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Effect of type and time of fertilizer application in foliar fertilization on production and seed quality of cayenne (*Capsicum frutescens* L. var. Bonita)

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Abstract

Cayenne (*Capsicum frutescens* L.) classified as a horticultural crop that has high economic value. The use of fertilizer can affect the maximum growth and production of cayenne plants, so it is necessary to know the right type and time. The purpose of the study was to find the best type and time of fertilizer application for the production and quality of cayenne seeds. This study used a randomized block design with two treatment factors, the first factor was the type of fertilizer, namely Gandasil B fertilizer, Bayfolan, White KNO_3 and NPK Mutiara, the second factor was the time of fertilizer application, namely fertilizer application during flowering, as well as during flowering and fruit enlargement. The results showed that the interaction between the type and time of fertilizer application had a very significant effect on the total sugar content of leaves. Fertilizer treatment has a very significant effect on the total sugar content of leaves, has a significant effect on the number of fruits per plant, weight per fruit, growth uniformity, percentage of normal and abnormal sprouts, and germination. The best type of fertilizer for fruit production is Bayfolan while judging from seed quality, the best type of fertilizer for seed production is NPK Mutiara. The timing of fertilizer application had a very significant effect on the total sugar content of the leaves but had no significant effect on other variables. The best application time for seed production is fertilizer application during flowering plants and fruit enlargement.

Keywords: Cayenne; Bayfolan; NPK Mutiara; Application time; Seed quality

1. Introduction

Cayenne (*Capsicum frutescens* L.) is classified as a horticultural crop that is widely cultivated in various regions of Indonesia because it has high economic value. Cayenne is usually used as a raw material for making daily dishes and food industries such as sauces, cayenne powder, flavoring and the pharmaceutical industry [11]. Cayenne grows at soil acidity (pH) of 6-7 (optimal pH 6.5). The temperature required for cayenne plants to grow well ranges from 18-30 ^{o}C. Cayenne can grow from the lowlands to the highlands. The altitude of the place generally affects the age of flowering, harvest age, and plant productivity [8].

Cayenne production in Indonesia reached 1.39 million tons in 2021. The Central Statistics Agency noted that this number decreased by 8.09 percent compared to the previous year which amounted to 1.5 million tons [2]. The production of cayenne which is lower than the level of consumer demand will cause an increase in prices. Bali Province is one of the provinces in Indonesia affected by this. According to data from the Central Bureau of Statistics, the production of cayenne in Bali in 2021 was 40,922 tons. This number decreased from 2020 which amounted to 43,380 tons [2]. The decline in production figures resulted in the average price of cayenne in the market soaring. The average price of cayenne in traditional markets in December 2022 touched IDR 74,480 per kilogram, while in Bali the average price of cayenne reached IDR 77,169 per kilogram [17].

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The potential for national cayenne production is still low, which will require the availability of good quality seeds [6]. High quality seeds are seeds that have physical quality (uniform size, proper moisture content, clean from dirt), genetic quality (low coefficient of variation in accordance with standards), physiological quality (germination and vigor), and no pathogens carried by seeds [3]. Quality seeds can be obtained through the right fertilizer, both the right type and time.

Fertilizers as materials applied to the soil, both organic and inorganic, are used by plants to meet nutrient needs [9]. Nutrient fulfillment can be done by applying the right type of fertilizer during the generative period of the plant. The type of fertilizer applied through the leaves can provide an increase in production in the cultivation of cayenne plants. The advantage of fertilizer through the leaves compared to root fertilizer is that the absorption of nutrients through the mouth of the leaf stomata runs fast. Some types of leaf fertilizers that can be used include Gandasil B, Bayfolan, White KNO_3, and NPK Mutiara compound fertilizer.

Gandasil B fertilizer is one of the fertilizers that can help plants in stimulating the process of flower emergence more quickly. Gandasil B is applied at the beginning of generative growth. The concentration of Gandasil B has a significant effect on plant height, number of main branches, flowering age, percentage of flowers that become fruit, harvest age, fruit weight per plant, number of fruits per plant, and the number of fruits remaining on the plant in cayenne plants [19].

