Nanotechnology Perceptions
ISSN 1660-6795
www.nano-ntp.com

The Effect of Chemical and Granular Organic Fertilizer with Hormone Mixed Formula (Ho) and Chemical Fertilizer on Growth of Cannabis (Cannabis Sativa L.) in Outdoor Condition

Worapong Plongyoou[1], Sethasilp Inthanon[2], Pumisak Intanon[1]

[1]Faculty of Agriculture, Natural Resources and Environment, Naresuan University, Phitsanulok, 65000, Thailand
[2]Centre of Excellence on Innovation of Environmental and Future Mobility, Naresuan University, Phitsanulok 65000, Thailand

This research was to study the effect of chemical and granular organic fertilizer with hormone mixed formula (HO) and chemical fertilizer to improve the vegetative growth of cannabis in outdoor conditions. The experiment was conducted in pots under natural conditions, using a Completely Randomized Design (CRD) with 13 treatments of fertilizer applied with 6 replications, totally 78 pot plants. The pot size is No.17 with 12 Kilograms of growing media per pot, The treatments included: T1 - No fertilizer (Control), T2 - Chemical fertilizer 25-7-7 (50 kg/rai, 1 rai = 0.16 ha), T3 - Chemical fertilizer 25-7-7 (100 kg/rai), T4 - Chemical fertilizer 16-8-8 (50 kg/rai), T5 - Chemical fertilizer 16-8-8 (100 kg/rai), T6 - Chemical fertilizer 15-15-15 (50 kg/rai), T7 - Chemical fertilizer 15-15-15 (100 kg/rai), T8 - HO-1 (50 kg/rai), T9 - HO-1 (100 kg/rai), T10 - HO-2 (50 kg/rai), T11 - HO-2 (100 kg/rai), T12 - HO-3 (50 kg/rai), and T13 - HO-3 (100 kg/rai). The test plant was 25-day-old Hang Kra Rok Phu Phan ST1 cannabis seedlings. The study was conducted from November 2022 to June 2023 in Moo 7, Wang Nok Aen Sub-district, Wang Thong District, Phitsanulok Province. Data were analyzed using ANOVA and means were compared using DMRT at 95% confidence level.
The experimental results revealed that 1) Nutrient analysis: HO fertilizers (HO-1, HO-2, HO-3) contained moderate levels of N-P-K, high levels of secondary (Ca-Mg-S) and micronutrients (Fe-Cu-Zn-Mn), whereas chemical fertilizers

lacked these secondary and micronutrients. HO fertilizers had slightly acidic pH (6.5-6.7), favorable for nutrient uptake. 2) Growing media analysis: before the experiment analysis showed high N-P-K and Ca-Mg levels, very low S, and low micronutrient levels. After the experiment, N decreased while other nutrients increased. HO treatments improved pH more than chemical fertilizers. 3) Water retention: HO fertilizers, especially T13 (HO-3, 100kg), significantly improved water retention capacity (from 26.1% to 29.9%). 4) Chlorophyll content: Increased with plant age, with T13 showing significantly higher levels at 30, 45, and 60 days after planting. 5) Growth parameters: Plant height, stem diameter, leaf number, canopy size, and branch number were highest in T13, T12, and T11, respectively, showing statistically significant differences. 6) Growth pattern: Chemical fertilizers promoted faster initial growth (first 30 days), while HO fertilizers demonstrated superior growth from 45-60 days. T13 (HO-3, 100kg) was identified as the most effective fertilizer for cannabis cultivation under outdoor conditions, demonstrating significantly greater growth than other treatments. The diverse nutrient composition and soil-enhancing properties of HO fertilizers contributed to more sustained cannabis growth compared to conventional chemical fertilizers.

Keywords: C Chemical and Granular Organic Fertilizer with Hormone Mixed Formula, HO Fertilizer, Chemical Fertilizer, Cannabis, Growing Media, Growth Characteristic.

