Foliar fertilizers improved fruit set and yield of cayenne pepper (*Capsicum frutescens* L.) grown off-season

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Foliar fertilizers improved fruit set and yield of cayenne pepper (*Capsicum frutescens* L.) grown off-season

I K D Jaya, K Umami, M Z Arifin, D R Anugerahwati and B E Listiana
Faculty of Agriculture University of Mataram, Jl. Majapahit 62 Mataram 83125, Lombok, West Nusa Tenggara, INDONESIA

E-mail: ikdjaya@unram.ac.id

Abstract. The fruit set and yield of cayenne pepper grown during the rainy season (off-season) is relatively lower than during the dry season. This study aimed to assess the effectiveness of some foliar fertilizers in improving the fruit set and yield of cayenne pepper grown off-season on dryland. An experiment was conducted during the rainy season of 2021/2022 on a dryland area of Gumantar, North Lombok, Indonesia. Four foliar fertilizers and one control were tested on two varieties of cayenne pepper. The foliar fertilizers were: bio-organic (Pomi), silicate and boron (X-ZO), micronutrients (Meroke Fitoflex), and a mix of macro and micronutrients (Bayfolan). The two varieties were: hybrid (Dewata 43) and open-pollinated (Sret). The treatments were arranged in a factorial randomized block design with three replications. After five harvests, the results showed no interaction between foliar fertilizer and variety in affecting fruit set and yield. The foliar fertilizers improved the fruit set and yield of cayenne pepper. The most significant improvement was the bio-organic fertilizer with 10.6% and 42.5 % for fruit set and fruit weight per plot, respectively, compared to the control treatment. The hybrid variety yielded 822.5 g plant^{-1}, higher than the open-pollinated ones with 632.3 g plant^{-1}.

1. Introduction

Chili is an essential part of traditional Indonesian cooking spices. As one of the horticultural products, chili has a strategic value in Indonesia for several reasons. The first reason is that chili peppers contain lots of antioxidants, micronutrients, and vitamins, so it is highly recommended to consume them regularly to nourish human health [1, 2]. The second reason is that almost all Indonesian consume chili as part of their cooking ingredients, so it has a high market opportunity and value. The third reason is that chili commodities often contribute to inflation in Indonesia [3]. This happens because chili prices fluctuate throughout the year; in the dry season, the price of chili is low, and in the rainy season, the price of chili is high. Therefore, the chili commodity has received serious government attention, both in its cultivation practice and distribution of its products. One of Indonesia's most widely used types of chili is cayenne pepper (*Capsicum frutescens* L.).

In the dry season, many farmers grow chili because the condition is optimum, as long as enough water is available. Large growing areas and high productivity during the dry season often produce chili overproduction, resulting in lower prices. Meanwhile, less the planting area in the rainy season (off-season) because chili plants do not like excessive water conditions [4]. During the rainy season, the presence of chili in the market is less while demand is relatively stable. Sometimes, the demand for chili is very high when religious public holidays also occurred in the rainy season. In this condition, the price of chili is skyrocketing. Population increase in Indonesia is the other factor to drive the

increase demand for chili. Developing appropriate technology to produce chili in general and cayenne pepper specifically in the rainy season to meet the community's needs and stabilize prices is important.

One of the constraints in producing cayenne pepper off-season is the low fruit set due to flower abortion. Previous research on dryland with sandy soil texture showed that flower abortion in cayenne pepper ranged between 18 and 31%, depending on the variety [5]. Furthermore, the same study showed that using a bio-organic foliar fertilizer could increase the number of cayenne pepper flowers in the rainy season by up to 89%. The reported increases in yield ranged between 33.0 and 64.8%, depending on the concentration of the bio-organic foliar fertilizer. All these facts show the possible vital role of foliar fertilizers in producing cayenne peppers off-season on dryland with sandy soils. The use of foliar fertilizers is essential because dryland with sandy soils, such as in most areas of North Lombok Regency, has a very low cation exchange capacity (CEC), ranging between 7.35 and 11.24 meq/100 g [6]. Under this condition, the potential for nutrient leaching is very high in the rainy season without precise fertilization.