Bayfolan leaf fertilizer is a liquid inorganic fertilizer containing macro nutrients N 11%, P 10%, and K 6% and micro nutrients namely Fe, Mn, Cu, Zn, Co, Mo [21]. Bayfolan foliar fertilizer is useful for accelerating plant growth, stimulating the formation of flowers, fruits, seeds and accelerating the harvest period. The concentration of Bayfolan fertilizer greatly affects the number of fruits and fruit weight per cayenne plant, but has no significant effect on the height of cayenne plants aged 30, 60 and 90 days after planting and the number of productive branches aged 60 and 90 HST in cayenne plants [1].

White KNO_3 fertilizer is in the form of white crystals, easily soluble in water and easily absorbed by plants. The K_2O content in White KNO_3 is quite large between 45-46% and the N content is 13% [23]. The application of KNO_3 fertilizer has a significant effect in increasing the number of rows per cob, the number of seeds per row, dry stover weight, production and potassium nutrient uptake in sweet corn plants [14]. The application of white KNO_3 fertilizer must be given according to the recommended time and dose.

NPK Mutiara compound fertilizer is one of the inorganic fertilizers that can be used in increasing the availability of macro nutrients (N, P and K) replacing single fertilizers such as Urea, SP-36, and KCl which are sometimes difficult to obtain in the market and very expensive [12]. NPK fertilizer can provide three types of nutrients in one fertilization, namely nitrogen (N), phosphorus (P), potassium (K) and sulfur (S). The application of NPK to plants gives an influence on flower age, harvest age, number of fruits per plant, fruit weight per fruit and fruit weight per plant on *timun suri* plants [5]. The addition of NPK inorganic fertilizer affects stem diameter, fruit length and fruit weight per plant [9] so it is recommended to get good production. The use of fertilizer types at the right application time will be able to increase the production and quality of cayenne seeds.

Applying fertilizer during the plant growth phase will cause the nutrient content in the plant to be higher [7]. Fertilization is carried out at two stages of the cultivation process, namely basic fertilization when making beds and supplementary fertilization. Supplementary fertilization is given during the vegetative and generative phases. In the generative phase, fertilizer can be applied once when flowering begins or by fertilizing twice when the plants flower and ripen the fruit. Based on this background, this study aims to find the best type of fertilizer and the right fertilizer application time in increasing the production and quality of cayenne seeds.

2. Material and methods

2.1. Location and experimental design

The research was conducted from September 2023 to January 2024. The research site was located at the Bogor Agricultural University (IPB) Tajur Experimental Farm located at Tajur highway, South Bogor District. The germination test of cayenne seeds was carried out at the Laboratory of the Center for Tropical Horticulture Studies (PKHT) IPB, Pajajaran Raya, Bogor, West Java and the analysis of total sugar content, P nutrient content of leaves was carried out at the Udayana University Laboratory, Sudirman Campus, Denpasar.

This study used a two-factor factorial Randomized Block Design (RBD). The first factor is the type of fertilizer applied through the leaves (J) consisting of 4 levels, namely: Gandasil B (Jg), Bayfolan (Jf), KNO3 White (Jk), and NPK Mutiara compound fertilizer (Jm), while the second factor is the application time (W) consisting of 2 levels, namely one-time application when flowering begins (Ws), and two-time application, namely when flowering begins and when fruit enlargement (Wd). Thus, there are 8 treatment combinations with 3 replicates, the total experimental units are 24. The combination treatment was tried on cayenne variety Bonita.

2.2. Crop maintenance

Plant maintenance follows the Standard Operating Procedure (SOP) for cayenne cultivation, namely rejuvenation of cayenne plants, watering, installation of stakes, pest and disease control, harvesting cayenne fruit before treatment, and weeding.

