The Study of nutrient removal and implementation of organic farming on broccoli cultivation to anticipate climate change

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Abstract. The excessive use of chemical fertilizers and pesticides continuously has some problems faced by farmers in horticulture cultivation. Implementation of an organic farming system is one way to adapt climate change for sustainable agriculture, improves soil quality, reducing of the detrimental effect on water quality, and efficient in the use of non-renewable energy. This study aim to determine the level of N, P and K removal, the growth and yield of broccoli on the three kinds of cropping systems in Batur, Getasan-Semerang. The research used a Completely Randomized Block Design with 3 treatments, namely organic, semi-organic, and conventional farming, and replicated 6 times. The soil and plant sampling were used the survey method and broccoli were harvested 8 and 10 weeks after planting. Soil properties analysis was taken before the experiment ongoing, including pH, N-total, C-organic, P-total and P-available, K-total and K-available, CEC, Particle density, Bulk density, and Percentage of total porosity. Plant growth parameters were carried out on 6, 8, and 10 weeks The result of study showed that the chemical and physical properties of the soil in the organic broccoli cultivation better than semi-organic and conventional farming, which proved by soil pH, organic C, total N, P, and K available have a higher value, while the particle density and soil bulk density have a lower value. Moreover, the total porosity and permeability have a higher value compared to conventional farming. Growth and yield of fresh broccoli by the organic farming system are increased about 21.81% and 31.43%, respectively than the conventional farming.

1. Introduction

The using a large number of chemicals fertilizers, pesticides, herbicides to achieve more production per unit area more dosages than optimum or recommended of these chemical fertilizers leads to several problems like environment pollution (soil, water, air pollution), reduced input efficiency, decreased food quality, resistance development in different weeds, diseases, insects, soil degradation, micronutrient deficiency in soil, toxicity to different beneficial living organism present above and below the soil surface.

The excessive use of chemical fertilizers and long harvest time are problems faced by farmers in the cultivation of broccoli (Brassica oleraceae var. Italica). Chemical fertilizers are fertilizers commonly used by farmers to improve the quantity of agricultural production, because they are easily obtained and the effects are given very quickly. Excessive use of chemicals has the disadvantage of increasing control costs, increasing the death of non-target organisms and reducing environmental quality, over supply of N leads to softening of plant tissue resulting in plants that are more sensitive to diseases and pests [1]. Generally, excessive amounts of inorganic fertilizers are applied to vegetables in order to achieve a
higher yield [2], and maximum value of growth [3][4]. However, the use of inorganic fertilizers alone may cause problems for human health and the environment. So, inorganic fertilizer is considered a major source of plant nutrients [5]. Organic manure can serve as alternative practice to mineral fertilizers and improving soil structure [6], and microbial biomass [7]. Therefore, utilization of locally produced manures by vegetable production operations may increase crop and quality of yields with less use of chemical fertilizer. In recent times, consumers are demanding higher quality and safer food and highly interested in organic products. Broccoli plant like from Batur, Getasan, Semarang is considered as a promising vegetable that could be developed for local and export purposes [8].

The Batur Village, Getasan district, Semarang Regency is taken place on the slopes of Mount Merbabu, where most of the people make a living as farmers. The results obtained from agriculture are used to meet the needs of life and improve the welfare of farmer households. The development of horticultural crops on the slopes of Mount Merbabu from year to year has increased both in production and harvested area. The community in the village began to realize that excessive use of chemical fertilizers and pesticides would disrupt the balance of the ecosystem, so that starting in the year of 1998, the farmers who were pioneered by Mr. Pitoyo encouraged to change their farming patterns to organic farming. However, there are still some farmers who follow the conventional method, namely using chemical fertilizers exceeding the recommended dosage, using pesticides, herbicides, fungicides and apparently not following production results after harvest. The current condition of organic farmers is advanced due to low production costs, such as fertilizers, pesticides and seeds. The price of organic vegetable commodiies is higher than conventional ones, so it can increase farmers' income [9]. The area of land and certified organic farmers is increasing every year. Until now, the certified organic land area has reached 5,024 hectares with 4,800 farmers. The supermarkets in around of Merbabu Mountain needed about 16 tons of organic vegetables from 167 types of vegetables every week. The demand also came from organic vegetable exporters to Taiwan, which reached 26 tons per week [10].

