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Increasing the production and quality of the yield of Siam orange fruits in off-season period through the application of liquid organic and guano fertilizer

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Abstract

This research was conducted in Belantih Village, Kintamani District, Bangli Regency, from October 2022 to June 2023. This research aimed to increase the production and quality of the yield of Siam orange through the application of liquid organic fertilizer from cow urine waste and guano fertilizer. This study used a randomized block design with 2 factors and 3 replications. The first factor was liquid organic fertilizer from cow urine waste consist of 4 concentration levels, *i.e.,* 0 ml/l (C_0); 5 ml/l (C_1); 10 ml/l (C_2) and 15 ml/l (C_3), while the second factor was guano fertilizer consists of 4 dose levels, *i.e.,* 0 g/tree (G_0); 1 kg/tree (G_1); 2 kg/tree (G_2) and 3 kg/tree (G_3). The results showed that the interaction between concentration of cow urine waste liquid fertilizer and guano fertilizer doses had no significant effect on all observed variables. Liquid organic from cow urine waste fertilizer improved the yield and quality of the fruits of Siam orange in off-season period, reflected by the higher of harvested fruit weight per tree and weight per fruit at a concentration of 15 ml/l (13.20 kg and 126.32 g), or an increase of 81.32% and 28.14% than those of control (7.28 kg and 98.58 g). While in the Guano fertilizer treatment, the weight per fruit and the weight of the harvested fruit per tree were highest at the dose of 3 kg/tree (118.50 g and 12.64 kg), or an increase of 10.05% and 33.33% compared to the control (107.68 g and 9.48 kg).

Keywords: Cow urine; Guano; Off-season; Organic; Siam orange

1. Introduction

Citrus is a fruit commodity that plays an important role in the world market. Siamese oranges are a potential fruit to be developed in an effort to fulfil consumer demand. About 70 to 80% of citrus species developed by Indonesian farmers are Siam oranges [1]. Oranges in general have a high vitamin C content, and it is needed by the body for metabolism and growth, especially to keep body cells from being damaged by free radicals, support the immune system, keep skin and hair fresh, reduce the effects of anemia, and treat flu [2]; [3]. Currently, Indonesia is the second biggest importer of citrus fruits in ASEAN after Malaysia, Brunei Darussalam, and the Middle East. Imports of citrus fruits in February 2020 totaled 14.5 thousand tons, down 45% compared to the previous month [4]. Therefore, national orange production has an important role in increasing people's income, employment opportunities, and also increasing the country's foreign exchange. Imports of fresh citrus fruits continue to increase, indicating that there are certain market segments that require the type and quality of prime citrus fruits that cannot be fulfilled by domestic producers [5].

In Bali, Siam orange is one of the horticultural crops that is a regional superior commodity and the production center is in the Bangli Regency area. The harvest of citrus fruits is utilized as infrastructure in the implementation of religious ceremonies [6]. Siam orange production in Bangli Regency in the last three years has continued to decline, namely in

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2020 (131.587 ton), 2021 (104.528 ton), and 2022 (87.011 ton). [7]. The low quantity and quality of citrus yields is caused by the low competence of farmers in performing citrus maintenance activities. Low crop production is caused by the limited availability of nutrients naturally in the field, resulting in nutrient deficiencies that have implications for low citrus crop production [8]. Efforts to increase the quality and quantity of citrus production can be done by paying attention to all aspects involved in citrus farming, such as effective and sustainable cultivation techniques and optimal garden maintenance, one of which is done with fertilizer cultivation technology. The use of appropriate and balanced fertilizers causes plants to grow healthier and balanced between vegetative and generative growth so that they can bear fruit [9].