This study used Bonita cayenne plants that were 8 months old after planting, and then rejuvenated. Rejuvenation of cayenne plants is done so that old cayenne plants can grow and bear fruit again without having to process the planting media from scratch. Rejuvenation is carried out starting from cutting unproductive branches and twigs. NPK fertilizer is also applied in the plant rejuvenation stage. The NPK fertilizer dose of 10 grams/l is applied by leaking once a week. This rejuvenation can stimulate the growth of new shoots that will later flower again, fertilizer application type and timing. Watering is done using a watering can, every morning or evening. If the media is still moist, no watering is done. Watering is done carefully so as not to damage the plant roots. Re-staking is done on cayenne plants that have not been given stakes or stakes that have been damaged are replaced with new ones. The stakes used are bamboo stakes to support the plants so that they do not easily fall or collapse.

The types of pesticides applied to the plants were Curacron insecticide, Samite acaricide, and Benlate fungicide. Curacron insecticide is applied after the replanting process. This type of insecticide can control pests such as aphids, fruit flies, leaf borers, fruit borers and thrips. One week later, Samite acaricide was applied to control the curling of the cayenne leaves. Benlate fungicide is also applied to control fungal attacks on plants. The pesticide is applied by spraying the solution to the affected parts of the plant at a concentration of 1-2 ml/l. This study was conducted on plants that had previously borne fruit. All fruits on cayenne plants must be picked before treatment, so that the results are not mixed with the results of the next treatment.

The types of fertilizers used in accordance with the treatment levels were Gandasil B, Bayfolan, white KNO_3, and NPK Mutiara compound fertilizer (16-16-16). The treatment concentration of each type of fertilizer was as recommended. Gandasil B fertilizer was applied at a concentration of 2 g/l, Bayfolan 2 ml/l, KNO_3 White 2 g/l, NPK Mutiara (16-16-16) compound fertilizer 2 g/l. The application of each type of fertilizer was adjusted to the level of treatment time, when the plants had reached 50% of the number of flowering plants, and 50% of the number of fruiting plants. Fertilizer application is done by spraying through the leaves on the crown, after the crown is evenly sprayed with fertilizer, the spraying is stopped. Weeding is done if there are weeds around the planted cayenne plants, then accompanied by hilling.

2.2.1. Harvesting

Harvesting is done by looking at the skin color, shape, size, and changes in the fruit and other plant parts. Harvesting cayenne is done every 3-5 days, adjusted to the maturity of the fruit. Cayenne fruit is picked when it is orange to red in color.

2.2.2. Seed extraction

Extraction of cayenne seeds is done by leaving the harvested cayenne fruit for 1 day. The cayenne fruit was extracted manually using a knife. The seeds obtained are then placed on the tray according to the treatment and dried for 2 days. When the seeds are dry, the dirt attached to the seeds is cleaned. The seeds were then packed in airtight plastic and stored.

2.3. Variable observation and measurement

The variables observed in this study consisted of: Fruit-set Percentage (%). Calculated by the formula:

$$\frac{\text{Number of fruits per plant}}{\text{Number of flowers per plant}} \text{ x } 100\%$$

Weight per Fruit (g). Calculated by taking 3 random fruit samples at each harvest, then averaged.

Weight per 1000 seeds (g). Observed after the seeds were harvested and extracted, calculated as follows:

$$\text{Weight per 1000 seeds} = B1+B2+B3+\cdots+B10$$

Where Bn = weight of 100 seeds at the nth weighing.

Seed growth uniformity (%). Growth uniformity is calculated based on the percentage of normal sprouts at 11 days after sowing (das). Observations were made by:

$$\text{Growth uniformity} = \frac{\sum \text{Seed that germinated normally at 11 das}}{\sum \text{Sowing seeds}} \text{ x } 100\%$$

Percentage of normal germination (%). The percentage of normal germination was calculated on day 14 after sowing (das), by means of

$$\frac{\sum \text{Seed that germinated mormally at 14 das}}{\sum \text{Sowing seeds}} \text{ x } 100\%$$