The occurrence of the phenomenon of climate change also contributes to the increased variability of rainfall [7]. These conditions make it challenging to manage plant nutrients in the soil, especially in sandy soils with low CEC. Climate change and intensive use of agricultural land also impact the availability of organic carbon in the soil, and hence, decreasing soil fertility [8]. The occurrence of high rainfall variability and reduced soil fertility are some of the reasons for the development of foliar fertilization methods. The method of foliar fertilization develops rapidly because, in this way, plants can get macronutrients, micronutrients, and microbes that are beneficial to plants effectively [9]. Currently, many foliar fertilizers are available, both in dissolved solids and solution forms. Foliar fertilizers contain macronutrients or micronutrients only or a mixture of macro and micronutrients. Some foliar fertilizers have certain elements needed by the plant, such as silicates and boron. There are also biofertilizers which, in addition to containing nutrients, also include microbial consortium. This study aimed to test the ability of several types of foliar fertilizers with different contents to increase the fruit set and yield of cayenne pepper planted off-season on dryland.

2. Materials and methods

2.1. Site description and experimental design

This study used an experimental method, and the experiment was conducted during the rainy season of the year 2021/2022 (October 2021 to March 2022). The site of the experiment was on dryland in Gumantar village, North Lombok, Indonesia (8.253654 S, 116.285695 E), and the soil ordo belongs to Entisol. The soil texture was sandy loam with 78.66% sand, 15.27% silt and 6.07% clay. The soil's chemical properties in the experimental area are presented in Table 1.

Table 1. Soil chemical properties at the experimental area before the experiment was started

Parameters	Unit	Method	Value	Status
pH (H_2O) 1:5 (Electrode)		Electrode	6.8	Neutral
C-organic (Walkey & Black)	%	Spectro	0.67	Very low
N-total	%	Kjeldalh	0.07	Very low
P- available	ppm	Spectro	42.54	Very high
K- exchange	meq%	Amon. acetate	0.37	Moderate

Two factors were tested in this experiment: foliar fertilizer type (F) and cayenne pepper variety (V). The foliar fertilizer treatments consisted of control or without foliar fertilizer (f0), bio-organic fertilizer (f1), silicate and boron fertilizer (f2), micronutrient fertilizer (f3), and a mix of macro and micronutrients (f4). Meanwhile, hybrid (v1) and open-pollinated (v2) were the two varieties of cayenne pepper. The commercial hybrid variety name is Dewata 43 and the open-pollinated variety

commercial name is Sret. All the treatments were arranged in a factorial randomized block design with three replications.

The bio-organic fertilizer contains macro and micronutrients, microbes consortium and growth regulator. The market product name is Pomi and produced by PT. Indo Acidatama. The silicate and boron fertilizer source was X-ZO, produced by PT. Hasil Aneka Oesaha. The micronutrients source of the foliar fertilizer was Pupuk Mikro Majemuk (Meroke Fitoflex), produced by PT. Meroke Tetap Jaya, and the source of a mix of macro and micronutrients was Bayfolan, produced by PT. Bayer Indonesia. The Dewata 43 is a hybrid cayenne pepper variety, while Sret is an open-pollinated variety. Another material used in the experiment was NPK (15-15-15) Phonska fertilizer, pesticides and fungicide.

2.2. Preparations, management and treatments

Seedlings of the two varieties of cayenne pepper were prepared in seedling trays for four weeks (seedlings had four true leaves). Two weeks prior to transplanting, thirty experimental plots were prepared by plowing and cleaning the soil from weeds and previous plant debris. The size of each plot was 600 × 100 cm and oriented north-south. Before laying a black-silver plastic mulch, each plot received 540 g (equal to 900 kg ha^{-1}) of NPK Phonska as basal fertilizer. This dose was based on the previous study at the same location by Jaya et al. [5]. The fertilizer was spread evenly in the middle of the plot surface and then mixed lightly with the soil. Each plot was covered with black-silver plastic mulch with the silver part facing up. Each plot had two rows of the plant to make 22 plants all together in each plot. The next step was planting holes with 60 cm between rows and 50 cm inside the row.