The continuous and steady application of inorganic fertilizers leads plant tissues to frequently absorb and accumulate heavy metals, which consequently decreases the nutritional and the yield quality of horticulture plants [11], including the broccoli vegetable. Broccoli (Brassica oleracea var. Italica) is a vegetable of the cabbage family (Brassicaceae). Broccoli originated in the Mediterranean region and was cultivated since Ancient Greece. These vegetables entered Indonesia around 1970 [12]. Broccoli scientifically known as “Brassica oleracea var. italic”, a Cruciferous green leaf Cole vegetable; is one such promising underexploited plant. This plant is native of Italy, but can be successfully grown in Indonesia. It is a source of valuable nutrients such as Vitamin A, vitamin B1, vitamin B2, vitamin C, vitamin E, vitamin K, folate, phosphorus, magnesium, potassium and riboflavin. It is also high in Iron and Calcium and is a non-fattening food and possesses various medicinal properties as well [13]. Broccoli is a “cool weather crop” and hot summer weather is not suitable for this plant. Broccoli grows best in temperature ranging between 18 °C and 23 °C. The cluster of flowers, also referred to as a “head”, appears in the center of the plant, and is green. Broccoli should be harvested before the flowers on the head turn bright yellow.

The broccoli plants require essential nutrients for maximum growth and yield. The use of organic fertilizer is one way to increase the growth and quality of broccoli plants, because it does not contain harmful elements (such as heavy metal elements) that can pollute the surrounding environment. Organic fertilizers are more carrier elements needed by plants and do not cause negative impacts on the environment even if used in large quantities. Organic fertilizers can be used evenly and have a density that can be adjusted according to the needs of plants [14]. Furthermore, broccoli cultivation in an organic farming system is a way of farming for broccoli commodities that rely on natural ingredients or inputs without using chemicals. So from inputs such as fertilizer to pest and disease control also naturally. This farming system can produce high quality products without damaging the environment. Agricultural products produced will be free from chemical contaminants such as synthetic fertilizers and pesticides. The land used will also improve in quality because there are no elements damaged due to chemical effects.
The organic agriculture can help to tackle climate change by reducing greenhouse gas emissions. There is a direct correlation between nitrous oxide emissions and the amount of nitrogen fertilizer applied to agricultural land. Organic agriculture has lower N₂O emissions from Nitrogen application, due to lower overall nitrogen input per ha than in conventional agriculture [15][16]. Because organic farming does not allow the use of synthetic nitrogen fertilizers, focusing instead on establishing closed nutrient cycles, minimizing losses via runoff, volatilization, and emissions, nitrogen levels on organic farms tend to be lower per hectare than on conventional farms which can contribute to a sustainable climate-friendly production system that delivers enough food [17]. In the organic agriculture, biomass is not burned, but recycled to the soil to improve fertility. This reduces the CH₄ and N₂O emissions in comparison to conventional agriculture, where crop residues are often burnt on the field [18].

There are several advantages if farmers apply an organic farming system which can reduce global climate warming, among others: the organic agriculture increase and stabilize soil organic matter. As a result, soils under organic management can better capture and store water than soils of conventional cultivation [19]. Organic production is thus less prone than conventional cultivation to extreme weather conditions, such as drought, flooding, and water-logging [20], which are expected to become much more frequent under climate change [21]. Organic farming practices have also been shown to reduce soil erosion [22], increase aggregate stability and stimulate soil biological activity [23]. Organic agriculture thus provides protective responses to key consequences of climate change, particularly those associated with increased occurrence of extreme weather events, storms, droughts and floods. Organic agriculture also increases soil quality and fertility, with regard to soil nutrients, improved soil structure and aeration, water retention capacity and thus water availability. The biological diversity of soil microbes, insects and earthworms is increased, all of which have important roles for soil quality [24].

This organic farming system is a big opportunity but also not easy to run. Here the farmers will choose and see the opportunities that exist to determine their fate. By implementing an organic farming system in broccoli cultivation, soil health will be maintained because it can improve and maintain soil pH. The agricultural waste can be optimized use, water quality safer for consumption, and increase the population of soil microorganisms. With some of the descriptions and cases in above, it is necessary to conduct the research to compare nutrient removal in organic, conventional and semi-organic farming systems and the yields obtained. Existing trends and the conscious impact of chemicals are also factors in the high demand. People prefer organic products over inorganic products. The superiority in terms of health of organic products is rich in essential nutritional content that can minimize cancer and can fight free radicals.