Germination (%). Germination was tested by the established rolled method. Germination was calculated at 7-14 days after sowing (das) [25] by means of:

$$\text{Germination (\%)} = \frac{\sum \text{Seed that germinated at 7}-\text{14 das}}{\sum \text{Sowing seeds}} \text{ x } 100\%$$

Seed growth rate (%/ethmal). Seed vigor index observations were calculated from the first day of germination to the last day of germination by means of:

$$\frac{N1}{D1} + \frac{N2}{D2} + \frac{N3}{D3} + \ldots + \frac{Nn}{Dn}$$

Nn = percentage of seeds that germinate on the n th day

Dn = n th day of germination

Relative water content of leaves (%). Measurement of Relative Water Content (KAR) of leaves was done twice. KAR value (%) was calculated by the formula:

$$\frac{\text{Fresh weight} - \text{dry weight}}{\text{Turgid weight} - \text{Dry weight}} \text{ x } 100\%$$

Leaf P nutrient content (%). Leaf P nutrient content was analyzed in the laboratory using leaf samples from the bottom, middle and top. Samples were taken during the flowering and fruit enlargement phases and then mixed. Leaf P nutrient content was measured by the Spectrophotometer method.

Total sugar content of leaves (%). Total sugar content analysis was conducted at the Laboratory of Agricultural Product Technology, Udayana University. The total sugar analysis procedure was analyzed using the Anthrone method.

2.4. Data analysis

Observation data were analyzed using analysis of variance (Anova). If the interaction shows a significant effect, it is continued with the Duncan test at the 5% level, while if the interaction has no significant effect, the single factor is tested with the BNT (Least Significant Difference) test at the 5% level.

3. Results and discussion

3.1. The significance of the treatment on the observation variable

Based on statistical analysis, the interaction between the type (J) and time application (W) of fertilizer on the production and quality of cayenne seeds showed a very significant effect on the observation variable of total leaf sugar content, while other observation variables had no significant effect.

In a single factor, the use of fertilizer type (J) has a very significant effect on the observation variable of total leaf sugar content, significantly affects the variables of weight per fruit, uniformity of growth, germination, and percentage of normal sprouts and has no significant effect on other observation variables. Fertilizer application time (W) has a very significant effect on the variable of total leaf sugar content, and has no significant effect on other observation variables.

3.2. Effect of type and time of application on observed variables

Table 1 Single Factor Results of Type and Time of Fertilizer Application on Observation Variables Fruit-set Percentage, Weight per Fruit, Weight per 1000 Seeds, and Seed Growth Uniformity

Treatment	Fruit-set Percentage (%)	Weight per Fruit (g)	Weight per 1000 Seed (g)	Growth Uniformity (%)
Fertilizer type (J)				
Gandasil B (Jg)	24,82 (29,34) a	1,00 (1,48) c	4,06 a	49,00 (44,62) b
Bayfolan (Jf)	38,42 (38,02) a	1,22 (1,60) a	4,24 a	59,50 (51,01) ab
White KNO_3 (Jk)	21,87 (27,06) a	1,00 (1,50) bc	4,10 a	44,83 (41,94) b
NPK Mutiara (Jm)	36,50 (36,80) a	1,17 (1,58) ab	4,26 a	70,50 (57,51) a
BNT 5%	11,05	0,09	0.37	10,93
Fertilizer application time (W)				
One-time application (Ws)	27,39 (30,56) a	1,09 (1,54) a	4,13 a	54,17 (47,63) a
Two-time application (Wd)	33,41 (35,05) a	1,10 (1,55) a	4,20 a	57,75 (49,91) a
BNT 5%	7,81	0,06	0,26	7,73

Description : Numbers followed by the same letter in the same treatment and column show no significant difference at the 5% level of the least significant difference test (BNT) and the numbers in parentheses are transformed data.

The percentage of fruit-set in the Bayfolan fertilizer type treatment with a value of 38.42% was not significantly different from Gandasil B, White KNO_3, and NPK Mutiara with values of 24.82%, 21.87%, and 36.50%, respectively. The percentage of fruit-set in the treatment of fertilizer application time between one time and two times was not significantly different, but there was a tendency for the highest value to be obtained at two times application with a value of 33.41% (Table 1).