Before transplanting in the third week of November 2021, flooded irrigation was applied to provide sufficient moisture in the planting beds. Irrigation was given because there was a lack of rainfall during that period. For the rest of the growing season, the water requirement for the crops was solely from rainfall, except in the first week of January of 2022 because the rain was lacking. Other crop management included fertilizer applications, weeding, and pest and disease control. The second dose (150 kg ha^{-1}) of NPK Phonska fertilizer was applied 28 days after transplanting (DAT), and the third with the same amount was applied at 56 DAT. Weeding was done manually by pulling weeds present in the planting holes at 27 and 55 DAT, a day before applying fertilizers. Meanwhile, the primary pest that attacked the crops was oriental fruit flies (*Bactrocera dorsalis*), and the flies were controlled using a mixed of pesticides with active ingredients of profenofos 500 g l^{-1} (Curacron 500EC) and metomil 40% (Metindo 40SP). Fungicide with active ingredients of xemium + piraklostrobin (Merivon 250/250SC) was applied to prevent anthracnose and other fungal diseases.

The foliar fertilizer treatments were started at 14 DAT and were repeated every two weeks up to the first harvest. The concentration used for each foliar fertilizer was according to the fertilizer company's recommendations. The foliar bio-fertilizer was applied at a concentration of 1.5 ml l^{-1}, silicate and boron fertilizer was 2.0 ml l^{-1}, the micronutrient fertilizer concentration was 0.125 ml l^{-1}, and the concentration of the mix of macro and micronutrients was 2.0 ml l^{-1}. All the crops received 50 ml of foliar fertilizer solution at each time of application. The foliar fertilizer solutions were applied in the morning before midday, depending on the weather.

2.3. Measurements and data analysis

Rainfall data during the course of the experiment was recorded using an ombrometer installed nearby the experimental site. Meanwhile, maximum and minimum temperature as well as relative humidity data was recorded daily using a thermo-hygrometer. Crops' measurements included growth variable (plant height, number of leaves and stem diameter, all recorded at the first harvest of each variety), number of flowers per plant, number of fruits per plant, fruit weight per plant and fruit weight per plot. The percentage of fruit set was calculated by dividing the number of accumulated fruits up to the third harvest by the number of accumulated flowers that turned into fruits up to the third harvest times 100%. The third harvest for the hybrid variety was at 83 DAT and for the open-pollinated one was at 99 DAT. The data of fruit weight per plot (6 m^2) reported in this study were the accumulation of fruit

weight up to the fifth harvest of each variety. The fifth harvest for hybrid was at 97 DAT and 113 DAT for the open-pollinated variety. All collected data were analyzed using Analysis of Variance (Anova) at 95% confidence interval in Minitab 18 Statistical Program continued with Tukey test at the same confidence interval for those significant parameters.

3. Results and discussion

3.1. Environmental conditions at the site of the experiment

The land where the experiment was carried out could be categorized as nutrient-poor because the C-organic and nitrogen content available in the soil was very low. However, the available P was very high, and the K exchange was moderate (Table 1). Previous studies in the same location reported that the soil's CEC was also very low, ranging from 7.35 to 11.24 meq/100 g. The low value of CEC was attributed to the low C-organic content in the soil [6]. The consequence of low CEC is fertilization efficiency is very low if not done carefully. In conditions like this, foliar fertilization is highly recommended because, in addition to being directly absorbed by plants, foliar fertilizers can also contain many nutrients, hormones, and microbes [9].

