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| **Improving Inceptisol Soil Fertility using Caterpillar Epigenetics: *Tenebrio molitor* (L.) Tenebrionidae. and *Bombyx mori* Linnaeus. as Facilitator of Soil Nutrient Amelioration and Plant Growth of *Capsicum frutescens* ‘Bird’s Eye’** | |
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| **Abstract**  The growth and development of the world's population necessitates the continued development of agriculture that will provide food for all living things, while reducing chemicals in agriculture. The use and rearing of insect caterpillars may increase in the next few years. Producing frass (insect caterpillar dung) from the frass of bamboo caterpillars or Hongkong caterpillars (Tenebrio molitor (L.) Tenebrionidae.) and silkworms (Bombyx mori Linnaeus.) can improve soil fertility and enhance the growth of red chilli (Capsicum frutescens ‘Bird's Eye’) plants. The minerals formed quickly and easily available in the soil in the form of available, and their efficiency is the same as inorganic fertilizers to increase biomass. Overall, the results showed that Hong Kong caterpillar frass (Tenebrio molitor L.) and silkworm frass (Bombyx mori Linnaeus.) have great potential as a substitute for Mineral NPK fertilizer. With the application of Hong Kong caterpillar frass (Tenebrio molitor (L.) Tenebrionidae.) and silkworm (Bombyx mori Linnaeus.), application with mineral fertilizer P (Phosphor) absorption concentration is five times lower and slower, with the presence of caterpillar frass will prevent loss in the soil and directly absorbed into the soil and needed by plants. | Article History  Received: 2024-02-04  Revised: 2024-03-02  Accepted: 2024-04-15 |
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**INTRODUCTION**

Tenebrio molitor (L.) Tenebrionidae. and Bombyx mori Linnaeus. are animals in the insect class and are usually mostly found in the larval phase. Larvae are prospective animals that will grow and grow and can live to reproduce outside of life. Larvae of Tenebrio molitor (L.) Tenebrionidae. are in dire need of food, and larval growth is very fast, where larval growth reaches the pupa (moulting) phase.

Hongkong caterpillars (Tenebrio molitor (L.) Tenebrionidae.) are very easy to cultivate and are highly used as animal feed. The content possessed by bamboo caterpillars commonly called Hongkong caterpillars (Tenebrio molitor (L.) Tenebrionidae.), has a very high nutritional content and is very suitable to be used as animal food. According to Finke & Winn (2004), the content contained in bamboo caterpillars or Hongkong caterpillars (Tenebrio molitor (L.) Tenebrionidae.) is 48% protein, 40% crude fat, 3% ash content, nitrogen extract and 57% moisture content.

The utilization of silkworm (Bombyx mori Linnaeus) is very relevant and can improve soil fertility. Silkworm frass (Bombyx mori Linnaeus) can be an organic fertilizer that is very effective in improving soil quality and chemical properties.

Improvements in soil chemical properties with the application of silkworm frass (Bombyx mori Linnaeus.) can increase soil chemical content such as organic carbon content, total soil nitrogen, available phosphorus, and potassium. The content contained in silkworm (Bombyx mori Linnaeus.) is the mineral content of iron (Felium) which is 2.6 mg, sodium content (Na) of 12 mg, potassium content (K) of 7 mg, calcium content (Ca) of 8 mg, zinc content (Zn) of 13 mg, phosphorus content (P) of 12 mg and nitrogen content (N) of 14 mg (Blakstad et al., 2023).

Hong Kong caterpillar or bamboo caterpillar (Tenebrio molitor (L.) Tenebrionidae.) faeces contain nitrogen (N) of 2.7% - 2.8%, phosphorus (P) of 1.0% - 1.5%, potassium (K) of 1.2% - 2.0% and other micronutrients such as Ca, Fe, and Mg. According to the results of research by Maha et al. (2021), the content of bamboo caterpillar frass (Tenebrio molitor (L.) Tenebrionidae.) according to soil needs consists of Nitrogen (N) 0.33% - 0.49%, Phosphor (P) 21.66 mg.100 g-1 - 36.81 mg.100 g-1. Potassium (K) 48.28 mg.100 g-1 - 49.25 mg.100 g-1.