The highest weight per fruit in the fertilizer type treatment was obtained at the Jf level with a value of 1.22 g, significantly different from the Jg and Jk levels with values of 1.00 g and 1.00 g, respectively, but at Jm it was not significantly different with a value of 1.17 g. Weight per fruit in the treatment of fertilizer application time between Ws and Wd was not significantly different with values of 1.09 g and 1.10 g respectively (Table 1).

Weight per 1000 seeds in the treatment of fertilizer types between Gandasil B, Bayfolan, White KNO_3, and NPK Mutiara were not significantly different, but there was a trend that the highest weight per 1000 seeds was obtained by the NPK Mutiara treatment with a value of 4.26g. Weight per 1000 seeds in the treatment of fertilizer application time was not significantly different between one-time and two-time applications with values of 4.13 g and 4.20 g respectively (Table 1).

The highest growth uniformity on the single factor of fertilizer type was obtained at the Jm level with a value of 70.50%, which was not significantly different from Jf with a value of 59.50%, compared to Jk the value had a difference of 0.44% higher, however, the Jm level with Jk and Jg were significantly different. Growth uniformity in the Wd treatment with Ws is not significantly different with values of 57.75% and 54.17% respectively, but the application time of the Wd level has increased by 0.07% compared to Ws (Table 1).

Table 2 Single Factor Results of Type and Time of Fertilizer Application on Observation Variables of Normal Germination Percentage, Germination Rate, and Seed Growth Rate

Treatment	Percentage of Normal Sprouts (%)	Seed Germination (%)	Growth Speed (%/ethmal)
Fertilizer type (J)			
Gandasil B (Jg)	50,17 (45,44) b	58,33 (50,61) b	12,24 (20,08) a
Bayfolan (Jf)	60,67 (51,82) ab	66,67 (55,99) ab	12,44 (20,31) a
White KNO_3 (Jk)	45,67 (42,43) b	53,33 (46,94) b	10,36 (18,70) a
NPK Mutiara (Jm)	73,67 (59,63) a	81,50 (65,31) a	15,68 (23,17) a
BNT 5%	11,33	12,15	8,74
Fertilizer application time (W)			
One-time application (Ws)	56,08 (48,92) a	63,08 (53,64) a	12,93 (20,71) a
Two-time application (Wd)	59,00 (50,74) a	66,83 (55,79) a	12,43 (20,42) a
BNT 5%	8,01	8,59	3,09

Description: Numbers followed by the same letter in the same treatment and column show no significant difference at the 5% level of the least significant difference test (BNT) and the numbers in parentheses are transformed data.

The highest percentage of normal sprouts in the single factor treatment of fertilizer type was obtained at the Jm level with a value of 73.67%, not significantly different from the Jf level, but with Jk (45.67%) and Jg (50.17%) significantly different. The percentage of normal sprouts in the treatment of fertilizer application time between Ws and Wd was not significantly different, but there was a trend that the highest value was obtained by Wd with a value of 59.00% (Table 2).

Germination in the treatment of NPK Mutiara compound fertilizer type with a value of 81.50% was significantly different from White KNO_3 with a value of 53.33%, but Gandasil B and Bayfolan were not significantly different with values of 58.33% and 66.67% respectively.

Germination in the treatment of fertilizer application time between twice and once application was not significantly different, but there was a tendency for the highest value to be obtained by twice fertilizer application with a value of 66.83% (Table 2).