Air temperatures at night that exceed 32°C can cause flowers to fall in chili plants [2]. During the experiment, the highest temperature during the day and the lowest temperature at night were recorded at 33.4°C and 24.5°C, respectively. From the recorded data, the temperature at night never exceeds 27°C, so the potential for flower fall due to high nighttime air temperature is minimal. The optimum temperature for chili plants to produce maximum yield is between 21°C to 33°C [10]. This means that the air temperature during the experiment was optimum for the growth and development of cayenne pepper plants. However, even though the air temperature is quite optimum, the chance of flower fall of cayenne pepper planted in the rainy season is relatively high due to the influence of high rainfall.

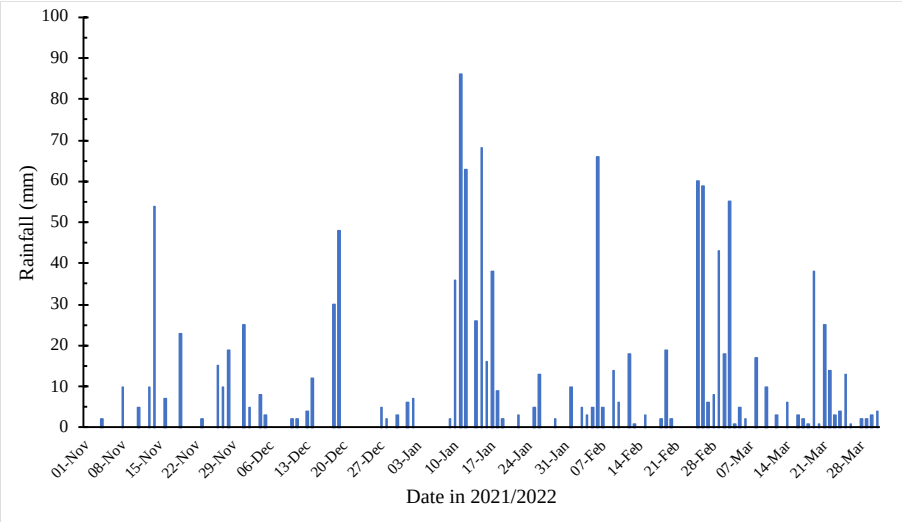

Figure 1. Rainfall pattern at the experimental site during the period of the experiment

The rainfall data during the experiment shown in Figure 1 shows that the distribution of rainfall during the experimental activities (November 2021 to March 2022) was relatively even. Almost all water needed for plants was met from the existing rainfall. Irrigation was only done once, namely in the first week of January 2022, because there was no rain and very little precipitation in the previous week. Figure 1 shows that the rainfall had been relatively high since the second week of January 2022, when the chili plants were fully blooming. With increased rainfall, there was the potential for pollen damage or a decline in fertility levels, resulting in flower fall. As reported, chili flowers will fully bloom for two days [11]. If there is heavy rain during blooming, the potential for a decline in pollen

quality is quite significant as a result of high humidity [12]. In addition to the influence of physical and chemical factors described previously, biological factors also exist, namely fruit fly attacks.

3.2. Effect of treatments on growth parameters

The analysis of variance showed that there was no interaction between varieties and types of foliar fertilizers in influencing all experimental parameters. At the time of the first harvest, the open-pollinated chili plants had larger stem sizes and were taller than the hybrid varieties of cayenne pepper. However, in terms of the number of leaves, hybrid cayenne pepper plants had more leaves than the open-pollinated ones (Table 2). The leaf size of the open-pollinated cayenne pepper plant was much larger than the leaf size of the hybrid variety. All the botanical characteristics of the chili plants follow the description of each variety, as stated in the Ministry of Agriculture Republic of Indonesia 084/Kpts/SR.120/D.2.7/ 10/2014 (CR 5243 F1) for the hybrid variety and number 436/Kpts/SR.120/4/2008 (CF 291) for the open-pollinated variety. Therefore, differences in genetic factors solely caused the differences that occurred in growth indices.

