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Development of Chemical and Granular Organic Fertilizer with Hormone Mixed Formula (HO) Compared to Chemical Fertilizer on Yield, Yield Quality and Cost-effective of Cannabis (Cannabis Sativa L.) in Outdoor Condition

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This research aimed to develop a chemical and granular organic fertilizer with hormone mixed formula (HO) and compare it with chemical fertilizers on the yield, yield quality and cost-effective of cannabis (Cannabis sativa L.) cultivated in outdoor condition. The experiment was conducted using 17-size pots filled with 12 kg of growing media, using a Completely Randomized Design (CRD) with 13 treatments and 6 replications, totaling 78 pots. 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 experiment was carried out from November 2022 to June 2023 at Moo 7, Wang Nok Aen Sub-district, Wang Thong District, Phitsanulok Province. Data were analyzed using ANOVA and DMRT at 95% confidence level.
The results showed that the HO-1, HO-2, and HO-3 fertilizers had moderate

levels of primary macronutrients (N-P-K) and high levels of secondary macronutrients (Ca-Mg-S) and micronutrients (Fe-Cu-Zn-Mn), while the chemical fertilizers had higher overall primary macronutrient (NPK) content but lacked the secondary and micronutrients. The HO fertilizers had a pH ranging from 6.5 to 6.7, which was suitable for plant nutrient uptake. In terms of growth parameters, the top three performing treatments were T13 (HO-3, 100 kg/rai), T12 (HO-3, 50 kg/rai), and T11 (HO-2, 100 kg/rai), which showed statistically significant differences. For yield and yield components, T13 (HO-3, 100 kg/rai) exhibited the highest values, which were significantly different from the other treatments. This treatment also had the highest THC (10.5%) and CBD (0.95%) contents. The economic analysis showed that T13 (HO-3, 100 kg/rai) had the highest profit of 170,010 baht/rai, while all the HO fertilizer treatments (T8-T13) were profitable, and the chemical fertilizer treatments (T2-T7) showed losses due to lower yields and higher production costs. In conclusion, the development of the HO fertilizer was successful, and the T13 (HO-3, 100 kg/rai) treatment was the most effective for outdoor cannabis cultivation, as it resulted in the highest plant growth, yield, THC/CBD content and highest profit.

Keywords: Chemical and Granular Organic Fertilizer with Hormone Mixed Formula, HO Fertilizer, Chemical Fertilizer, Growing Media, Cannabis, THC, CBD, Cost Effective.

1. Introduction

Cannabis is a plant in the genus Cannabis, containing cannabinoids such as THC (Tetrahydrocannabinol) and CBD (Cannabidiol), which have garnered significant attention in the medical field. Cannabinoids regulate functions such as body temperature, pain management, energy balance, heart rate, and blood pressure. THC is psychoactive and can induce euphoria, mood alterations, psychiatric symptoms, paranoia, hallucinations, memory impairment, and poor decision-making (Department of Medical Sciences, 2022). In contrast, CBD is non-psychoactive and non-addictive. Due to the classification of cannabis as a category 5 narcotic, research on increasing its yield and key substances has been limited. This study aims to develop three formulations of HO (Hormone Organic Granular Fertilizer) and compare them with three types of chemical fertilizers to examine their effects on the yield and quality (THC/CBD content) of cannabis grown in an open cultivation system.

Definition of Terms:

HO Fertilizer (Chemical and Granular Organic Fertilizer with Hormone Mixed Formula): HO fertilizer refers to a combination of 16 essential plant nutrients, based on soil analysis to meet the specific needs of particular plants. These nutrients are mixed with Effective Microorganisms (EM), liquid organic hormones, herbal extracts, soil amendments, and immune-boosting substances. The mixture is then granulated into 3-5 mm pellets, coated to create a slow-release fertilizer. This process results in a fertilizer formula customized for specific plants (Intanon, 2009; Raksarikorn, 2013; Jubkaew & Intanon, 2012; Intanon, 2013a).

Growing Media: Growing media refers to a mixture of five components: consisting of 30% chicken manure, 30% commercial compost, 20% black top soil, 10% rice husk charcoal and 10% coconut coir, mixed by volume, with 20% moisture added. The mixture is then covered with plastic for 12 hours before use in experiments.