The objective of this study was to determine the levels of N, P and K transported on broccoli cultivation of organic, semi-organic, conventional farming, observation of the growth and yields of Broccoli obtained on Batur village, Getasan district – Semarang.

2. Material and methods
The research was carried out in the vegetable farm land of Batur Village, Getasan District, Semarang Regency, which owned by local farmers who grown broccoli crop in an organic, semi-organic and conventional farming system. The study was conducted from April to July 2018. The Altitude of study area was about 1550 m above sea level in the slopes of Mount Merbabu, and take place on the coordinate of 07°23'55"–07°24'30" Latitude and 110°24'40"–110°25'10" Longitude, with the average of rainfall of about 2,115 mm per year.

The tools used in this experiment were pest sprayers, long hoses, hoes, measuring cups, meters, stationery, cameras, thermometers, analytical scales, biomass scales, sacks, buckets, plastics, sickles and other tools for broccoli vegetable cultivation, which is commonly used by local farmers. The materials used in this experiment include broccoli seeds, Urea fertilizer, SP-36, KCl and Phonska NPK (15:15:15), rice straw mulch and biological pesticides. The experimental design used was a Complete Randomized Block Design (RCBD) with 3 treatments, namely organic, semi-organic and conventional farming systems. Each treatment was repeated 6 times and the local farmers' land was repeated. The research method uses survey methods in soil and plants sampling in organic, semi-organic and conventional
farming systems of broccoli cultivation. The planting distance of broccoli plant on three ways of cultivating plants were 60 cm x 80 cm and the size of plant sampling was 2 m x 2 m or 8 crops per sampling then converted into hectares.

The observation of soil analysis properties before the experiment included: soil pH, N-total, C-organic, P-total and P-available, K-total and K-available, CEC soil, Particle density and Soil Bulk density, Permeability and Percentage of total porosity. Plant growth parameters were observed for broccoli plant height, leaf diameter, the number of leaves, fresh and dry matter of broccoli plant yields were carried out from the age of 8 and 10 weeks after planting. The nutrients removal of N, P and K were analyzed at 10 weeks of plant age.

The data analysis was used SAS Version 9.0 program to determine the response of the treatment, which was carried out by the analysis of variance (ANOVA) and to differentiate the significance between the treatments was continued by the DMRT test with a 5% level of significance.

3. Result and discussion

The chemical and physical soil properties of the study area presented in Table 1. In broccoli vegetable cultivation organically, soil pH is rather acidic, average of 5.84. Meanwhile, the soil pH of semi-organic and conventional vegetable cultivation is more acidic than organic broccoli cultivation, which ranges between 5.26 and 4.92. The soil acidity in organic vegetable cultivation is caused by organic acids (fulvic acid and humic acid) which are released by compost or other organic matter (as much as 5 tons ha\(^{-1}\) season\(^{-1}\)) used by farmers, while decreased soil pH in semi-organic and conventional broccoli cultivation system is because of the excessive use of mineral fertilizers (250 kg urea, 250 kg Phonska (NPK), 200 kg ZA ha\(^{-1}\) season\(^{-1}\)) and animal manure 2 tons ha\(^{-1}\) season\(^{-1}\) by farmers. Soil C-organic content and total N-total on the organic cultivation system is classified as high, which ranges from 3.67% and 0.55%, respectively whereas on the conventional systems has a lower value, namely 2.19% for C-organic and 0.21% for N total. According to [25], stated that the same thing which a high soil organic matter contents (C-organic and total N) were found in soil soils that were managed with given animal manure or organic matter continuously and planted with legume cover crops. The Phosphorus total content extracted with 25% HCl shows that the organic broccoli cultivation shows a high content which is around 201.43 mg.100 g\(^{-1}\) P\(_2\)O\(_5\) whereas in conventional systems it is up to 137.61 mg .100 g\(^{-1}\) P\(_2\)O\(_5\) (average) The same cases were reported by [26].