1. Introduction

Cannabis, a plant from the genus Cannabis, contains important cannabinoids such as THC (Tetrahydrocannabinol) and CBD (Cannabidiol), which have garnered significant attention in the medical field. Cannabinoids play a role in regulating temperature, pain, energy balance, heart rate, and blood pressure. THC has addictive properties, causing euphoria, mood alterations, psychotic symptoms, paranoia, hallucinations, memory impairment, and impaired decision-making (Department of Medical Sciences, 2022). Cannabidiol (CBD) is a Non-Psychoactive and Non-Addictive Cannabinoid. Since 2022, Thailand has rescheduled cannabis from a Category 5 narcotic to allow for medical use at the household level and cultivation as an economic crop. However, due to its previous status as a narcotic, research on enhancing cannabis growth and yield has been limited, with most studies conducted abroad in high-cost closed systems. This research aims to develop three formulations of granular organic hormone-enriched fertilizer (HO) and compare them with three types of chemical fertilizers to study their influence on cannabis growth in open-field conditions. HO fertilizers have been reported to increase crop yields more effectively than chemical fertilizers while simultaneously improving soil conditions (Choom & Intanon, 2016; Phet-amphai & Intanon, 2019; Konchom et al., 2024; Sonklien et al., 2019). The ultimate goal is to develop innovative soil and fertilizer management techniques for natural (open-field) cultivation systems, which are low-cost and accessible to Thai farmers at the household level.

Definition of Terms

Chemical and Granular Organic Fertilizer with Hormone Mixed Formula (HO Fertilizer) refers to a fertilizer made by combining all 16 essential plant nutrients, based on soil analysis and the specific plant's requirements, with Effective Microorganisms (EM), organic liquid hormones, herbal extracts, soil amendments, and various immune-boosting substances. These components are formulated into granules with controlled nutrient release, producing a slow-release fertilizer specifically tailored for each crop (Intanon, 2009; Raksarikorn, 2013; Jubkaew & Intanon, 2012; Intanon, 2013a).

Mixed Solution refers to a solution produced from the fermentation of three substances (bio-fermentation liquid, organic liquid hormone, and herbal fermentation liquid), which are prepared by fermenting in advance for one month. The three solutions are filtered and mixed in a 1:1:1 ratio by volume. This mixed solution is used in the preparation of growing media and in granulating HO fertilizer on a pelletizer disc to ensure a complete nutrient profile, enhance plant hormone, and provide pest and disease protection in the HO fertilizer granules (Intanon & Raksarikorn, 2012).

2. Materials and Methods

Materials include 17-liter pots, growing medium, chemical fertilizers (25-7-7, 16-8-8, 15-15-15), HO fertilizers (HO-1, HO-2, HO-3), and 25-day-old cannabis seedlings (Hang Kra Rok Phu Phan ST1 strain from the Department of Thai Traditional Medicine).

HO Fertilizer Production Method:

1. Weigh dry ingredients, including chemical fertilizers, according to each formulation (HO-1, HO-2, HO-3) to ensure sufficient primary nutrients for cannabis growth.

2. Filter and mix bio-fermented solution, organic liquid hormones, and herbal extracts in a 1:1:1 ratio to create the "Mixed Solution."

3. Place dry ingredients on a rotating pan, spray with mixed solution, and add agricultural lime powder. Continue rotating until 1mm granules form. Air-dry for 12 hours to create initial granules.

4. Reprocess initial granules by spraying with organic liquid hormones and adding agricultural lime powder. Continue rotating until 2-3mm granules form. Air-dry for 12 hours to create hormone granules.

5. Process hormone granules a third time, spraying with a solution to control nutrient release. Rotate for 10 minutes until 3-5mm granules form. Sun-dry for 6 hours to reach 15-17% moisture content, resulting in the final HO fertilizer.

6. Screen, package in 50kg bags, and store at room temperature for up to one year (Table 1).

Table 1: Components of HO Mixed Pellet Hormone Fertilizer

	Components of HO Mixed Pellet Hormone (% by weight)							
	Primary nutrients	Organic Matter	Micro organisms	Herbal Extract	Bio-fermented Solution	Soil Conditioner	Liquid Organic Hormone	Total %
HO-1 Fertilizer	15	15	15	15	5	30	5	100
HO-2 Fertilizer	20	15	15	15	5	25	5	100
HO-3 Fertilizer	25	10	5	5	15	30	10	100

Source: Adapted from Intanon (2018); Sonklien et al. (2019); Raksarikorn (2013): Primary nutrients = chemical fertilizer (NPK 15-15-15)

Growing Media Mixing

Five types of growing media were combined, consisting of 30% chicken manure, 30% commercial compost, 20% black top soil, 10% rice husk charcoal and 10% coconut coir, by volume. The materials were mixed thoroughly using a shovel, turning the mixture 3-4 times to ensure even distribution. During the mixing process, moisture was added using the "Mixed Solution" to achieve 20% moisture content. The mixture was then covered with plastic sheeting and left for 12 hours before use in the experiment.