Fertilization is very important in plant growth and development, related to the provision of nutrients needed by plants. For citrus plants in their growth in able to produce good quality fruit, complete and balanced fertilizers need to be given [10]. In the cultivation of Siamese oranges, it is inseparable from fertilization activities carried out by considering the doses and time intervals of application. The availability of nutrients for plants during the growth period is very necessary because the availability of nutrients is one of the main requirements in increasing crop yields [11]; [12]. Nutrients are naturally available in the soil, but not all soils provide sufficient nutrients to support optimal plant growth, so it needs to be assisted by adding nutrients through the application of fertilisers, both organic and inorganic fertilisers [13]. Organic fertilizers have characteristics that are beneficial for soil fertility, such as organic matter in the mineralization process will release complete plant nutrients such as N, P, K, Ca, Mg, S, and micronutrients although in relatively small amounts. Organic matter increases cation exchange capacity so that the ability to bind cations becomes higher. Consequently, if the soil is fertilized with organic matter, plant nutrients are not leached easily [14]; [15]. The application of organic fertilizer is highly recommended, especially to improve the physical, chemical and biological properties of soil, as a medium for plant growth. In applying organic fertilizer, the time of application, the amount (dose), the method of application, and the type of fertilizer applied should be considered [16]; [17].

Guano fertilizer is a type of organic fertilizer made from bat droppings + natural super phosphate containing 7% N; 13% P_2O_5; 10% K_2O; 12% C-organic; 12% CaO; 12% BO; 2% Mg [18]. Meanwhile, [19] stated that guano fertilizer is a fertilizer derived from bat droppings that contains nitrogen, phosphorus and potassium which are good for supporting growth, stimulating root growth, strengthening stems and fruit maturity [20]; [21] stated that guano fertilizer contains many macro and micro nutrients C, minerals so that it can fertilize the soil and improve soil texture and contains microorganisms that can eliminate toxins in the soil, control fungi and nematodes [22] added that guano fertilizer is a good source of organic fertilizer or natural fertilizer for the cultivation of fruit crops, vegetables and various other food crops. Based to [23] stated that in red guava plants, at the age of one year, guano fertilizer is given at a dose of 500 g/plant and after the age of 2 years and above, 1-2 kg/tree is given.

Liquid organic fertilizer based on cow urine can be used as organic fertilizer because it contains nitrogen, phosphorus, potassium, and water, easily dissolves in the soil and brings important elements for soil fertility, can be done more practically and more evenly so that it is easily absorbed by the soil as well as plants [24]; [25]. Cow urine liquid organic fertilizer besides containing nutrients also contains growth stimulating substances that can be used as growth regulators in plants. It also has a distinctive smell of cattle urine so that it can prevent the arrival of various plant pests. It can be concluded that liquid organic fertilizer from cow urine has 3 main functions, namely as a liquid fertilizer for plants, as a plant growth regulator, and also as a vegetable pesticide [26] and [27]. The application method of cow urine liquid organic fertilizer when used as a foliar fertilizer is by dissolving 10 ml of cow urine liquid organic fertilizer into 1 liter of water and then spraying it to all parts of the plant, spraying once a week [28].

2. Material and methods

This research was conducted in Bayung Gede Village, Kintamani District, Bangli Regency, from October 2022 to June 2023. The design used was a factorial Randomized Group Design with 2 treatment factors, namely, the application of guano fertilizer (G) consisting of 4 dose levels, namely: G_0 = 0 g/tree, G_1 = 1000 g/tree, G_2 = 2000 g/tree, and G_3 = 3000 g/tree. Furthermore, the application of liquid organic fertiliser of cow urine waste (U) consisting of 4 concentration levels, namely: U_0 = 0 ml/l, U_1 = 5 ml/l, U_2 = 10 ml/l, and U_3 = 15 ml/l. Thus, there are 16 treatment combinations, each of which is repeated 3 times so that 48 citrus plants are needed. Sample plants were selected that were already in production with relatively uniform tree size, 4 years old, under the same ownership with the same maintenance history. Prior to treatment, weeds were cleared and holes were made around the plant in a circular manner at a distance of 50 cm from the main stem near the roots for guano fertiliser application. The guano fertiliser treatment was carried out by immersing the holes into previously prepared larvae and applied once during the study according to the treatment (0, 1000, 2000, and 3000 g/tree). Liquid organic fertilizer of cow urine waste was applied in the morning with the concentration according to the treatment (0, 5, 10 and 15 ml/l water) by spraying to all plants given once every 1 month during the study with the same concentration in each treatment every time. The variables observed in this research

were: number of flowers formed per tree, number of fruits formed per tree, percentage of fallen fruits per tree, number of harvested fruits per tree, fruit diameter, weight per fruit, weight of harvested fruits per tree, total soluble solids, leaf relative water content, leaf chlorophyll content, leaf total sugar content, leaf reducing sugar content, and leaf sucrose content.