Table 3 Single Factor Results of Type and Time of Fertilizer Application on Observation Variables Leaf Relative Water Content, Leaf P Nutrient Content

Treatment	Relative Water Content of Leaves (%)	Leaf P Nutrient Content (%)
Fertilizer type (J)		
Gandasil B (Jg)	78,46 a	0,39 (1,12) a
Bayfolan (Jf)	78,74 a	0,46 (1,15) a
White KNO_3 (Jk)	77,70 a	0,30 (1,05) a
NPK Mutiara (Jm)	79,44 a	0,35 (1,09) a
BNT 5%	5,25	0,13
Fertilizer application time (W)		
One-time application (Ws)	78,75 a	0,32 (1,06) a
Two-time application (Wd)	78,42 a	0,43 (1,14) a
BNT 5%	3,72	0,09

Description : Numbers followed by the same letter in the same treatment and column show no significant difference at the 5% level of the least significant difference test (BNT) and the numbers in parentheses are transformed data.

Seed growth speed in the treatment of NPK Mutiara compound fertilizer type was not significantly different from other levels, but there was a tendency to increase by 0.51% compared to the White KNO_3 fertilizer type. The speed of growth in the treatment of fertilizer application time, between one-time and two-time fertilizer applications, was not significantly different with values of 12.93%/ethmal and 12.43%/ethmal respectively (Table 2).

The highest leaf relative water content in the single factor treatment of fertilizer type was obtained in the Pearl NPK Compound fertilizer treatment with a value of 79.44% while the lowest value was obtained in the White KNO_3 treatment with a value of 77.70%, but all fertilizer type treatments were not significantly different. The relative water content of leaves in the treatment of fertilizer application time was not significantly different between Ws and Wd, but there was a trend that the highest value was obtained at the Ws level with a value of 78.75% (Table 3).

The highest leaf P nutrient content in the single factor treatment of fertilizer types between Gandasil B, Bayfolan, White KNO_3, and NPK Mutiara was not significantly different, but there was a trend that the highest leaf P nutrient content was obtained at the Bayfolan fertilizer treatment with a value of 0.46%. Leaf P nutrient content in the treatment of fertilizer application time was not significantly different between one-time and two-time applications with values of 0.32% and 0.43%, respectively (Table 3).

3.3. Treatment interaction on total leaf sugar content variable

The highest total leaf sugar content was obtained in the treatment combination of Gandasil B fertilizer and application time at flowering (JgWs) with a total sugar content of 35.98%, while the lowest total sugar content was in the treatment combination between the use of White KNO_3 fertilizer and fertilizer application time at flowering (JkWs) with a total sugar content of 35.01%.

Table 4 Interaction of Type (J) and Time (W) of Fertilizer Application on Total Leaf Sugar Content (%)

Treatment	**Total Sugar Content of Leaves (%)**			
	Gandasil B (Jg)	**Bayfolan (Jf)**	**White KNO_3 (Jk)**	**NPK Mutiara (Jm)**
One-time application (Ws)	35,98 a	35,01 a	16,13 d	24,59 b
Two-time application (Wd)	34,31 a	17,07 cd	17,79 cd	20,83 b

Description: numbers followed by different letters in each variable indicate significantly different in Duncan's multiple range test at 5% level.

The highest total sugar content in the type of Gandasil B fertilizer, obtained at the time of one-time application of 35.98%, was not significantly different from the two-time fertilizer application.The highest total sugar content in the treatment of Bayfolan fertilizer type was obtained at application time one with a value of 35.01% and significantly different from the application of fertilizer twice.The highest total sugar content in the treatment of White KNO_3 fertilizer type, obtained twice fertilizer application with a value of 17.79% and was not significantly different from Ws.The highest total sugar content at the fertilizer type level was obtained by one-time fertilizer application with a value of 24.59% and had no significant effect with two-time fertilizer application.

The highest total sugar content at the time of one fertilizer application was obtained by Gandasil B fertilizer with a value of 35.98%, significantly different from the type of fertilizer White KNO_3 and NPK Mutiara, and not significantly different from Bayfolan fertilizer. The highest total sugar content in the treatment of fertilizer application twice, obtained by Gandasil B with a value of 34.31%, significantly different from Bayfolan, White KNO_3, and NPK Mutiara.