| Parameter of soil sampling analysis | Organic farming system | Semi organic farming system | Conventional farming system |
|-----------------------------------|------------------------|-----------------------------|-----------------------------|
| pH soil (H\(_2\)O)                | 5.84                   | 5.26                        | 4.92                        |
| C-organic (%)                    | 3.67                   | 2.53                        | 2.19                        |
| N-total (%)                      | 0.35                   | 0.28                        | 0.21                        |
| C/N ratio                        | 10.79                  | 9.04                        | 10.42                       |
| P-total (HCl 25%)                | 202.43                 | 168.35                      | 137.61                      |
| P-available (mg/100 gr)          | 46.63                  | 44.39                       | 49.36                       |
| K-total (HCl 25%)                | 76.84                  | 54.97                       | 42.76                       |
| K-available (mg/100 gr)          | 38.94                  | 29.41                       | 27.45                       |
| CEC soil (me/100 g)              | 68.39                  | 55.04                       | 50.17                       |
| Particle Density soil (gr/cm\(^3\)) | 1.96                  | 2.02                        | 2.09                        |
| Bulk Density soil (gr/cm\(^3\)) | 0.87                   | 1.04                        | 1.18                        |
| Total porosity (%)               | 68.74                  | 60.18                       | 54.36                       |
| Soil Permeability (cm.hour\(^{-1}\)) | 21.65                 | 10.27                       | 6.19                        |

The parameters of soil physical characteristics observed were BJ, BV and soil porosity, and soil permeability. Broccoli cultivation in organic, semi-organic and conventional system are presented in
Table 1. In general, the soil bulk density of organic broccoli cultivation is smaller than 1.0. This is indicated that the soil to be used as a farming area classified as soil type of Andisols and the provision of organic matter (compost, chicken manure or organic matter) of 5 tons ha$^{-1}$ season$^{-1}$ is able to maintain the presence of soil physical properties (soil bulk density, total porosity and also soil permeability), become more better condition to the vegetables plant growth and crop yields [27]. Furthermore, judging from the total pore space, organic and semi-organic broccoli cultivation shows values higher than 60, meaning that both systems are equally good and the soil is easily penetrated by plant roots. This is suspected because in both systems it is rich in organic matter content (C-organic).

Table 2 shows the growth of broccoli plants in the observation of plant height on 6, 8 and 10 weeks after planting. At the beginning of the observation (6 weeks) it was seen that the broccoli vegetable crops with organic farming systems experienced lower compared to semi-organic farming systems and conventional systems. This is due to the conventional system using chemical fertilizers (Urea, Ponska NPK, SP-36 and KCl) which are readily available so that broccoli plants can be directly absorbed while the organic farming system still requires decomposition of the elements so that plant height growth is lower. Furthermore, at the age of 10 weeks the broccoli organic farming system can be followed the plant height on semi-organic farmings system, and on the last growth period the broccoli plant more higher than conventional farming system. This condition was similar to the research by [28], which stated that Addition of organic fertilizers to the field gives some benefits to land and crops. Apart from providing nutrients, the content of organic matter which helps increased amount of metabolic activity soil biology and micro body activities to assist the decomposition process. In addition, organic materials can be provide good physical condition, so the development of plant roots to be better.

Table 2. The average plant height of broccoli on organic, semi-organic and conventional farming systems.

| Treatment                | Time observation on broccoli plants |
|--------------------------|------------------------------------|
|                          | 6 weeks (cm) | 8 weeks (cm) | 10 weeks (cm) |
| Organic farming system   | 38.3 a       | 51.4 a       | 62.8 ab       |
| Semi organic            | 40.6 b       | 55.3 ab      | 63.7 a        |
| Conventional farming    | 42.4 b       | 56.5 b       | 60.2 b        |

On Table 3, it shows that on the age of 6 weeks, the application of compost (animal dung) as much as 5 tons ha$^{-1}$ applied to the organic farming system has not been decomposed into perfectly available nutrients so that the amount leaves was the same with semi organic and conventional farming system and the result have not significantly different. Then on the next observation (8 and 10 weeks), the number of broccoli leaves on organic farming system become more grow fast and got the result that were become more higher amount than conventional farming system. This is in accordance with the results of [29] research, which states that manure is a complete fertilizer because in addition to causing the availability of nutrients for plants, it can also develop the life of microorganisms (microorganisms) in the soil which can affect the physical and chemical properties of the soil. Microorganisms can change litter and crop residues become humus so that it can increase the water retention power so that it can facilitate the roots of plants to absorb food to increase their growth and development, so that production results can increase significantly.