Experimental Design

The experiment was conducted in 17-liter pots, each containing 12 kg of growing media. A completely randomized design (CRD) was used, consisting of 13 treatments with 6 replications, resulting in 78 pots. Hang Kra Rok Phu Phan ST1 Cannabis seedlings (obtained from the Department of Thai Traditional Medicine) aged 25 days were planted, with one plant per pot (equivalent to 1,333 plants per rai). The treatments included: T1 - No fertilizer (Control), T2 - Chemical fertilizer 25-7-7 (50 kg/rai, 1 rai = 0.16 ha), T3 - Chemical fertilizer 25-7-7 (100 kg/rai), T4 - Chemical fertilizer 16-8-8 (50 kg/rai), T5 - Chemical fertilizer 16-8-8 (100 kg/rai), T6 - Chemical fertilizer 15-15-15 (50 kg/rai), T7 - Chemical fertilizer 15-15-15 (100 kg/rai), T8 - HO-1 (50 kg/rai), T9 - HO-1 (100 kg/rai), T10 - HO-2 (50 kg/rai), T11 - HO-2 (100 kg/rai), T12 - HO-3 (50 kg/rai), and T13 - HO-3 (100 kg/rai). The pots were placed outdoors (open system). Fertilizer was applied in 8 split doses during the plants' growth stages, between 35-84 days after germination.

Data Collection

Data collected included local climate conditions from the Phitsanulok Meteorological Station, fertilizer analysis of both HO and chemical fertilizers, and pre- and post-experiment growing media analysis. Chlorophyll content in leaves (measured using SPAD-502 Plus) was recorded three times during the plant growth period. Growth data were recorded weekly. The experiment was conducted at Moo 7, Wang Aen Sub-district, Wang Thong District, Phitsanulok Province.

Statistical Analysis

Data were analyzed using Analysis of Variance (ANOVA), and mean differences were compared using Duncan's New Multiple Range Test (DMRT) at a 95% confidence level.

The experiment was conducted between November 2022 and June 2023.

3. Results and Discussion

Weather conditions during the experiment (February - May 2023) showed minimum and maximum temperatures of 21.51°C and 37.71°C, respectively, with an average relative humidity of 60%. No rainfall was recorded due to the dry season, necessitating manual irrigation.

Analysis of HO-1, HO-2, HO-3 Organic Fertilizers and Chemical Fertilizers

Fertilizer analysis revealed that HO-1, HO-2, and HO-3 fertilizers contained moderate to high levels of primary nutrients (N, P, K) comparable to chemical fertilizers. However, HO fertilizers also contained secondary nutrients (Ca, Mg, S) and micronutrients (Fe, Cu, Zn, Mn, B) not present in chemical fertilizers. Organic matter content in HO fertilizers ranged from 1.13-1.20%. All fertilizers had slightly acidic pH levels. HO fertilizers demonstrated higher electrical conductivity (EC) values compared to chemical fertilizers, likely due to their more diverse nutrient composition. The pH of HO fertilizers (6.5-6.7) was suitable for plant nutrient uptake. The comprehensive nutrient profile of HO fertilizers suggests they may have greater potential for improving soil fertility and structure compared to chemical fertilizers. The slow-release nature of HO fertilizers may enhance nutrient uptake efficiency and reduce nutrient losses from the growing media. Post-experiment analysis showed higher levels of primary, secondary, and micronutrients in HO fertilizers, it can be concluded that HO fertilizers have a more significant impact on soil fertility and improvement compared to chemical fertilizers. The nutrient levels in HO-1, HO-2, and HO-3 fertilizers were found to increase progressively, which is attributed to the composition of HO fertilizer formulas derived from diverse agricultural materials as mentioned earlier. This composition provides a complete and balanced nutrient profile for plant growth. HO fertilizers can modify both the chemical and physical soil environment to enhance plant growth conditions. Specifically, they can adjust soil pH to optimize nutrient uptake by plants. The composition of HO fertilizers includes a substantial proportion of soil amendments, ranging from 25-35% by weight (Intanon et al., 2017a; Intanon, 2013b; Jubkaew & Intanon, 2012), which primarily consists of agricultural lime.

Furthermore, HO fertilizers are slow-release fertilizers, gradually releasing nutrients over time. This characteristic enhances nutrient uptake efficiency in plants and reduces nutrient loss from the growing media consequently, post-experiment analysis revealed that the HO group fertilizers exhibited higher levels of primary, secondary, and micronutrients compared to those treated with chemical fertilizers (Table 2).