2. Materials and Methods

Materials: The experiment utilized size 17 pots (17 liters), growing media, chemical fertilizers with compositions of 25-7-7, 16-8-8, and 15-15-15, as well as fertilizers HO-1, HO-2, and HO-3. Cannabis seedlings, 25 days old, of the Hang Kra Rok Phu Phan ST1 strain (provided by the Department of Thai Traditional Medicine) were used. The components of each HO fertilizer type are detailed in Table 1.

Table 1: Components of HO Fertilizers

	Components of HO Fertilizers (% 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)

The experimental using 17 cm pots filled with 12 kg of growing media per pot. The study was designed as a Completely Randomized Design (CRD) consisting of 13 treatments with 6 replications, totaling 78 pots. Cannabis seedlings of the sativa variety, aged 25 days (sourced from the Department of Thai Traditional Medicine), was used as the test plants, with one seedling per pot (1,333 seedlings per rai). The treatments include: 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 included of gathering information on the climatic conditions of the experimental area, analyzing both HO and chemical fertilizers, and recording key growth parameters when the plants reach full maturity at 84 days, such as canopy size, number of branches per plant, and number of leaves per plant. Additionally, yield and yield components recorded once the plants flower fully at 120 days. Quality analysis of the yield focuses on THC/CBD contents, along with a brief analysis of costs, revenues, and profits. The experiment was conducted in Moo 7, Wang Nok Aen Sub-district, Wang Thong District, Phitsanulok Province. Statistical data analysis using Analysis of Variance (ANOVA) to compare mean by DMRT at a confidence level of 95% from November 2022 to June 2023.

3. Results and Discussion

Environmental Conditions

The environmental conditions in the experimental site during the study period from February 2023 to May 2023 were characterized by a minimum temperature of 21.51°C, a maximum temperature of 37.71°C, an average relative humidity of 60%, and no rainfall (0 mm) as the site was transitioning into the dry season. Due to the lack of rainfall, the plants were irrigated using a hose to prevent any adverse effects.

Fertilizer Analysis

The analysis of the organic fertilizers HO-1, HO-2, and HO-3, as well as the chemical fertilizer used in the experiment, revealed the following:

Primary Nutrients: The levels of the primary macronutrients, namely Nitrogen (N), Phosphorus (P), and Potassium (K), were moderately high in all three HO fertilizers and did not differ significantly from the chemical fertilizer.

Secondary Nutrients: The levels of secondary nutrients, including Calcium (Ca), Magnesium (Mg), and Sulfur (S), were found to be higher in the HO fertilizers compared to the chemical fertilizer, which did not contain these secondary nutrients.

Micronutrients: The HO fertilizers also contained higher amounts of micronutrients, such as Iron (Fe), Copper (Cu), Zinc (Zn), Manganese (Mn), and Boron (B), whereas the chemical fertilizer did not have these micronutrients.

Soil pH: The pH values of both the HO fertilizers and the chemical fertilizer were slightly acidic, ranging from 6.2 to 6.7.

Overall Nutrient Content: When considering the total nutrient content, the HO-1, HO-2, and HO-3 fertilizers showed an increasing trend in nutrient levels and contained a complete set of secondary and micronutrients (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

Quantification of Vegetative Growth Parameters

The experiment examined the effects of various fertilizer treatments on Vegetative growth parameters, including canopy size, branch number, and leaf number (Table 3).

Canopy Size

The treatments that resulted in the largest canopy sizes were T13 (HO-3, 100 kg), T12 (HO-3, 50 kg), T11 (HO-2, 100 kg), T10 (HO-2, 50 kg), T9 (HO-1, 100 kg), T8 (HO-1, 50 kg), T7 (15-15-15, 100 kg), T6 (15-15-15, 50 kg), T3 (25-7-7, 100 kg), T5 (16-8-8, 100 kg), T2 (25-7-7, 50 kg), T4 (16-8-8, 50 kg), and T1 (Control), in descending order.