Small Red Cayenne Pepper (Capsicum frutescens 'Bird's Eye') is a vegetable crop that has the potential to be developed; this chilli is smaller than curly red chilli but has the potential to be very spicy (Prajnanta, 2002) Putri. Importing chillies is still being done, and Indonesia is still doing this, whether the chillies are fresh, dried or powdered. So, there is a need for the expansion of planting and an increase in fertilization techniques through cultivation techniques so that plants can produce well and efficiently in their productivity (Ferawati et al., 2014).

**METHODS**

This research was conducted in the nursery area of the Soil Management Field Laboratory, Institut Teknologi Sawit Indonesia (ITSI) Medan. Inceptisol soil medium was taken from the oil palm nursery of PPKS Tanjung Morawa, North Sumatra. Small Red Chilli (*Capsicum frutescens* ‘Bird's Eye’) seedlings were used in polybags at the age of one month. The research was conducted for four months, from November 2024 to March 2025.

This study used a non-factorial Randomised Group Design (RGD), where Factor 1 Epigenetic caterpillar: *Tenebrio molitor* (L.) Tenebrionidae. (T) with 2 treatment levels, T1 = 250 ml. polybag-1, T2 = 500 ml. polybag-1. Factor 2 Epigenetic caterpillar: *Bombyx mori* Linnaeus. (B) with 2 treatment levels, B1 = 250 ml. polybag-1, B2 = 500 ml. polybag-1, Factor 3 mixture of genetic fluid and frass from caterpillars *Tenebrio molitor* (L.) Tenebrionidae. and *Bombyx mori* Linnaeus. (TB) with 2 treatment levels, TB1 = 250 ml. polybag-1, TB2 = 500 ml. polybag-1.

Soil analysis and experiments were conducted at the Soil Laboratory, Indonesian Oil Palm Research Institute (IOPRI or PPKS) Medan, and the Soil, Plant, Fertilizer and Water Laboratory at the Institute for Agricultural Technology (IAT or BPTP) Johor, Medan, North Sumatra.

The use of epigenetic caterpillars from silk (*Bombyx mori* Linnaeus.) and bamboo or Hongkong (*Tenebrio molitor* (L.) Tenebrionidae.) is their faeces, then mixed with the results of the genetic fluid from the silk caterpillars and Hongkong caterpillars. The genetic fluid from the silkworm and bamboo or Hongkong caterpillar frass was soaked in 5 litres of water mixed with 500 ml of rice washing water for 30 days, and the bamboo (*Tenebrio molitor* (L.) Tenebrionidae.) and silkworm (*Bombyx mori* Linnaeus.) faeces were composted with brown sugar and 1 litre of *Effective Microorganisms*-4 (EM-4) liquid and covered for 30 days. The final application method into polybags was 1:1 in use.

Research observations and research indicators from the beginning were soil physical properties, namely Soil Texture (%), soil chemical properties consisting of Soil C-Organic (%), N-Total (%), P2O5-avl (P-Bray-I) (ppm P), Potential K2O Ex. HCl 25% (me.100 g-1), Cation Exchange Capacity (CEC) (me.100 g-1), Soil Acidity (pH) H2O, Al-dd (me.100 g-1), Al Saturation (%), Ca-dd (me.100 g-1), K-dd (me.100 g-1), Mg-dd (me.100 g-1), Na-dd (me.100 g-1), MnO Ex. HCl 25% (%) and the final study of Inceptisol soil on the planting media are as follows: Soil C-Organic (%), N-Total (%), P2O5-avl (P-Bray-I) (ppm P), Potential K2O Ex. HCl 25% (me.100 g-1), Cation Exchange Capacity (CEC) (me.100 g-1), Soil Acidity (pH) H2O, Al-dd (me.100 g-1), Al Saturation (%), Ca-dd (me.100 g-1), K-dd (me.100 g-1), Mg-dd (me.100 g-1), Na-dd (me.100 g-1), and vegetative growth, as well as vegetative growth of small red chilli (*Capsicum frutescens* ‘Bird's Eye’) plants consisting of plant height (cm), root length (cm), number of chilli fruit.tree-1 (fruit).

