combination of organic nutrient sources, EM, PGR, soil stimulants, along with 40% inorganic nutrient sources, as in T15 had proved to be beneficial for robust growth of marigold as compared to other treatments. These performance may also be due to the activities of EM. Kumar et al. (2010) ascribed the improvement in stem size, number of branches and plant spread in marigold to the production of PGR and increased nutrient availability around the rhizosphere by EM. In addition, microbial decomposition might had favored the stimulation and production of axillary buds resulting in the formation of more number of branches (Zaredost et al., 2014). As the number of branches plant-1 increased in T15, plant spread equally increased, and might had favored rapid photosynthesis and dry matter accumulation for proper growth, and converted vegetative growth in early stages to produce more flower at (72.33 DAP). But the control took more days (77.33 days) to accrue 80% flowering due to late emergence of flower buds. Previous report of Li and Han (2016) confirmed the significance of organic matter on plant growth, OM contains essential nutrients which has a positive effect for chlorophyll molecules and chloroplast formation. Organic acids and carbon dioxide have a role in enhancing the availability of some nutrients such as Mg which plays an important role in the formation of the chlorophyll molecule. This findings are in agreement with (Hassan et al., 2014; Jubkaew and Intanon, 2012). The percentage increment of 25.0%, 32.1%, 36.5% and 50.3% in plant height, stem diameter, number of branches and leaf chlorophyll content (60 DAP), respectively were realized in T15 compared to the control (T1).Each subsequently higher dose of fertilizer produced a significant effect on dry matter weight. A total dry mater of 59.67 g, representing an increase of 86.1% over the control was observed in T15 nourished plots, **Table 4**. The nutrients (N, Fe, Cu, Zn, S and Mg) are also important elements in the synthesis of organic compounds (carbohydrate) in crops (Intanon, 2013a); as such the fertilizers which contained higher and balanced amount of these nutrients produced the greatest dry matter weight. A similar response was observed for dry flower weight, total flower yield plant-1, and blooming period (Ahmad et al., 2011).

A significant improvement in soil properties were observed after the trial, **Tables 5** and 6. In spite of the effectiveness of raising fertilizer rate to 150 kg rai-1, its impact of soil properties were generally not significant over the 100 kg rai-1. Residual NPK were more pronounced in the HO groups at 150 kg rai-1, the maximum of 0.08%, 26.28 ppm and 254.43 ppm, respectively were measured in T15. This results was due to the composition of HO in **Table 1**. EM and bio-fertilizers have the ability to convert nutritionally important elements, N and P from unavailable to available forms via biological process (Dikr and Belete, 2017). The highest Ca, Mg, Fe, Mn, Cu and Zn content observed among the HO fertilizers could be related to their composition. Other properties; OM, CEC, EC, WC (1.33%, 20.90 mg 100g-1, 195.00 uS cm-1 and 8.09%, respectively) and pH 6.10 were best expressed in T15 and T14 respectively. CEC is related to the percentage of OM in the soil. Research bears out the correlation between EC and CEC through their relationship on plant growth (Sharma et al. 2017). EC relates closely to other soil properties used to determine soil productivity (Sharma et al. 2017). Therefore, the high values of these properties in T15 are also a reason for its performance. Li and Han (2016) reported that, sole chemical fertilization reduces soil organic matter, resulting in lower soil biological activity and deterioration of soil physical properties. This explains the low performance of T2 on soil improvement. For marigold, a pH between 5.0 and 6.5 is recommended (Robbins and Evans, 2010). Higher pH may result in the deficiency of micronutrients, especially Fe (Fisher et al., 2003). The pH of all the treated plots were within the recommended range after the experiments.

Conclusions

In summary, the HO fertilizers contained a complete source of plant nutrients needed to promote optimum marigold growth, **Table 2**. Vegetative growth variables namely: plant height plant-1, stem diameter plant-1, number of branches plant-1, canopy spread plant-1, leaf chlorophyll content plant-1, dry matter weight plant-1 and days to 80% blooming plot-1 were highest in T15, Tables 3and 4. Similarly, maximum improvement in soil properties viz: N, P, K, Ca, Mg, Fe, Mn, Cu and Zn were in T15, Tables 5 and 6. The best soil pH, 6.10 was recorded in T14. Additionally, T15 again realized the most enhanced OM, CEC, EC and WC. Increasing fertilizer dosage from 100 kg rai-1 to 150 kg rai-1 did not impact marigold growth and residual soil properties much, except in dry matter weight. This investigation had demonstrated that T15 is the best fertilizer to boost marigold growth and simultaneously, improve soil properties.

Conflict of interest

There is no conflict of interest to this work.

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