Table 2: Analysis of HO-1, HO-2, HO-3 Organic Fertilizers and chemical Fertilizers

Fertilizer Properties		25-7-7	16-8-8	15-15-15	HO-1	HO-2	HO-3
Primary nutrients	Total N (%)	25.00	16.00	15.00	9.15	9.75	10.66
	Total P (%)	7.00	8.00	15.00	8.57	9.82	10.78
	Total K (%)	7.00	8.00	15.00	10.43	10.58	10.93
Secondary nutrients	Ca (%)	0.00	0.00	0.00	4.27	6.12	8.70

	Mg (%)	0.00	0.00	0.00	1.69	1.86	1.96
	S (%)	0.00	0.00	0.00	0.13	0.17	1.53
Micronutrients	Fe (mg kg-1)	0.00	0.00	0.00	2.22	2.67	2.88
	Mn (mg kg-1)	0.00	0.00	0.00	319.00	522.00	682.00
	Zn (mg kg-1)	0.00	0.00	0.00	96.00	165.00	197.20
	Cu (mg kg-1)	0.00	0.00	0.00	26.01	28.04	34.08
	Cl (mg kg-1)	0.00	0.00	0.00	2.30	2.34	3.03
OM (%)		0.00	0.00	0.00	0.92	1.15	1.38
pH (1:5)		6.40	6.32	6.25	6.53	6.69	6.59
EC (1:10; dS cm-1)		26.42	26.55	28.60	53.75	85.10	98.15

Analysis of Growing Media Properties Before and After the Experiment

The chemical analysis of the growing media before the experiment showed that the levels of primary nutrients (N 0.16%, P 85.52 mg kg^{-1}, K 93.15 mg kg^{-1}) were high, particularly potassium. The levels of secondary nutrients were also high, except for sulfur (S 4.9 mg kg^{-1}), which was low. The micronutrients (Fe, Cu, Zn, Mn) were present at low levels, with manganese having the highest concentration. The organic matter content was high (OM 32.5%), in line with the growing media standard (Choovoravej, 2005). The media had a slightly acidic pH (5.7), a CEC of 10.45 meq/100g, and an EC of 84.21 ds cm^{-1}. Physically, the media had a moderate water holding capacity (WC 25.10%). After the experiment, the analysis of the growing media showed that nitrogen (N) had a decreasing trend compared to before the experiment, as nitrogen can be lost through various pathways. Other nutrients increased. The water-holding capacity of the growing media increased, with the HO fertilizer group (T8-T13) exhibiting higher water-holding capacity than the chemical fertilizer group (T2-T7), with the highest result in T13 (HO-3 100 kg). This indicates that the HO fertilizer group had higher porosity than the chemical fertilizer group. The pH of the HO fertilizer group was improved compared to the chemical fertilizer group, with the highest result in T13 (HO-3 100 kg). Organic matter (OM) increased in all fertilized treatments, with the HO fertilizer group showing higher increases, particularly in T13 (HO-3 100 kg). Comparing the growing media before and after the experiment in T13 (HO-3 100 kg), the CEC increased from 10.45 meq/100g to 84.90 meq/100g, the EC increased from 84.21 ds cm^{-1} to 294 ds cm^{-1}, and the water holding capacity increased from 25.10% to 29.96%. Overall, the growing media in the HO fertilizer group (T8-T13) had higher levels of primary, secondary, and micronutrients than the chemical fertilizer group, with the highest results in T13 (HO-3 100 kg). This indicates that the media had high organic matter content, a balanced nutrient profile, and moderate water-holding capacity, making it suitable for cannabis cultivation, which requires high air circulation (O_2, CO_2). The decrease in nitrogen (N) in all treatments may be due to the various pathways of nitrogen loss or the high nitrogen demand of cannabis for continuous growth and development. Nitrogen is essential for branching, canopy expansion, and chlorophyll production in cannabis, which has a large leaf area. Other nutrients, including phosphorus (P), potassium (K), secondary nutrients (Ca, Mg, S), and micronutrients (Fe, Cu, Zn, Mn), increased, and the chemical properties were improved, particularly in the HO fertilizer group (T8-T13), with the most prominent results in T13 (HO-3 100 kg). This is attributed to the

composition of HO fertilizers, which are made from a diverse blend of agricultural materials, including organic fertilizers, compost, soil amendments (agricultural lime), biofertilizers, organic hormones, and herbal extracts for disease and pest control, along with balanced additions of primary nutrients from chemical fertilizer sources. The slow-release nature of HO fertilizers also helps to efficiently provide nutrients and reduce nutrient losses through leaching, thereby enhancing plant growth and leaving a residual nutrient reserve in the growing media after crop cultivation (Ahmad et al., 2011). This is consistent with the observed increases in CEC and EC values in the growing media after the experiment (Table 3).