**RESULT AND DISCUSSION**

1. **Results of Analysis of Physical and Chemical Properties of Inceptisol Soil**
2. ***Initial Soil Analysis – Inceptisol Soil***

An initial analysis of the quality and fertility of Inceptisol soil was conducted to determine the characteristics of planting media in Inceptisol soil. The following Table 1 lists the results of the initial soil analysis on Inceptisol Soil as follows:

**Table 1. Preliminary Soil Analysis Results – Inceptisol Soil**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Texture** | **Method of Analysis** | **Units** | **Results** | **Description** |
|
| Sand | Hydrometer | % | 89,00 | *Loam Sandy* |
| Dust | 17,30 |
| Clay | 3,22 |
| **Analysis** | **Method of Analysis** | **Units** | **Results** | **Description** |
|
| C-Organic | Spectrophotometry | % | 4,88 | h |
| N-Total | Kjedhal | % | 0,30 | l |
| P2O5-avl (P-Bray-I) | Spectrofotometry | ppm P | 1,88 | vl |
|
| K2O Potential Ex. HCl 25% | AAS/Asam Acetat 1 N | me.100 g-1 | 0,11 | VL |
|
| MnO Ex. HCl 25% | Spectrofotometry | % | 0,27 | h |
| CEC | Volumetry/NaCl 10% | me.100 g-1 | 41,22 | h |
|
| pH H2O | Electrometry | ----- | 6,8 | m  (Neutral) |
|
| Al Saturation | Titrimetry | % | 0,0 | nm |
| Al-dd | me.100 g-1 | 0,0 | nm |
| Mg-dd | AAS/Asam Acetat 1 N | me.100 g-1 | 2,16 | h |
| Ca-dd | 5,50 | l |
| K-dd | 0,17 | l |
| Na-dd | 0,40 | m |

*Description: Criteria for Planting Media, h = High, l = Low, m = Medium, sl = Slightly Low, vl = Very Low, vh = Very High, n = Neutral, nm = Not Measurable*

The results of the initial soil analysis can be seen in Table 1, where the results of the Inceptisol Soil analysis show that the Soil Physics analysis test on Inceptisol soil texture includes Sandy Loam texture, where the sand texture is 89%, dust texture is 17.30% and clay texture is 3.22%. These results determine the texture of Inceptisol soil, which has appropriate criteria. While the Soil Chemistry analysis test on C-Organic with 4.88% analysis results including high criteria, N-Total with 0.30% analysis results with low criteria, P2O5-avl with P-Bray-I test analysis results with 1.88 ppm P with very low criteria and K2O Potential Ex. HCl 25% analysis result in 0.11 me.100 g-1 with very low criteria.

In the analysis of Cation Exchange Capacity (CEC), the analysis result is 41.22 me.100 g-1 with high criteria, while in soil acidity (pH) H2O the analysis result is 6.8 with high criteria and includes acidic soil. According to Novizan (2018) and Hadad, M.E.A., E. Randriani, and C. Firman (2018), bacteria and fungi can grow in soil with soil acidity (pH) ranging from 5.5 to 7.0 and can decompose organic matter in the soil. At the decomposition of organic matter in the soil, microorganisms will decompose, which can be produced into humus, which will increase Cation Exchange Capacity (CEC) levels in the soil (Sutanto, 2002).

In the exchangeable cation test, the analysis results on aluminium; the soil is not bound to aluminium and remains healthy. The analysis of magnesium exchangeable (Mg-dd) with high criteria means it can be measured where the analysis results are 2.16 me.100 g-1. Ca-dd and K-dd include low criteria, which is low availability of exchangeable calcium and potassium nutrients in the soil and exchangeable sodium nutrients (Na-dd) with analysis results of 0.40 me.100 g-1, including with moderate criteria, indicates that sodium has the ability of positive ions to hold and exchange ions.

The soil fraction is directly proportional to the fraction content, which means that the soil is very suitable for plants and plant growth. The lower the clay content in Inceptisol soil, the better the plant growth (Ruhnayat, A., & Martini, 2015; Lubis, 2023).

In the results of exchangeable cation analysis, low nutrient availability will result in H+ activity or pH in the soil. According to the opinion of Leiwakabessy et al. (2002), in Hasibuan (2023), low nutrients of Potassium (K) and Magnesium (Mg), so these ions are difficult to exchangeable cations, then these nutrients are more difficult to absorb by plants. Meanwhile, according to Lubis et al. (2023), the analysis of nutrient availability in the soil is very decisive in the presence of nutrients in the soil so that hydrogen activity or acidity ions occur, and if there is a lack of poisoning in the soil, then ions will not occur.