Table 4 shows that from the 6th to 10th week of observation, the growth of leaf area in organic farming systems was shown significantly different results than conventional farming. This point out that the organic farming system in broccoli cultivation, apart from being able to improve yield quality, also give significantly result in quantity compare to the conventional farming, which farmer fully used chemical fertilizer. While if that was compared to semi-organic farming systems does not show a significant difference in observation of leaf area.
Table 3. The average of number leaves of broccoli on organic, semi-organic and conventional farming systems.

| Treatment                  | 6 weeks | 8 weeks | 10 weeks |
|----------------------------|---------|---------|----------|
| Organic farming system     | 12.74 a | 14.92 a | 17.37 a  |
| Semi organic               | 11.28 a | 14.04 a | 15.94 ab |
| Conventional farming       | 11.93 a | 13.57 b | 14.26 b  |

Table 4. The average leaf area of broccoli on organic, semi-organic and conventional farming systems.

| Treatment                  | 6 weeks | 8 weeks | 10 weeks |
|----------------------------|---------|---------|----------|
| Organic farming system     | 407.38 a| 989.26 a| 1246.19 a|
| Semi organic               | 356.41 b| 913.54 ab| 1172.56 ab|
| Conventional farming       | 305.82 b| 846.37 b| 1068.74 b|

This is similar to the research conducted by [30], which stated during the vegetative phase, plants really need nitrogen and phosphorus elements. These two elements are very influential in the formation of cells and are the main components of organic compounds. Elemental N is the basic material for forming amino acids and proteins which plants use for metabolic processes. The number of N which is enough will accelerate the plant’s metabolism so that the growth of organs such as stems, leaves and roots becomes better. Roots absorb nutrients needed by plants in vegetative form so that the plant stems grow tall and affect the number and area of leaves formed.

Table 5. Fresh and dry matter partitioning of harvesting broccoli plant during 8 and 10 weeks.

|                     | Fresh matter (ton.ha⁻¹) | Dry matter (ton.ha⁻¹) |
|---------------------|-------------------------|-----------------------|
|                     | 8 weeks | 10 weeks | 8 weeks | 10 weeks |
| **Organic farming system** |         |          |         |          |
| Leaves              | 22.89   | 36.72    | 2.79    | 4.58     |
| Stems               | 14.57   | 20.16    | 1.49    | 2.03     |
| Roots               | 3.26    | 5.84     | 0.47    | 0.83     |
| Main heads/Flowers  | 13.74   | 21.35    | 1.73    | 2.67     |
| Total               | 54.46 a | 84.07 a  | 6.48 a  | 10.11 a  |
| **Semi organic farming system** |         |          |         |          |
| Leaves              | 20.17   | 31.48    | 2.15    | 4.06     |
| Stems               | 15.84   | 18.36    | 1.29    | 1.89     |
| Roots               | 3.05    | 5.27     | 0.38    | 0.75     |
| Main heads/Flowers  | 11.78   | 19.42    | 1.56    | 2.38     |
| Total               | 50.84 b | 74.53 b  | 5.38 b  | 9.08 ab  |
| **Conventional farming system** |         |          |         |          |
| Leaves              | 18.68   | 26.53    | 18.64   | 3.62     |
| Stems               | 14.74   | 15.81    | 1.02    | 1.28     |
| Roots               | 2.87    | 5.09     | 0.26    | 0.43     |
| Main heads / Flowers| 11.83   | 16.48    | 1.47    | 2.02     |
| Total               | 48.12 b | 63.91 c  | 4.64 c  | 7.35 b   |

Table 5 shown that the fresh and dry matter production of harvesting broccoli plants on organic farming systems are significantly different from those semi-organic and conventional systems.
Meanwhile, the last two systems are mostly not significantly different. This shows the organic farming system is able to maintain quality and it is proven to be able to increase the quantity if the farming systems was carried out continuously and environmentally friendly conditions can be maintained.