Table 3: Analysis of Growing Media Properties Before and After the Experiment

	Before-experimental Growing Media Properties													
	N	P	K	Ca	Mg	S	Fe	Cu	Zn	Mn	OM	pH	CEC	EC	WC
	(%)	(ppm)									(%)	(1:1)	(meq/100g)	(ds cm^{-1})	(%)
	0.16	85.52	93.15	397.40	373.24	4.9	5.64	12.12	66.53	210	32.5	5.7	10.45	84.21	25.10
	After-experimental Growing Media Properties														
Experimental Treatments	N	P	K	Ca	Mg	S	Fe	Cu	Zn	Mn	OM	pH	CEC	EC	WC
	(%)	(ppm)									(%)	(1:1)	(meq/100g)	(ds cm^{-1})	(%)
T1 Control	0.04	86.52	93.15	397.40	373.24	4.92	5.68	15.10	65.52	213.21	32.6	5.8	10.45	82.20	25.10
T2 25-7-7 (50kg)	0.08	123.20	197.07	425.38	335.05	5.61	6.13	15.21	101.67	287.21	33.6	5.7	15.52	133.20	25.90
T3 25-7-7 (100kg)	0.08	128.74	270.68	544.51	332.45	5.61	6.33	16.22.	107.33	293.52	33.6	5.7	15.88	154.95	25.71
T4 16-8-8 (50kg)	0.06	126.50	275.41	557.88	357.37	5.67	6.71	15.14	119.67	307.41	32.6	5.8	15.53	172.60	25.26
T5 16-8-8 (100kg)	0.07	128.85	276.86	508.25	323.37	5.63	6.80	15.67	112.33	250.23	32.6	5.8	16.16	179.50	25.24
T6 15-15-15 (50kg)	0.07	155.93	325.29	592.36	349.87	5.68	6.87	15.55	105.67	270.18	32.5	5.8	19.33	182.40	25.39
T7 15-15-15 (100kg)	0.08	158.11	398.45	516.72	329.18	5.64	8.93	15.54	116.33	343.12	32.5	5.8	20.25	191.80	25.69
T8 HO-1 (50kg)	0.07	155.82	244.05	157 7.84	350.54	6.44	10.45	26.24	228.34	377.14	35.7	6.5	21.28	251.05	26.12
T9 HO-1 (100kg)	0.08	176.64	295.14	164 1.58	346.48	6.42	12.47	28.53	226.00	367.56	35.8	6.5	32.48	263.45	26.26
T10 HO-2 (50kg)	0.07	184.38	300.70	155 7.87	352.35	8.37	13.55	28.76	224.00	344.64	36.7	6.6	50.83	278.95	27.79

T11 HO-2 (100kg)	0.08	196.12	351.63	1588.73	352.53	8.35	13.93	28.88	225.00	373.73	36.7	6.7	62.73	284.10	27.86
T12 HO-3 (50kg)	0.07	226.08	494.10	1632.08	358.46	9.66	13.98	29.21	227.33	373.78	37.6	6.7	72.23	287.95	29.95
T13 HO-3 (100kg)	0.08	248.29	454.43	1652.04	380.91	9.68	14.12	29.55	283.14	386.67	37.6	6.8	84.90	294.00	29.96

Quantification of Foliar Chlorophyll Content

The chlorophyll content was recorded three times during the plant growth period at 30, 45, and 60 days after planting, using a Chlorophyll Meter SPAD-502 Plus (Minolta) during 9:00-11:00 AM. The top three chlorophyll content values at 30 days after planting were T13 (HO-3, 100 kg), T12 (HO-3, 50 kg), and T8 (HO-1, 50 kg), respectively. At 45 days after planting, the top three were T12 (HO-3, 50 kg), T13 (HO-3, 100 kg), and T11 (HO-2, 100 kg), respectively. At 60 days after planting, the top three were T13 (HO-3, 100 kg), T12 (HO-3, 50 kg), and T11 (HO-2, 100 kg), respectively. T13 (HO-3, 100 kg) had the highest chlorophyll content, which was significantly different from the other treatments. The next highest were T12 (HO-3, 50 kg), T11 (HO-2, 100 kg), and T10 (HO-2, 50 kg), respectively.The chlorophyll content increased with the plant's age, as the plants at 30 days were still in the early growth stage, and the chlorophyll content did not show significant differences between treatments. During this period, the plants might have received sufficient nutrients from the growing media, and the influence of the fertilizer treatments was not yet apparent. At 45 and 60 days after planting, the plants were in the full growth stage, with a larger canopy size and more leaves. The differences between treatments became evident. The nitrogen from the chemical fertilizer alone was not sufficient for the chlorophyll production in the cannabis plants with a large leaf number. In comparison, the HO fertilizer treatments, which contained higher levels of essential nutrients, such as nitrogen (N), magnesium (Mg), sulfur (S), iron (Fe), copper (Cu), zinc (Zn), and manganese (Mn), directly involved in chlorophyll synthesis and photosynthesis, resulted in the highest chlorophyll content, particularly in T13 (HO-3, 100 kg) (Table 4).