1. ***Final Soil Analysis 1 – Inceptisol Soil***

To determine the characteristics of planting media in Inceptisol Soil, a final analysis of the quality and fertility of Inceptisol soil that has been applied is conducted. The following Table 2 lists the results of the final soil analysis on Inceptisol soil as follows:

**Table 2. Final Analysis Results 1 – Inceptisol Soil**

|  |  |  |  |
| --- | --- | --- | --- |
| **Caterpillar Epigenetics** | **C-Organik** | **CEC** | **pH H2O** |
| **%** | **me.100 g-1** | **----** |
| *Tenebrio molitor* (L.) Tenebrionidae. | 4,93 h | 43,78 h | 6,9 m (n) |
| *Bombyx mori* Linnaeus. | 4,99 h | 45,12 h | 7,2 m (n) |
| *Tenebrio molitor* (L.) Tenebrionidae.  **+** *Bombyx mori* Linnaeus. | 5,27 h | 49,98 h | 7,4 m (n) |
|

Description: Criteria for Planting Media, h = High, l = Low, m = Medium, sl = Slightly Low, vl = Very Low,

vh = Very High, n = Neutral, nm = Not Measurable

In the final analysis of Inceptisol soil, the analysis of soil organic carbon (C-Organic) was found to have increased after the application of genetic caterpillars: *Tenebrio molitor* (L.) Tenebrionidae. and *Bombyx mori* Linnaeus. As well as a mixture of both genetics on both caterpillars. In the HongKong caterpillar (*Tenebrio molitor* (L.) Tenebrionidae.) with the results of soil C-Organic analysis of 4.93%, silkworm (*Bombyx mori* Linnaeus.) with the results of the analysis of 4.99% and with a mixture of both eugenics caterpillars is the result of analysis of 5.27%. This happens because of the benefits between the role of organic matter that has been perfect so that the carbon formed in Inceptisol soil has increased, and the increasing levels of organic carbon in the soil, the plants will thrive, due to the role of organic carbon levels that increase the availability of nutrients for plants, and will also improve the structure and texture of the soil by organic matter.

The cation exchange capacity (CEC) provisions also determine that the CEC results in epigenetic caterpillars: *Tenebrio molitor* (L.) Tenebrionidae. was 43.78 me.100 g-1 soil, *Bombyx mori* Linnaeus. Caterpillar was 45.12 me.100 g-1 soil and the mixture of both epigenetic caterpillars was 49.98 me.100 g-1 soil. This can be a basis that if the provisions in achieving plant success in its growth, must meet the criteria of moderate to high cation exchange capacity (CEC). This also means that the higher the level of CEC in the soil, the soil will be able to trap and be able to provide nutrients in the soil for plants, and this shows that a high or higher CEC (Cation Exchange Capacity) will be able to hold and be able to exchange positive ion cations in the soil such as calcium (Ca), magnesium (Mg), potassium (K), and sodium (Na).

In soil acidity (pH) analysis, H2O has different results, in epigeneitic caterpillars: *Tenebrio molitor* (L.) Tenebrionidae. with pH 6.9 with neutral criteria, caterpillar *Bombyx mori* Linnaeus. with pH 7.2 with neutral criteria and a mixture of both epigenetic caterpillars with pH 7.4. This shows that the provision of organic matter needed by the soil will make the soil acidity level experience a mildly acidic to neutral condition. The provision of epigenetic fluid from the caterpillars *Tenebrio molitor* (L.) Tenebrionidae. and *Bombyx mori* Linnaeus. can help keep the soil in neutral or near neutral conditions on soil acidity.