Table 2. Growth variables of cayenne pepper as affected by foliar fertilizer (FF) treatments

	Variables measured		
Treatments	Plant height (cm)*	Number of leaves*	Stem diameter (mm)*
Variety			
Hybrid (v1)	74.7^{b}	796.9^{a}	14.0^{b}
Open-pollinated (v2)	83.0^{a}	335.6^{b}	17.5^{a}
Foliar Fertilizer (FF)			
No FF (f0)	70.7^{c}	493.7^{a}	14.0^{b}
Bio-organic FF (f1)	88.1^{a}	669.1^{a}	17.4^{a}
Silicon and boron FF (f2)	83.5^{ab}	566.9^{a}	16.4^{ab}
Micronutrients FF (f3)	74.8^{bc}	552.6^{a}	15.4^{ab}
Mixed nutrients FF (f4)	77.0^{abc}	548.9^{a}	15.7^{ab}

*Means that do not share a letter in the same column and treatment are significantly different according to Tukey Test at 95% confident interval

Foliar fertilizer significantly affected the botanical characteristics of cayenne pepper plants, such as the parameters of plant height and stem diameter (Table 2). The tallest plants at the time of the first harvest were produced from the treatment of bio-organic fertilizers. Still, they were not significantly different from the plants treated with a mixture of silicate and boron fertilizer and a mix of macro and micronutrients. This fact shows that plants need macronutrients, such as N, P, and K, to support their growth. The availability of these macronutrients in sufficient quantities produced plant leaves that grew well so they could carry out photosynthetic activities properly [13] to support plant growth. Bio-organic fertilizers and a mixture of macro and micronutrients provide additional macronutrients for chili plants. Meanwhile, silicate fertilizer treatment was also reported to increase plant height [14].

In stem diameter parameters, plants that received additional nutrients through foliar fertilizer treatment had larger stem sizes than those not treated with foliar fertilizers. However, all plants treated with foliar fertilizers had the same stem diameter (Table 2). This showed that the nutritional requirements for the growth of cayenne pepper plants had not been met optimally, even though they were fertilized with high doses through the soil. This fact reinforces the theory that fertilization efficiency is very low in sandy soils with low CEC [15], especially in high rainfall conditions.

3.3. Effects of treatments on fruit set and yield

The fruit set was not affected by variety, with a value of about 79% (Table 3). This means that the percentage of flowers that fall from the two varieties of cayenne pepper tested was around 21%. Compared with previous studies results (same variety and location), the percentage of flower fall was much lower, especially in the Dewata 43 variety [5]. Differences in rainfall patterns and intensity may

be one of the causes of this difference. The data in Table 3 also shows that the fruit set was affected by foliar fertilizer treatments. All treatments with foliar fertilizers could increase fruit set compared to untreated plants with foliar fertilizers. The highest fruit set was produced from bio-organic foliar fertilizer treatment and was significantly different from other foliar fertilizer treatments. The other three foliar fertilizer treatments were not significantly different in terms of the percentage of fruit set. This data again shows the importance of additional nutrients applied through the leaves for cayenne pepper plants grown off-season on dryland with sandy soil texture. Bio-organic foliar fertilizer contains nutrients and includes a consortium of microbes, such as *Bacillus* sp., *Lactobacillus* sp., *Pseudomonas* sp., *Saccharomyces* sp., *Streptomyces* sp., *Azospirillium* sp., *Azotobacter* sp., and *Rhizobium* sp., produced a higher percentage of fruit set than other foliar fertilizers. The results of previous studies on red chili plants also showed that organic foliar fertilizer containing *Azotobacter* microbes could increase plant growth and yield [16].