Table 4: Quantification of Foliar Chlorophyll Content

Experimental Treatments	Cannabis Plant Age at Measurement (Unit: SPAD units)		
	30 days	45 days	60 days
T1 (Control)	40.38	44.78b	50.18c
T2 (25-7-7, 50kg)	41.62	51.70a	52.13bc
T3 (25-7-7, 100kg)	41.65	51.74a	52.25bc
T4 (16-8-8, 50kg)	41.45	51.54a	52.14bc
T5 (16-8-8, 100kg)	41.52	51.62a	52.32bc
T6 (15-15-15, 50kg)	41.84	51.64a	52.67b
T7 (15-15-15, 100kg)	41.92	51.84a	52.88b
T8 (HO-1, 50kg)	42.41	51.31a	53.33ab
T9 (HO-1, 100kg)	41.39	51.15a	53.55ab

T10 (HO-2, 50kg)	41.59	52.17a	53.63ab
T11 (HO-2, 100kg)	42.38	52.28a	53.88ab
T12 (HO-3, 50kg)	42.56	53.10a	54.26ab
T13 (HO-3, 100kg)	42.84	53.05a	54.55a
CV (%)	6.46	2.43	2.19
F-Test	ns	*	*

Note: ns indicates no statistically significant difference

* indicates a statistically significant difference at the 95% confidence level

Quantification of Vegetative Growth Parameters

Plant Height

The study found that the top three treatments for maximum plant height were T13 (HO-3, 100kg), T12 (HO-3, 50kg), and T9 (HO-1, 100kg), respectively.

Stem Size

The top three treatments for stem size were T13 (HO-3, 100kg), T12 (HO-3, 50kg), and T11 (HO-2, 100kg), respectively.

Canopy Size

The largest canopy sizes were observed in treatments T13 (HO-3, 100kg), T12 (HO-3, 50kg), and T11 (HO-2, 100kg), respectively.

Number of Leaves per Plant

The highest number of leaves per plant was recorded in treatments T13 (HO-3, 100kg), T12 (HO-3, 50kg), and T11 (HO-2, 100kg), respectively.

Leaf Length

The greatest leaf length was found in treatments T7 (15-15-15, 100kg), T12 (HO-3, 50kg), and T11 (HO-2, 100kg), in that order.

Leaf Width

The top three treatments for leaf width were T7 (15-15-15, 100kg), T12 (HO-3, 50kg), and T11 (HO-2, 100kg), respectively.

Number of Branches per Plant

The highest number of branches per plant was observed in treatments T13 (HO-3, 100kg), T12 (HO-3, 50kg), and T11 (HO-2, 100kg), respectively.

Summary and Explanation:

Overall, the results indicate that plant height, stem size, canopy size, number of leaves per plant, and number of branches per plant were highest in T13 (HO-3, 100kg), T12 (HO-3, 50kg), and T11 (HO-2, 100kg) in that order, with T13 (HO-3, 100kg) significantly outperforming others statistically. For leaf length and width, T7 (15-15-15, 100kg)

outperformed the HO fertilizers. This can be attributed to T7's high primary nutrient content, which is fast-releasing, especially nitrogen, facilitating rapid cell division and leaf expansion. This aligns with Sanjeeva Rao et al. (1998) who noted that nitrogen positively affects cell division and expansion.

The HO fertilizers release nutrients gradually, supporting continuous growth, meeting cannabis's ongoing nutrient needs. Therefore, HO fertilizers showed superior growth from 45-60 days post-planting through harvest. Within the HO fertilizers, T13 (HO-3, 100kg), T12 (HO-3, 50kg), and T11 (HO-2, 100kg) exhibited the best growth, due to the ascending levels of nutrients in HO-1, HO-2, and HO-3. Besides N-P-K, secondary nutrients like Fe, Cu, and Zn are essential for the highest rate of photosynthesis in T13 (HO-3, 100kg), resulting in optimal growth.

The findings support previous studies (Hussein et al., 2011; Kumar & Singh, 2011), indicating variations in nutrient concentration and diversity significantly impact plant development. Consistent with Jubkaew & Intanon (2012), the HO fertilizers enhanced growth more than other fertilizers.