1. ***Final Soil Analysis 2 – Inceptisol Soil***

To determine the characteristics of planting media in Inceptisol Soil, a final analysis of the quality and fertility of Inceptisol soil that has been applied is conducted. The following Table 3 lists the results of the final soil analysis on Inceptisol soil as follows:

**Table 3. Final Analysis Results – Inceptisol Soil**

|  |  |  |  |
| --- | --- | --- | --- |
| Caterpillar Epigenetics | N-Total | P2O5-avl  (P-Bray-I) | K2O Ex.  HCl 25% |
| % | ppm P | me.100 g-1 |
| *Tenebrio molitor* (L.) Tenebrionidae. | 0,34 m | 8,20 m | 0,52 m |
| *Bombyx mori* Linnaeus. | 0,37 m | 8,33 m | 0,55 m |
| *Tenebrio molitor* (L.) Tenebrionidae.  + *Bombyx mori* Linnaeus. | 0,40 m | 9,10 m | 0,56 m |
|

Description: Criteria for Planting Media, h = High, l = Low, m = Medium, sl = Slightly Low, vl = Very Low,

vh = Very High, n = Neutral, nm = Not Measurable

The results of soil analysis are shown in Table 3. The results of the analysis on total nitrogen (N-Total) in the soil showed the provision of genetic liquid and epigenetic caterpillars and epigenetic caterpillar frass, namely the *Tenebrio molitor* (L.) Tenebrionidae caterpillar. and *Bombyx mori* Linnaeus caterpillar. on the results of N-Total analysis on the *Tenebrio molitor* (L.) Tenebrionidae caterpillar. showed a result of 0.34% with moderate criteria. Likewise with the caterpillar *Bombyx mori* Linnaeus. Showed a result of 0.37% with moderate criteria. However, it differs from the mixture of the two epigenetic caterpillars, where the result is 0.40% with moderate criteria. This states that the soil's total nitrogen content, which was originally low, is now medium and can be accepted by the soil and plants. It is also said that the provision of liquid organic matter of epigenetic caterpillars: caterpillar *Tenebrio molitor* L. and caterpillar *Bombyx mori* Linnaeus. It can add nitrogen to the soil so that it can be needed by *Capsicum frutescens* 'Bird's Eye' plants. The results also show that with the soil analysis results, total nitrogen content (N-Total) is better and good for plant growth than high analysis results. This is because if the analysis is high, it can cause plants to grow more than desired; the leaves are easily broken, brittle, and susceptible to disease.

In the results of phosphorus analysis, the application of the caterpillar *Tenebrio molitor* (L.) Tenebrionidae. is 8.20 ppm P with moderate criteria, the caterpillar *Bombyx mori* Linnaeus. is 8.33 ppm P with moderate criteria, and the mixture of the two epigenetic caterpillars is 9.10 ppm P with moderate criteria. This is support for plants in their growth because moderate to high phosphorus conditions will have a positive impact on plants in their growth.

In the final result of the potassium analysis, it can be seen that the soil potassium level the affected by the application of epigenetic caterpillars: *Tenebrio molitor* (L.) Tenebrionidae. and *Bombyx mori* Linnaeus. caterpillars have a significant impact, where at the beginning of the analysis, it appears very low and now becomes moderate. This suggests potassium levels applied to liquid organic matter from epigeneitic caterpillars: *Tenebrio molitor* (L.) Tenebrionidae. and *Bombyx mori* Linnaeus. caterpillars positively impact soil and plant growth of *Capsicum frutescens* 'Bird's Eye'. The application of liquid organic from epigenetic caterpillars: *Tenebrio molitor* (L.) Tenebrionidae. and *Bombyx mori* Linnaeus. caterpillars, which have a high potassium content, make plants increase plant robustness, stimulate plant root growth, make plants susceptible to pests and diseases and overcome water shortages in the growing medium.

1. ***Final Soil Analysis 3 – Inceptisol Soil***

To determine the characteristics of planting media in Inceptisol Soil, a final analysis of the quality and fertility of Inceptisol soil that has been applied is conducted. The following Table 4 lists the results of the final soil analysis on Inceptisol soil as follows:

**Table 4. Final Analysis Results – Exchangeable Cations in Inceptisol Soil**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Caterpillar Epigenetics** | **Al-dd** | **Al Saturation** | **Ca-dd** | **K-dd** | **Mg-dd** | **Na-dd** |
| **me.100 g-1** | **%** | **me.100 g-1** | **me.100 g-1** | **me.100 g-1** | **me.100 g-1** |
| *Tenebrio molitor* (L.) Tenebrionidae. | 0,0 nm | 0,0 nm | 10,12 m | 0,77 h | 2,00 m | 0,67 m |
| *Bombyx mori* Linnaeus. | 0,0 nm | 0,0 nm | 10,15 m | 0,79 h | 2,00 m | 0,68 m |
| *Tenebrio molitor* (L.) Tenebrionidae. + *Bombyx mori* Linnaeus. | 0,0 nm | 0,0 nm | 10,77 m | 0,82 h | 2,10 m | 0,72 h |
|