On Table 6 can be seen that the NPK nutrients transported (nutrients removal) are varied. In the organic farming system for broccoli vegetable cultivation it is shown that the N nutrients removal have the high value aside K nutrient and it has significantly different from conventional farming systems, whereas for the P nutrients removal total by the organic farming systems there is significant different compare to semi-organic and conventional farming system. While the value of P nutrient removal on semi organic and conventional farming system were not significant different. The researcher [31], reported that for vegetable plants the element K was the highest absorption (nutrients transported), then followed by the N nutrient and finally P. In plants that absorb the lowest N and K nutrient, it can be identified that broccoli yields will be the lowest, and the highest NPK nutrients accumulated in the leaves, then followed by the stems, then broccoli flowers and finally the roots. Furthermore other statement put forward by [32], although broccoli plants accumulate substantial quantities of plant material and nutrients, most of the nutrients remain in the field and are not removed with the market heads. Only 21.8% of fresh matter and 19.1% of the dry matter are removed from the farming field with the heads. The remainder is left and contributes to the soil organic matter pool.

**Table 6** The partitioning of N, P₂O₅ and K₂O nutrients removal of broccoli on the organic, semi-organic and conventional farming systems.

| Plant part       | N (kg/ha) | P₂O₅ (kg/ha) | K₂O (kg/ha) |
|------------------|-----------|--------------|-------------|
| Organic farming system |           |              |             |
| Leaves           | 174.58    | 23.46        | 205.61      |
| Stems            | 41.42     | 12.72        | 107.42      |
| Roots            | 14.63     | 4.51         | 34.75       |
| Main heads / Flowers | 118.47   | 55.29        | 128.54      |
| Total            | 349.12    | 95.98 a      | 476.32 a    |
| Semi organic farming system |      |              |             |
| Leaves           | 116.24    | 15.52        | 147.32      |
| Stems            | 32.85     | 13.85        | 78.29       |
| Roots            | 11.28     | 3.43         | 20.34       |
| Main heads / Flowers | 76.92   | 34.84        | 91.47       |
| Total            | 237.29 b  | 67.64 b      | 337.42 b    |
| Conventional farming system |      |              |             |
| Leaves           | 125.62    | 18.32        | 164.52      |
| Stems            | 28.73     | 10.65        | 88.37       |
| Roots            | 12.37     | 3.73         | 26.82       |
| Main heads / Flowers | 91.46   | 41.36        | 103.48      |
| Total            | 258.18 b  | 74.06 b      | 383.19 b    |

The observations of soil temperature at a depth of 5cm and 10 cm are shown in Table 1. Soil temperature varied from 18 to 30°C, during the broccoli vegetable growing season, with the average of 23.62°C and 21.05°C at 5 and 10 cm soil depth, respectively. The average soil temperature with the application of organic farming is lower than other farming systems. This situation was happened because the quantity and quality of organic matters in soil in term of SOM mineralization and litter decomposition of organic compounds was related to climatic parameters in the environmental farming field [33][34]. In general, soil organic matter is increases with precipitation and decreases with temperature [35]. Moreover Alvarez and Lavado [36] reported that soil organic matter content in the 0-50 cm soil layer significantly related with the precipitation/ temperature ratio. However, the
relationship between Soil Organic Matter and climate variables on a large scale is relatively strong, as a function of projected climate change on the continental scale [37].

![The observation of temperature on 5 cm soil depth](image1)

**The observation of temperature on 5 cm soil depth**

![The observation of temperature on 10 cm soil depth](image2)

**The observation of temperature on 10 cm soil depth**

**Figure 1.** The observation of temperature on 5 cm soil depth (a) and 10 cm soil depth (b) at three kinds of cropping systems.

4. **Conclusion**

The chemical and physical properties of soil on organic broccoli cultivation are better than semi-organic and conventional farming systems, it shown that C-organic, N total, P and K available and the other soil characteristics have a higher value. Some physical properties, which shown as particle density and bulk density, has a lower value, while total porosity and permeability slightly increase compare to conventional farming. It means the condition of the soil structure is getting better and more crumby condition.

Growth and production of fresh broccoli on 10 weeks after planting by organic farming is higher than that of semi-organic and conventional farming, which is shown from the nutrients removal of the element N and K have more higher 35.22% and 24.31% respectfully, of the total partitioning nutrient removal on broccoli cultivation. The application of organic farming system in broccoli cultivation has shown the average soil temperature of 5 and 10 cm depth is lowest than other farming systems, the lower soil temperature indicates that organic farming better practice toward anticipate climate change.
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