4. Discussion

The highest total leaf sugar content was obtained by the combination of Gandasil B fertilizer treatment applied once (JgWs) with 35.98%, the lowest was in the treatment of KNO_3 White fertilizer applitcation once (JkWs) with 16.13%, while the treatment of NPK Mutiara compound fertilizer application twice (JmWd) had 20.83%. On a single factor basis, the total leaf sugar content of the Mutiara NPK compound fertilizer treatment (22.71%) was not significantly different from the Bayfolan and White KNO_3 fertilizer types. The low total leaf sugar content in the Mutiara NPK compound fertilizer treatment was supported by the low leaf P nutrient content (0.35%). The low content of total sugar and leaf P nutrients in the Mutiara NPK compound fertilizer treatment is because the total sugar content and P nutrients are more directed to the formation and enlargement of seeds so that the nutrient content contained in the leaves becomes lower.

The observation variable that shows fruit production is the percentage of fruit-set. The highest fruit-set percentage was obtained by Bayfolan fertilizer treatment with a percentage of 38.42%. This number increased by 0.41% compared to the White KNO_3 fertilizer treatment. This percentage shows that fertilization can increase the plant's ability to prevent the failure of the number of flowers that form into fruit, so that the value of fruit-set percentage can increase.

One of the external factors that affect the yield of cayenne is rainfall. Observations of rainfall were made at the research site for 3 months from October to December 2023, using a simple tool made of a jerry can with a capacity of 5 liters, a funnel with a diameter of 20 cm and a 5/8 inch hose. Based on the observations, the rainfall at the study site was around 623.91 mm/month, so it was categorized as high because the value was >500 mm/month.

Rainfall that is not in accordance with the requirements for cayenne growth will have a negative impact on the process of pollination and the formation of cayenne fruit. High rainfall creates moist soil conditions that can increase the risk of pest and disease attacks on plants. The weight per fruit of Bayfolan fertilizer treatment has a higher number than other levels (1.22 g), supported by higher leaf P nutrient content compared to Gandasil B, White KNO_3 and NPK Mutiara compound fertilizer treatments. P nutrients play a role in energy transfer, transport and metabolism of carbohydrates and proteins in leaf cells [24].

Quality seed includes genetic quality, physical quality, physiological quality and health quality. Quality seeds can be produced by you as long as it is done by following the correct methods. Based on the research that has been carried out, the observation variable that shows the physical quality of seeds is the weight of 1000 seeds. The highest weight 1000 seeds were obtained by the NPK Mutiara compound fertilizer (Jm) treatment with an increase value of 0.04% compared to the White KNO_3 treatment. The weight of 1000 seeds is related to the physical quality of seeds, indicating the level of seeds. The higher the 1000 seed weight value, the more nutritious the seeds produced. It is also supported by the weight per cayenne fruit (1.17 g) which has a tendency to be higher than the Gandasil B and White KNO_3 fertilizer treatments.

The high relative water content of the leaves of NPK Mutiara compound fertilizer treatment (79.44%) plays an important role in supporting the process of photosynthesis so as to get good plant yields. The high KAR of the leaves shows that the application of Mutiara NPK compound fertilizer can increase the water content of the cayenne plant tissue. Water content in plant leaves plays an important role in the process of photosynthate formation, where the photosynthate will be transported to all parts of the plant [22].

Good crop yields will produce good quality seeds. Observation variables signaling physiological quality are germination and seed growth speed. NPK Mutiara compound fertilizer treatment has a germination rate of 81.50%. The percentage is categorized as good because the percentage is more than 80%. The high germination rate is supported by the growth speed value Jm (15.68%/ethmal) which tends to be higher than the other fertilizer treatments. Growth speed shows the speed and uniformity of seeds to germinate.

Seed vigor is influenced by several factors such as seed genetic conditions, environment, and seed storage. Genetic factors include seed hardness, parent plant vigor, resistance to mechanical damage, and seed chemical composition [10]. Environmental factors of seed development include temperature, humidity, soil fertility, and seed harvesting and seed storage factors include storage time and storage environment.