Table 3. Fruit set and yield of cayenne pepper as affected by foliar fertilizer (FF) treatments

	Variables measured			
Treatments	Fruit set (%)*	Number of fruits plant^{-1}*	Weight of* fruits plant^{-1} (g)	Weight of fruits plot^{-1} (kg) *
Variety				
Hybrid (v1)	79.8^{a}	313.0^{a}	822.5^{a}	10.4^{a}
Open-pollinated (v2)	79.4^{a}	226.4^{b}	632.3^{b}	8.3^{b}
Foliar Fertilizer (FF)				
No FF (f0)	76.1^{c}	227.3^{c}	641.0^{b}	8.0^{b}
Bio-organic FF (f1)	84.1^{a}	339.4^{a}	890.1^{a}	11.4^{a}
Silicon and boron FF (f2)	80.2^{b}	276.2^{b}	750.3^{ab}	9.6^{ab}
Micronutrients FF (f3)	79.1^{b}	261.2^{bc}	690.0^{b}	9.0^{b}
Mixed nutrients FF (f4)	78.4^{b}	244.4^{bc}	665.5^{b}	8.5^{b}

*Means that do not share a letter in the same column and treatment are significantly different according to Tukey Test at 95% confident interval

The yield of cayenne pepper in hybrid varieties was higher than in the open-pollinated variety until the fifth harvest (Table 3). The crop yield in this case, was indicated by the parameter of fruit weight per plot with a plot size of 6 m^2. Although the fruit sets of the two varieties were not significantly different, the hybrid variety studied had considerably more flowers than the open-pollinated one (data not shown). Hybrid variety also demonstrated higher values in the components of crop yields, namely the number of fruits and fruit weight per plant (Table 3). It is obvious that hybrid varieties are created to be more adaptive to unfavorable environmental conditions and are more resistant to pests and diseases [17].

There was a significantly different effect on the treatment of foliar fertilizers on yields and yield components of cayenne pepper planted off-season (Table 3). As in the case of fruit sets, the highest yield (fruit weight per plot) was also produced by the treatment of bio-organic foliar fertilizer. Yield improvement from foliar bio-organic fertilizer treatment compared to the non-treated foliar fertilizer was 42.5%. However, the yield from bio-organic foliar fertilizer was not significantly different from that of plants treated with a mixture of silicate and boron fertilizer. An earlier study showed that boron played an important role in affecting the growth and yield of tomato plant [18]. The other foliar fertilizer treatments, including the mixed silica and boron fertilizer, were not significantly different in yielding fruit per plot with treatments without foliar fertilizers (table 3). The correlation value between fruit set and fruit weight per plot was r^2= 0.72, which was categorized as a strong correlation but not very strong. Likewise, the correlation value was also substantial in the relationship between fruit set and the number of fruits per plant, with r^2 = 0.70. Meanwhile, the correlation value between the number of fruits per plant and fruit weight per plant, as well as fruit weight per plot, was very strong, r^2= 0.95 and r^2= 0.97, respectively. Those correlation values indicated another factor influencing the relationship between fruit set and fruit weight per plot.

The environmental factor that most likely to influence the relationship between the percentage of fruit set and crop yields were the biological factor, namely the oriental fruit fly (*Bactrocera dorsalis*) attack. This could be evidenced by the presence of black dots on mature fruits, which signified that fruit flies had laid their eggs in the fruits. Furthermore, after hatching, the caterpillars eat the fruits from the inside, so the fruits become rotten and fall off. Fruit flies caused significant damage to the fruit of the cayenne pepper before the fruit was ready to be harvested. Fruit fly attacks on chili plants that are not chemically controlled can cause damage up to 37.5%, while chemically controlled damage levels reach 29.1% [19]. In this study, fruit flies were controlled with pesticides with active ingredients of metomil 40% and profenofos 500 g l^{-1}, but the number of fallen fruit was still quite large.

4. Conclusions

There was no interaction between foliar fertilizer and variety in affecting all measured parameters. Foliar fertilizers improved the fruit set of cayenne pepper grown off-season, but only the bio-organic foliar fertilizer improved the yield by up to 42.5%. It is well recommended to apply foliar fertilizer containing complete nutrients with beneficial microbes to improve fruit set and yield of cayenne pepper grown off-season in dryland.

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