Branch Number

The treatments with the highest branch number per plant were T13 (HO-3, 100 kg), T12 (HO-3, 50 kg), T11 (HO-2, 100 kg), T7 (15-15-15, 100 kg), T10 (HO-2, 50 kg), T9 (HO-1, 100 kg), T6 (15-15-15, 50 kg), T5 (16-8-8, 100 kg), T8 (HO-1, 50 kg), T3 (25-7-7, 100 kg), T2 (25-7-7, 50 kg), T4 (16-8-8, 50 kg), and T1 (Control), in descending order.

Leaf Number

The treatments with the highest leaf number per plant were T13 (HO-3, 100 kg), T12 (HO-3, 50 kg), T11 (HO-2, 100 kg), T7 (15-15-15, 100 kg), T9 (HO-1, 100 kg), T2 (25-7-7, 50 kg), T3 (25-7-7, 100 kg), T6 (15-15-15, 50 kg), T5 (16-8-8, 100 kg), T4 (16-8-8, 50 kg), T10 (HO-2, 50 kg), T8 (HO-1, 50 kg), and T1 (Control), in descending order.

The top three treatments that consistently showed the highest values for all the growth parameters were T13 (HO-3, 100 kg), T12 (HO-3, 50 kg), and T11 (HO-2, 100 kg). Notably, T13 (HO-3, 100 kg) exhibited significantly higher growth compared to the other treatments. The superior performance of the HO-3 and HO-2 fertilizers can be attributed to their well-balanced and comprehensive nutrient profiles, containing high levels of primary macronutrients (N, P, K), secondary nutrients (Ca, Mg, S), and micronutrients (Fe, Cu, Zn, Mn, B) (Intanon et al., 2017; Intanon, 2013b; Jubkaew & Intanon, 2012). The HO fertilizers also possess unique characteristics, such as soil pH adjustment, improved physical and biological properties, and the presence of organic hormones, which collectively contribute to enhanced nutrient availability and uptake by the plants (Zhang et al., 2012; Chuinon & Intanon, 2011). In addition to the primary nutrients N-P-K, secondary and micronutrients such as Mg, S, Fe, Cu, Zn, and Mn, which are essential for photosynthesis in plants, also reached their highest levels in T13 (HO-3, 100 kg). Consequently, plant growth exhibited its maximum performance in T13 (HO-3, 100 kg), differing significantly from other treatments (Hussein et al., 2011; Kumar & Singh, 2011).

Table 3: Quantification of Vegetative Growth Parameters

Experimental Treatments	Data Recorded at Maximum Vegetative Growth Stage (84 Days After Sowing)		
	Canopy size	Number of branches per plant	Number of leaves per plant
T1 (Control)	52.12g	3.40i	38.60g
T2 (25-7-7, 50kg)	94.50e	19.40g	328.65d
T3 (25-7-7, 100kg)	96.12e	20.00f	300.10e
T4 (16-8-8, 50kg)	89.12f	18.00h	283.24e
T5 (16-8-8, 100kg)	95.73e	22.00d	285.25e
T6 (15-15-15, 50kg)	96.21e	22.50d	297.21e
T7 (15-15-15,100kg)	96.60e	24.80c	344.12c
T8 (HO-1, 50kg)	108.42d	21.30e	120.10f
T9 (HO-1, 100kg)	115.45c	23.50cd	331.21d
T10 (HO-2, 50kg)	116.44c	23.70cd	279.11e
T11 (HO-2, 100kg)	118.23c	25.40c	348.20c
T12 (HO-3, 50kg)	120.00b	27.80b	380.45b
T13 (HO-3, 100kg)	122.42a	29.80a	406.20a
CV(%)	2.29	5.44	6.92
F-Test	*	*	*

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

Yield and Yield Components

When cannabis reaches full reproductive maturity (120 days old), the yield is harvested, and the yield components are assessed. The number of flower clusters per plant revealed that the top three treatments with the highest number of flower clusters per plant were T13 (HO-3, 100 kg), T12 (HO-3, 50 kg), and T11 (HO-2, 100 kg), respectively. It was found that T13 (HO-3, 100 kg) produced the highest yield, significantly differing from other treatments.

Regarding flower cluster length per plant, the study identified that the top three treatments with the longest flower clusters per plant were T13 (HO-3, 100 kg) and T12 (HO-3, 50 kg), with T13 (HO-3, 100 kg) again demonstrating superior performance. For fresh leaf weight and dry leaf weight per plant, the top three treatments were T13 (HO-3, 100 kg), T12 (HO-3, 50 kg), and T11 (HO-2, 100 kg), where T13 (HO-3, 100 kg) significantly outperformed other treatments.