Cannabis stem and leaf growth are significant for culinary uses, as leaves are widely used for flavoring and ingredients. The comprehensive range of nutrients in HO fertilizers, alongside liquid organic hormones and bio-liquid fertilizers, increases indo-acetic acid (IAA) production, stimulating cell expansion and efficient nutrient absorption (Zhang et al., 2012; Chuinon & Intanon, 2011). These fertilizers boost phytochemical hormones, such as gibberellins, cytokinins, and IAA, promoting growth and tissue development.

HO fertilizers contain beneficial microorganisms (approximately 4.36 x 10^2 CFU/g), capable of nitrogen fixation and converting phosphate rock into utilizable phosphorus (Dikr & Belete, 2017). Organic Matter (OM) is decomposed into humus by EM, enhancing soil fertility and water retention, thus improving nutrient uptake and plant growth. Consequently, HO fertilizers, specifically T13 (HO-3, 100kg), showed statistically significant growth superiority, influenced by their nutrient concentration and factors (Intanon et al., 2017; Intanon, 2013b; Jubkaew & Intanon, 2012). (Table 5)

Table5: Quantification of Vegetative Growth Parameters

Data Recorded at Maximum Vegetative Growth Stage (84 Days After Sowing)							
Experimental Treatments	Plant height	Stem diameter	Canopy spread	Number of leaves per plant	Leaf length	Leaf width	Number of branches per plant
T1 (Control)	38.45h	3.70g	52.12g	38.60g	9.31e	9.30e	3.40i
T2 (25-7-7, 50kg)	74.40d	9.02d	94.50e	328.65d	14.22bc	15.20b	19.40g
T3 (25-7-7, 100kg)	74.80d	6.50f	96.12e	300.10e	14.42bc	15.10b	20.00f
T4 (16-8-8, 50kg)	64.20e	7.10e	89.12f	283.24e	13.12bc	12.60cd	18.00h
T5 (16-8-8, 100kg)	67.66e	8.10e	95.73e	285.25e	15.32b	16.00b	22.00d
T6 (15-15-15, 50kg)	60.10f	7.91e	96.21e	297.21e	15.15b	12.00d	22.50d
T7 (15-15-15,100kg)	72.56d	7.65e	96.60e	344.12c	16.55a	17.40a	24.80c
T8 (HO-1, 50kg)	64.14f	5.32f	108.42d	120.10f	10.00e	12.30cd	21.30e

T9 (HO-1, 100kg)	86.32c	8.86d	115.45c	331.21d	12.80d	13.20cd	23.50cd
T10 (HO-2, 50kg)	44.85g	4.56g	116.44c	279.11e	16.00a	12.80cd	23.70cd
T11 (HO-2, 100kg)	64.45e	10.12c	118.23c	348.20c	16.34a	16.30b	25.40c
T12 (HO-3, 50kg)	104.15b	10.55b	120.00b	380.45b	16.45a	16.40b	27.80b
T13 (HO-3, 100kg)	108.54a	11.80a	122.42a	406.20a	14.30c	13.52c	29.80a
CV(%)	2.81	11.87	2.29	6.92	5.28	5.21	5.44
F-Test	*	*	*	*	*	*	*

Note: * indicates a statistically significant difference at the 95% confidence level

4. Conclusions

The study of the effect of chemical and granular organic fertilizer with hormone mixed formula (HO) compared to chemical fertilizers on the growth of cannabis in outdoor condition can be summarized as follows:

1. The results of the growing media mixture for cannabis cultivation showed that it was suitable, slightly acidic, with complete nutrients, high organic matter, and moderate water holding capacity.

2. The 3 HO fertilizer formulations (HO-1, HO-2, HO-3) developed were able to improve both the chemical and physical properties of the soil while being applied as a slow-release fertilizer with a balanced high-level of plant nutrients. This reduced nutrient loss, adjusted the pH, and increased water holding capacity, allowing suitable for open-system cannabis cultivation.

3. All 3 HO fertilizer formulations were more effective than chemical fertilizers for open-system cannabis cultivation, especially T13 (HO-3 at 100 kg/rai), which resulted in the highest and statistically significant plant growth in almost all parameters.