3. Results and discussion

Based on the results of statistical analysis, it was found that the treatment interaction between liquid organic fertilizer and guano fertilizer had no significant effect on all observed variables. The liquid organic fertilizer treatment of cow urine waste had a real to very real effect on all the variables observed except for the variable number of flowers formed per tree which had no real effect. Meanwhile, guano fertilizer treatment had a very significant effect on all variables observed. The highest harvested fruit weight per tree was obtained in the liquid organic fertilizer treatment of cow urine waste at the level of 15 ml/l (U_3) which was 13.20 kg, an increase of 38.66% and 81.31% compared to the 5% level (U_1) and U_0 (control) which were only 9.52 kg and 7.28 kg. The high weight of harvested fruits per tree in the U_3 treatment was supported by the greater number of harvested fruits per tree (98.75 fruits), fruit diameter (6.32 cm) and weight per fruit (126.32 g) compared to the control which was only 77.58 fruits, 5.36 cm and 98.58 g or an increase of 27.28%, 17.91% and 28.14% (Table 3). The high number of fruits harvested per tree in U3 was supported by the high number of flowers formed per tree (111.50 florets) and the number of fruits formed per tree (105.75 fruits) or an increase of 11.31% and 16.30% compared to the control which was only 98.5 florets and 90.93 fruits (Table 2). In this research, it can be stated that plants treated with liquid organic fertilizer can stimulate plant growth, especially the formation of flowers and fruits. Cow urine liquid organic fertilizer contains various nutrients such as N 4.70%, P 5.80%, K 3.8%, CaO 0.5% and MgO 0.8% (laboratory analysis results) so that it can increase plant growth and development. Better growth in fertilizer with liquid organic fertilizer cow urine is related to the increase in relative water content (KAR) of leaves and chlorophyll content of leaves. The KAR of the leaves at the 15 ml/l level of cow urine liquid organic fertilizer was 87.65% which was significantly higher than the control which was only 73.31%. The higher KAR indicates that fertilization with cow urine liquid organic fertilizer can increase tissue water content so that it has a positive effect on the physiological processes that occur, which is indicated by increased chlorophyll formation and better ability to absorb nutrients so as to help the formation of flowers and fruits increase. Leaf chlorophyll content at the 15 ml/l level (79.89 SPAD) was significantly higher than the control (60.80 SPAD). The increase in leaf KAR and leaf chlorophyll content, caused the metabolic process in plants to increase as indicated by the content of total sugar, reducing sugar and sucrose in leaves at the 15 ml/l level of liquid organic fertilizer was higher (22.54%; 10.77% and 11.77%) than the control (12.48%; 5.02% and 7.46%). The high chlorophyll content has a positive effect on photosynthesis which has implications for increasing yield and fruit quality. Highest fruit quality in fertilization with liquid cow urine fertilizer at the level of 15 ml/l (U3) was also indicated by the value of total soluble solids of 9.99 ^{0}brix, significantly higher by 42.92% compared to the control of 6.99 ^{0}brix. Supported by the statement [29]; [30] that chlorophyll is able to absorb sunlight that plays a role in the process of photosynthesis, especially as a source of plant energy, able to convert the substrate of photosynthesis into photosynthate. Similar results were obtained by [31] on mangosteen and [32] on salak that increasing the relative water content of leaves causes the total sugar and sucrose content of leaves to increase, thereby reducing fruit drop and increasing fruit yield. A better metabolic process, especially the formation of photosynthate, will determine the level of competition between fruits for photosynthate which will affect the level of fruit loss which will ultimately determine the final yield of plants such as the number of fruits, fruit weight and fruit diameter. In this study, the level of fruit loss reflected by the percentage of fallen fruit per tree was lowest at the 15 ml/l liquid organic fertilizer level at 6.61% compared to the control which reached 14.68%. The increase in yield and yield components in the treatment of cow urine liquid organic fertilizer is inseparable from the nutrients contained in it such as macro and micro nutrients. Supported by statements [25] and [33] that the function of N in plant growth is to stimulate vegetative growth, especially an increase in the number of twigs, leaf area development, root development, flower and fruit formation and important in protein synthesis. In addition, N plays an important role in the formation of leaf forage which is very useful in the photosynthesis process. One of the functions of element P is also to contribute to the growth of seeds, roots, flowers, and fruits. In the process of plant growth, the K element is one of the primary macro nutrients needed by plants in large quantities. The function of potassium also helps in root development so that plants grow straighter and stronger or can prevent flowers and fruits from falling easily. [34] also stated that by giving POC cow urine waste to some extent can activate the process of cell elongation and division, which will affect the growth and development of subsequent plants, causing the number of fruits per tree, the weight of fruit per tree and the weight per fruit in plants treated with liquid organic fertiliser cow urine higher than in the control.