In terms of fresh branch weight and dry branch weight per plant, the top three treatments were T13 (HO-3, 100 kg), T12 (HO-3, 50 kg), and T11 (HO-2, 100 kg). T13 (HO-3, 100 kg) and T12 (HO-3, 50 kg) displayed no significant difference between them but were significantly different from other treatments.

For fresh stem weight and dry stem weight per plant, the study showed that T13 (HO-3, 100 kg), T12 (HO-3, 50 kg), and T11 (HO-2, 100 kg) ranked highest, with T13 (HO-3, 100 kg) significantly outperforming other methods. The weights of fresh flowers and dry flowers per plant also revealed the top three treatments as T13 (HO-3, 100 kg), T12 (HO-3, 50 kg), and T11 (HO-2, 100 kg), with T13 (HO-3, 100 kg) again showing the highest yield.

The fresh root weight and dry root weight per plant indicated that the top three treatments were T13 (HO-3, 100 kg), T12 (HO-3, 50 kg), and T11 (HO-2, 100 kg), where T13 (HO-3, 100 kg) and T12 (HO-3, 50 kg) had similar results that were significantly different from other treatments. The total fresh weight and total dry weight per plant identified that T13 (HO-3, 100 kg), T12 (HO-3, 50 kg), and T11 (HO-2, 100 kg) ranked highest, with T13 (HO-3, 100 kg) significantly outperforming other treatments.

The results indicated that in every measured category, T13 (HO-3, 100 kg) consistently showed the highest yield, statistically distinct from other treatments, followed by T12 (HO-3, 50 kg), T11 (HO-2, 100 kg), and T10 (HO-2, 50 kg). These results demonstrate that HO fertilizer is effective and influential in enhancing crop yields due to the integration of diverse agricultural materials in its formulation (Table 1). The preparation of raw materials for decomposition occurred approximately one month prior to their incorporation into the HO fertilizer formula. After granulation, the grains were coated to regulated the slow release efficiency, resulting in a complete nutrient profile within HO fertilizer and providing comprehensive growth factors for plants (Choomman & Inthanon, 2016).

Notably, T13 (HO-3, 100 kg) exhibited the highest concentrations of nutrients, surpassing those of HO-2 and HO-1 when applied at higher rates (100 kg/rai), leading to greater yield and yield components of cannabis compared to any other treatments. The influence of HO fertilizers significantly improved the physical, chemical, and biological properties of the growing media alongside fertilizer application, particularly concerning pH levels. HO fertilizer contains 25-35% agricultural lime and approximately 1.38% organic matter (Sonklien et al., 2019; Raksarikorn, 2013). The collaboration with Effective Microorganisms (EM) resulted in enhanced porosity and friability of the growing media, directly affecting oxygen transfer and water retention capacity, thereby allowing roots to expand optimally and facilitating nutrient absorption by the plants (Johnson & Raymond, 1965). As water retention capacity increases, soil acidity improves, and nutrients are sufficiently available around the plant roots. This subsequently elevates the uptake and transport of nutrients into the plant for photosynthesis, promoting enhanced vegetative growth, including canopy size, number of branches per plant, and number of leaves per plant. Higher rates of photosynthesis lead to increased production of photosynthates, resulting in greater accumulation of dry matter in terms of fresh leaf weight, dry leaf weight per plant, fresh branch weight, dry branch weight per plant, fresh root weight, and dry root weight. This, in turn, contributes to higher yields and yield components overall (Juthangkka et al., 2000).

Additionally, the inclusion of bio-liquid hormone in all HO fertilizers promotes the efficient translocation of starches and sugars within the yield and yield components. The high concentrations of potassium (K), calcium (Ca), and boron (B) present in HO fertilizers play pivotal roles in starch and sugar accumulation in yield and yield components. The integration of these organic substances and plant hormones stimulates increased flower bud formation and

blooming. Consequently, there is a notable increase in flower size, fresh flower weight, and dry flower weight, as well as total fresh and total dry weight across the HO fertilizer treatments compared to chemical fertilizers. Specifically, T13 (HO-3, 100 kg), which possesses the highest concentration of formula components, consistently exhibited superior performance across all measured parameters compared to other treatments, following by T12 (HO-3, 50 kg), T11 (HO-2, 100 kg), and T10 (HO-2, 50 kg) respectively. Therefore, it can be concluded that HO fertilizer influences the accumulation of dry matter in yield and yield components more effectively than chemical fertilizers (Table 4).