Description: Criteria for Planting Media, h = High, l = Low, m = Medium, sl = Slightly Low, vl = Very Low,

vh = Very High, n = Neutral, nm = Not Measurable

1. **Growth Analysis Results of *Capsicum frutescens* ‘Bird’s Eye’**

To see the results of *Capsicum frutescens* ‘Bird's Eye’ plant growth against the application of Epigenetic Caterpillars: Tenebrio molitor (L.) Tenebrionidae. and *Bombyx mori* Linnaeus. then produced in Table 5 as follows:

**Table 5. Growth and Yield of *Capsicum frutescens* ‘Bird’s Eye’**

|  |  |  |  |
| --- | --- | --- | --- |
| **Caterpillar Epigenetics** | **Plant Height** | **Root Lenght** | **Number of Fruit.Tree-1** |
| **cm** | **cm** | **Fruit** |
| *Tenebrio molitor* (L.) Tenebrionidae. | 68 | 39 | 86 |
| *Bombyx mori* Linnaeus. | 69 | 43 | 88 |
| *Tenebrio molitor* (L.) Tenebrionidae. +  *Bombyx mori* Linnaeus. | 72 | 49 | 98 |
|

In the analysis of vegetative growth and yield on *Capsicum frutescens* ‘Bird's Eye’ plants, it can be seen that the plant height with the application of Caterpillar *Tenebrio molitor* (L.) Tenebrionidae. has a height of 68 cm, Caterpillar *Bombyx mori* Linnaeus. has a height of 69 cm and a mixed formulation of Caterpillar Epigenetics: *Tenebrio molitor* (L.) Tenebrionidae. and *Bombyx mori* Linnaeus. had a height of 72 cm. It is said that the application of the Epigenetic Caterpillar can increase plant growth without the addition of NPK inorganic fertilizer. This is due to the content possessed by Epigenetic Caterpillars so that the increase in plant height takes place properly. While in the length of plant roots, the application of Epigenetic Caterpillar *Tenebrio molitor* (L.) Tenebrionidae. which is 39 cm and Caterpillar *Bombyx mori* Linnaeus. which is 43 cm and a mixed formulation of Epigenetic Caterpillar: *Tenebrio molitor* (L.) Tenebrionidae. and *Bombyx mori* Linnaeus. which is 49 cm. It is said that the application of Epigenetic Caterpillars is very suitable for Inceptisol soil and plants that grow because the application of Epigenetic Caterpillars can increase the length of the roots of *Capsicum frutescens* 'Bird's Eye' so that the roots of plants can find water and nutrients in the soil.

In the generative analysis of *Capsicum frutescens* ‘Bird's Eye’ plants, it was seen that the number of yields of spicy red small chillies in the application of Caterpillars *Tenebrio molitor* (L.) Tenebrionidae. Amount to 86 fruits, while Caterpillars *Bombyx mori* Linnaeus. amounted to 88 fruits and mixed formulations of Epigenetic Caterpillars: Caterpillar *Tenebrio molitor* (L.) Tenebrionidae. and Caterpillar *Bombyx mori* Linnaeus. totalled 98 fruits. This includes the highest number of chilli fruits and the fastest producing fruit yields, without any formulation with inorganic fertilizers. This states that liquid organic Caterpillar Epigenetics can make plants thrive and produce fruit in conditions without the formulation of inorganic fertilizers.

**CONCLUSION**

In this study's conclusion, the application of Epigenetic Caterpillars: Caterpillar *Tenebrio molitor* (L.) Tenebrionidae. and Caterpillar *Bombyx mori* Linnaeus. able to increase the fertility of Inceptisol soil experiencing nutrient deficiencies, reduce cation ions that can poison the soil and plants, and increase and add cation ions in the soil. In observing the growth and yield of *Capsicum frutescens*, 'Bird's Eye' plants can increase plant height and root length without adding chemical fertilizers or inorganic fertilizers so that production results continue to be produced without the role of inorganic fertilizers.

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