4. The appropriate application rate for both HO and chemical fertilizers was 100 kg/rai.

References

1. Ahmad, I. I., Asif, M., Amjad, A., & Ahmad, S. (2011). Fertilization enhances growth, yield and xanthophyll contents of marigold. Turkish Journal of Agriculture and Forestry, 35(6), 641-648.
2. Choovoravej, N. (2005). Technical document on organic fertilizer knowledge. Department of Agriculture.
3. Chuinon, C., & Intanon, P. (2011). Development of high quality bio-fertilizer for rice production. Naresuan University Journal, 19(2), 8-18.
4. Choomman, W., & Intanon, P. (2016). Influence of compound hormone pelletized fertilizer on growth, yield, and brown planthopper infestation in rice. Khon Kaen Agriculture Journal, 44(2), 265-274.
5. Department of Medical Sciences. (2022). Analysis of THC and CBD concentrations in plasma using chromatography techniques. Ministry of Public Health. https://nih.dmsc.moph.go.th/data/data/65/27062565.pdf
6. Dikr, W., & Belete, K. (2017). Review on the effect of organic fertilizers, bio-fertilizers and

inorganic fertilizers (NPK) on growth and flower yield of marigold (Tagetes erecta L.). Academic Research Journal of Agricultural Science and Research, 5(3), 192-204.
7. Hussein, M. M., Sakr, R. A., Badr, L. A., & Mashat, K. M. A. L. (2011). Effect of some fertilizers on botanical and chemical characteristics of pot marigold plant (Calendula officinalis L.). Journal of Horticultural Science and Ornamental Plants, 3, 220-231.
8. Intanon, P. (2009). Fertilizer technology. Department of Agricultural Science, Faculty of Agriculture, Natural Resources and Environment, Naresuan University.
9. Intanon, P. (2013a). 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.
10. Intanon, P. (2013b). Comparison of fertilizer management to increase yield and quality of rice. In Proceedings of the 4th International Conference on Environmental and Rural Development. International Society of Environmental and Rural Development.
11. Intanon, P. (2018). Production and application of high-efficiency bio-organic pelletized fertilizers. Ubon Ratchathani University Press.
12. Intanon, P., & Raksarikorn, C. (2012). Effects of chemical fertilizers and compound hormone pelletized fertilizers on early growth of rubber trees. Naresuan University Journal, 20(3), 18-27.
13. Intanon, P., Keteku, A. K., & Intanon, R. (2017). Effect of soil pH improvement substance on soil properties, plant growth and yield of maize (Zea mays L.). In Proceedings of the 13th International Conference of the East and Southeast Asia Federation of Soil Sciences (pp. 39-44).
14. Jubkaew, S., & Intanon, P. (2012). Effect of hormones compound granular fertilizer on growth and yield of rice. Khon Kaen Agriculture Journal, 40(4), 105-109.
15. Konchom, R., Intanon, P., & Raksarigorn, C. (2024). Effects of compound hormone pelletized fertilizer (HO) on yield and essential compounds of holy basil (Ocimum tenuiflorum L.). Prawarun Agricultural Journal, 21(1), 44-51.
16. Kumar, A., & Singh, A. K. (2011). Effect of spacing and nitrogen levels on vegetative growth, flowering behaviour and yield of calendula (Calendula officinalis L.). Plant Archives, 11, 941-944.
17. Natewet, P. (2021). Influence of artificial light quality on photosynthetic index and dry flower yield of cannabis in a semi-closed cultivation system. Khon Kaen Agriculture Journal, 49(Suppl. 1), 348-354.
18. Phet-amphai, N., & Intanon, P. (2019). Influence of compound pelletized fertilizer and chemical fertilizer on organic matter accumulation in leaves and total soluble solids of mango fruits. Journal of Agricultural Production, 1(2), 1-10.
19. Raksarikorn, C. (2013). Influence of chemical fertilizers and compound hormone pelletized fertilizers on growth and latex yield of rubber trees [Master's thesis, Naresuan University].
20. Sanjeeva Rao, P., Saraswathyamma, C. K., & Sethuraj, M. R. (1998). Studies on the relationship between yield and meteorological parameters of para rubber tree (Hevea brasiliensis). Agricultural and Forest Meteorology, 90, 235-245.
21. Sonklien, C., Intanon, P., and Terapongtanakorn, S. (2019). Effect of chemical and granular organic fertilizer with hormone mixed formula (HO) on soil improvement and growth of marigold (Tagetes erecta L.). Khon Kaen Agriculture Journal, 47(6), 1323-1336.
22. Zhang, F. S., Cui, Z. L., Chen, X. P., Ju, X. T., Shen, J. B., Chen, Q., Liu, X. J., Zhang, W. F., Mi, G. H., Fan, M. S., & Jiang, R. F. (2012). Integrated nutrient management for food security and environmental quality in China. Advances in Agronomy, 116, 1-40.