Table 4: Yield and Yield Components

Treatment	Fresh Leaf Weight (g/plant)	Dry Leaf Weight (g/plant)	Fresh Branch Weight (g/plant)	Dry Branch Weight (g/plant)	Fresh Stem Weight (g/plant))	Dry Stem Weight (g/plant)	Fresh Root Weight (g/plant)	Dry Root Weight (g/plant)	Fresh Flower Weight (g/plant)	Dry Flower Weight (g/plant)	Total Fresh Weight (g/plant)	Total Dry Weight (g/plant)
T1 (Control)	17.33g	7.67g	11.50f	2.00f	21.67f	9.00f	28.50h	2.53h	19.0i	5.60i	97.00k	26.70k
T2 (25-7-7, 50kg)	45.50c	21.50c	25.50e	9.50e	24.10e	10.62e	40.00g	3.24g	20.00i	6.85i	155.10j	52.17j
T3 (25-7-7, 100kg)	47.20c	22.15c	26.55e	9.80e	24.80e	11.15e	45.86f	4.20f	20.28i	7.10i	164.69i	54.40i
T4 (16-8-8, 50kg)	44.61d	20.30d	30.56d	13.54d	24.16e	14.00d	60.17e	5.04e	25.64h	9.98h	185.14h	62.86h
T5 (16-8-8, 100kg)	44.10d	20.12d	31.67d	14.18d	25.62c	14.04d	60.24e	5.24e	25.80h	10.12h	188.43h	63.70h
T6 (15-15-15, 50kg)	40.50e	18.61e	39.20b	23.14b	25.67c	14.18d	63.57fd	5.51d	27.65g	11.66g	196.39g	73.08g
T7 (15-15-15, 100kg)	40.70e	18.88e	39.16b	23.25b	25.85c	14.37d	65.84d	5.80d	27.80g	11.80g	199.35g	74.37g
T8 (HO-1, 50kg)	37.20f	17.14f	33.44c	19.62c	25.23cd	14.14d	70.18c	6.12bc	70.88f	27.58f	236.93f	84.60f
T9 (HO-1, 100kg)	37.50f	17.50f	34.65c	20.40c	25.62c	14.24d	70.68c	6.50bc	75.50e	29.37e	243.95e	88.01e
T10 (HO-2, 50kg)	53.10b	25.54b	39.24b	23.18b	27.14b	17.53c	85.17b	7.00b	82.66d	32.16d	287.07d	105.35d
T11 (HO-2, 100kg)	54.55b	26.60b	39.50b	23.52b	27.64b	18.27c	86.63b	7.20b	85.00c	34.50c	292.98c	110.09c
T12 (HO-3, 50kg)	58.40a	28.58a	55.48a	25.02a	29.61a	20.55b	96.42a	8.62a	95.62b	37.21b	335.53b	119.98b
T13 (HO-3, 100kg)	59.63a	29.67a	56.52a	25.18a	29.80a	22.00a	98.45a	9.50a	98.55a	39.50a	342.95a	125.85a
CV(%)	1.64	4.39	3.55	3.62	2.36	5.22	1.39	13.19	2.41	4.81	5.40	1.74
F-Test	*	*	*	*	*	*	*	*	*	*	*	*

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

Analysis of Yield Quality (Concentration of Active Ingredients in Flower Clusters: THC/CBD)