Other variables that indicate the physiological quality of seeds are the percentage of normal sprouts and uniformity of growth. The NPK Mutiara compound fertilizer treatment increased the percentage of normal sprouts by 0.61% when compared to the KNO_3 White treatment. This percentage is supported by the growth uniformity of NPK Mutiara of 70.50%. Growth uniformity greater than 70% is categorized as high growth vigor. An indication of high seed growth vigor can be seen from the ability to grow seeds. Growth uniformity greater than 70% indicates high vigor of growth vigor while the percentage less than 40% indicates less vigorous seeds [10]. Uniform and strong seed growth will have high growth vigor.

Two-time application fertilizer time (Wd) was applied when the percentage of flowering and fruiting plants had reached 50% of the total sample plants. The highest fruit-set percentage was obtained when fertilizer was applied twice with 33.41%. The percentage shows that the time of fertilizer application can affect the number of flowers that become fruit. The time of fertilizer application affects the number of fruits per plant, the number of total fruits per plant, the weight of fruits per plant and the weight of total fruits per plant [18].

The weight per fruit between one-time and two-time fertilizer application was not significantly different, but there was a tendency for the weight per fruit of two-time fertilizer application (1.10 g) to be higher than that of one-time fertilizer application (1.09 g). Fruit weight is influenced by several factors such as flesh thickness, skin thickness and nutrient

content of the fruit. Based on the results of statistical analysis, the P nutrient content between one-time and two-time fertilizer applications was not significantly different, but the two-time fertilizer application treatment (0.43%) had a tendency to be higher than the one-time application treatment (0.32%). P nutrients play an important role in the growth process along with potassium, phosphorus is used by plants to stimulate flowering and fruit formation. Fruit formation and filling are influenced by nutrients (N, P and K) which will be used in the photosynthesis process as a constituent of carbohydrates, fats, proteins, minerals and vitamins that will be translocated to the storage part of the fruit [13].

The observation variables that indicate the physiological quality of seeds in the application time treatment are germination, growth uniformity, and the percentage of normal sprouts. A disturbed fruit enlargement process can reduce the quality of the seeds produced. The germination rate of two fertilizer applications was obtained with 66.83%, although the germination rate was categorized as low because it was below 80%, but the percentage had a higher trend than the one-time fertilizer application treatment which had a percentage of 63.08%. Supported by growth uniformity (57.75%) and the percentage of normal sprouts (59.00%) which tend to be higher when viewed from the numbers obtained, although the test results are not significantly different. Low seed germination is caused by several factors, the length of storage power after the seed drying process is one of them. Cayenne seeds are orthodox seeds that have low moisture content and dormancy properties. Cayenne seeds will enter the dormancy period after the drying process.

Cayenne seeds have the disadvantage that there is dormancy, if germinated directly the growth will not be simultaneous [16]. Seed dormancy influenced by inhibitory substances such as Abscisic acid (ABA), lignin layer, structurally protective and hydrophobic compounds of the seed coat even more impermeable if dried [4]. Testing germination after the drying process without the storage process first, will make the imbibition process not simultaneous and the growth of seeds into normal sprouts becomes not simultaneous as well. The storage length factor plays a role in seed quality. Determination of seed shelf life is done by storing seeds for different periods of time and under certain conditions [20]. Seed germination test is conducted to determine the ability of seeds to germinate after optimal handling [15].

5. Conclusion

Fertilizer type had a significant effect on weight per fruit, growth uniformity, percentage of normal and abnormal sprouts, and seed germination and a very significant effect on total leaf sugar content. NPK Mutiara (16-16-16) is the best fertilizer for seed production and quality, while Bayfolan is the best fertilizer for cayenne fruit production.

The timing of fertilizer application between once and twice had no significant effect on all observation variables of seed production and quality, very significant effect only on total leaf sugar content, but economically, twice fertilization gave higher seed production and quality than once.

The interaction of type and time of fertilizer application had no significant effect on all observation variables of seed quality, very significant effect only on the total sugar content of the leaves so it is recommended to use Pearl NPK fertilizer (16-16-16) to get good seed production and quality.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that there is no conflict of interest.

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