The analysis of the concentration of active ingredients in flower clusters revealed that the treatment with the highest concentration of Tetrahydrocannabinol (THC) was T13 (HO-3, 100 kg), followed by T12 (HO-3, 50 kg), T10 (HO-2, 50 kg), T11 (HO-2, 100 kg), T6 (15-15-15, 50 kg), T7 (15-15-15, 100 kg), T2 (25-7-7, 50 kg), T3 (25-7-7, 100 kg), T4 (16-8-8, 50 kg), and T5 (16-8-8, 100 kg), T8 (HO-1, 50 kg), T9 (HO-1, 100 kg), and T1 (Control), with average concentrations of 10.5, 10.4, 9.5, 8.6, 8.3, 7.4, and 5.2 % W/W, respectively. The treatment with the highest concentration of Cannabidiol (CBD) was T13 (HO-3, 100 kg), followed by T12 (HO-3, 50 kg), T10 (HO-2, 50 kg), T11 (HO-2, 100 kg), T8 (HO-1, 50 kg), T9 (HO-1, 100 kg), T6 (15-15-15, 50 kg), T7 (15-15-15, 100 kg), T2 (25-7-7, 50 kg),

T3 (25-7-7, 100 kg), T4 (16-8-8, 50 kg), and T5 (16-8-8, 100 kg), and T1 (Control), with average values of 0.95, 0.93, 0.91, 0.76, 0.68, 0.41, and 0.31 % W/W, respectively. The concentrations of THC and CBD were found to be highest in T13 (HO-3, 100 kg) and were statistically significantly different from other treatments. The increase in THC/CBD concentrations was a result of the plants receiving a complete nutrient supply, allowing for substantial accumulation of organic matter from photosynthesis. This process was facilitated by the mobilization of organic hormones, which worked synergistically with potassium (K), calcium (Ca), and boron (B) to drive the movement of organic substances such as starches and sugars (photosynthates). The volatile compounds and synthesized THC/CBD were then directed to accumulate in the harvestable yield and its components. The fertilizer treatment T13 (HO-3, 100 kg), which exhibited the highest concentration levels, resulted in maximum vegetative growth in parameters such as plant size, number of branches per plant, and number of leaves per plant. Therefore, it can be concluded that T13 (HO-3, 100 kg) demonstrated superior photosynthesis and organic matter production compared to other treatments. As the plants transitioned into the reproductive stage of flowering and fruiting, these organic substances and THC/CBD compounds were transported to the yield, thereby enabling T13 (HO-3, 100 kg) to yield statistically significant results compared to other treatments (Mady & Youssef, 2014; Nair & Kumar, 1980) (Table 5).

Table 5: Concentration of Active Ingredients in Flower Clusters (THC/CBD)

Treatment	Tetrahydrocannabinol (THC) %W/W	Cannabidiol (CBD) %W/W
T1 (Control)	5.2f	0.31g
T2 (25-7-7, 50kg)	8.3d	0.41f
T3 (25-7-7, 100kg)	8.3d	0.41f
T4 (16-8-8, 50kg)	8.3d	0.41f
T5 (16-8-8, 100kg)	8.3d	0.41f
T6 (15-15-15, 50kg)	8.6c	0.68e
T7 (15-15-15, 100kg)	8.6c	0.68e
T8 (HO-1, 50kg)	7.4e	0.76d
T9 (HO-1, 100kg)	7.4e	0.76d
T10 (HO-2, 50kg)	9.4b	0.91c
T11 (HO-2, 100kg)	9.4b	0.91c
T12 (HO-3, 50kg)	9.5b	0.92b
T13 (HO-3, 100kg)	10.5a	0.95a
CV(%)	20.09	30.10
F-Test	*	*

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

Production Costs, Revenue, and Profit per Rai (Concise Overview)

The concise overview of production costs, revenue, and profit per rai focuses solely on variable costs, which fluctuate with production volume, such as materials, labor, and miscellaneous expenses. Fixed costs, including containers, well drilling, and water pumps, are excluded from this analysis under the assumption that they are constant across all treatments. Analysis revealed that the three treatments with the highest total costs were T3 (25-7-7, 100kg), T7 (15-15-15, 100kg), and T13 (HO-3, 100kg), with average total costs of 250,570, 250,270, and 250,270 baht/rai, respectively. However, when considering revenue generated from selling dried cannabis inflorescences at 8,000 baht/kg (as of December 2018) and subtracting costs, the three most profitable treatments were T13 (HO-3, 100kg), T12 (HO-3, 50kg), and T11 (HO-2, 100kg), yielding profits of 170,010, 146,594, and 117,010 baht/rai, respectively. Cost

analysis indicated that although T13 (HO-3, 100kg) had high costs comparable to chemical fertilizer (T3 15-15-15), its superior yield resulted in the highest profit of 170,010 baht/rai after deducting expenses from sales revenue. Notably, all HO fertilizer treatments (T8-T13) generated profits due to high yields, while all chemical fertilizer treatments (T2-T7) incurred losses due to low yields and reduced concentrations of active compounds. (Table 6).

Table 6: Production Costs, Revenue, and Profit per Rai (Concise Overview)

Item	Treatment												
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13
Material Costs (Baht/Rai)													
1,330 cannabis seedlings	19,950	19,950	19,950	19,950	19,950	19,950	19,950	19,950	19,950	19,950	19,950	19,950	19,950
Organic growing media for 1,330 plants x 12 kg x 12 Baht	191,520	191,520	191,520	191,520	191,520	191,520	191,520	191,520	191,520	191,520	191,520	191,520	191,520
Fertilizer costs per treatment (Table 4 , 5)	0	1,100	2,200	850	1,700	950	1,900	800	1,600	850	1,700	950	1,900
Organic liquid hormone costs	500	500	500	500	500	500	500	500	500	500	500	500	500
Herbal insecticide costs	500	500	500	500	500	500	500	500	500	500	500	500	500
Irrigation system and connectors for entire plot	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000
Labor Costs (Baht/Rai)													
Labor for growing media preparation	600	600	600	600	600	600	600	600	600	600	600	600	600
Crop maintenance labor 300 Baht x 90 days	27,000	27,000	27,000	27,000	27,000	27,000	27,000	27,000	27,000	27,000	27,000	27,000	27,000
Harvesting labor 5 persons x 300 Baht x 2 days	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000
Miscellaneous Expenses (Baht/Rai)													
Electricity costs	800	800	800	800	800	800	800	800	800	800	800	800	800
Water costs	500	500	500	500	500	500	500	500	500	500	500	500	500
Total Production Costs	248,370	249,470	250,570	249,220	250,070	249,320	250,270	249,170	249,970	249,220	250,070	249,320	250,270
Revenue (Baht/Rai)													
Fresh flower yield (kg/Rai)	25.27	27.60	27.97	34.10	34.31	36.77	36.97	94.27	100.42	109.94	113.05	127.17	131.07
Dry flower yield (kg/Rai)	7.45	9.11	9.44	13.27	13.46	15.51	15.69	36.68	39.06	42.77	45.89	49.49	52.54
Revenue from dry flower sales (8,000 Baht/kg)	59,584	72,884	75,544	106,187	107,677	124,062	125,552	293,451	312,497	342,482	367,080	395,914	420,280
Profit (Baht/Rai)	-188,786	-176,586	-175,026	-143,033	-142,393	-125,258	-124,718	44,281	62,527	93,262	117,010	146,594	170,010
Rank	13	12	11	10	9	8	7	6	5	4	3	2	1

4. Conclusions

Based on the experimental results mentioned above, the development of mixed formula pelletized hormone fertilizers (HO) compared to chemical fertilizers in relation to yield and quality in open-field cannabis cultivation can be summarized as follows:

1. All three developed HO fertilizers demonstrate suitability and high efficacy for cannabis cultivation in an open system, particularly the HO-3 fertilizer at a rate of 100 kg (T13), which resulted in the highest plant growth, yield, and yield components, with higher concentrations of active ingredients compared to chemical fertilizers.

2. The three developed HO fertilizers significantly influence the quality and concentration of active ingredients in cannabis flower clusters, showing that THC and CBD levels were highest in the HO fertilizer group, particularly in T13 (HO-3, 100 kg), which differed significantly from other treatments.

3. In terms of cost, income, and profitability, T13 (HO-3, 100 kg) yielded the highest net profit of 170,010 Baht per rai. The entire HO fertilizer group (T8-T13) generated profits between 44,281 and 170,010 Baht per rai, while the chemical fertilizer group (T2-T7) exhibited a loss due to high costs associated with planting materials, seedlings, and labor, resulting in lower yields and therefore lower income.

5. Recommendations

Given that this experiment was conducted in a natural open-field setting, future studies should consider implementing mist spraying or supplemental lighting during certain growth stages, which may enhance yields or active ingredient concentrations.

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