The guano fertilizer treatment gives the highest harvest fruit weight per tree at the level of 3000 g/tree (G_3) which is 12.64 kg or an increase of 29.91% and 55.33% when compared to the level of 2000 g/tree (G_1) and G_0 (control) which are only 9.73 kg and 9.48 kg. The increase in harvested fruit weight per tree in the G_3 treatment was supported by an increase in the number of harvested fruits per tree (101.08 fruits), fruit diameter (6.93 cm), and weight per fruit (126.32

g) or an increase of 30.29%; 15.12%; and 17.31% when compared to the control which was only 77.58 fruits; 6.02 cm; and 107.68 g (Table 3). The increase in the number of fruits harvested in the G_3 treatment was also supported by an increase in the variable number of flowers per tree (110.08 florets) and the number of fruits formed per tree (106.50 fruits) which increased by 14.46% and 25.66% when compared to the control which was only 96.17 florets and 84.75 fruits (Table 2).

Table 1 The effect of liquid organic fertilizer treatment of cow urine waste (U) and dose of guano fertilizer (G) on the variables number of harvested fruit per tree, weight per fruit, fruit diameter and fruit weight per tree

Treatment	Number of fruits harvested per tree (fruit)	Weight per Fruit (g)	Fruit Diameter (cm)	Fruit Weight per tree (kg)
Cow Urine Liquid Organic Fertilizer (U)				
U_0 (0 ml/l)	73.63 d	98.58 d	5.36 b	7.28 d
U_1 (5 ml/l)	84.69 c	109.92 c	6.02 a	9.52 c
U_2 (10 ml/l)	94.74 b	117.16 b	6.23 a	11.11 b
U_3 (15 ml/l)	101.81 a	126.32 a	6.32 a	13.20 a
BNT 0,05	**2.11**	**3.18**	**0.35**	**1.47**
Guano Fertilizer (G)				
G_0 (0 g/tree) (control)	77.58 d	107.68 d	5.03 c	9.48 b
G_1 (1000 g/ tree)	87.71 c	111.28 c	6.18 b	9.73 b
G_2 (2000 g/ tree)	93.73 b	114.53 b	6.63 a	10.73 b
G_3 (3000 g/ tree)	98.75 a	118.50 a	6.93 a	12.64 a
BNT 0,05	**2.11**	**3.18**	**0.35**	**1.47**

Note: The average value followed by the same letter in the same treatment and column means that it is not significantly different at the 5% LSD test level.

Table 2 Effect of liquid organic fertilizer treatment from cow urine waste (U) and dose of guano fertilizer (G) on the number of flowers and number of fruit formed per tree, percentage of fallen fruit per tree and total soluble solids

Treatment	The number of flowers formed per tree (bud)	The number of fruits formed per tree (fruit)	Percentage of fallen fruit per tree (%)	Total soluble solids (^{0}brix)
Cow Urine Liquid Organic Fertilizer (U)				
U_0 (0 ml/l) (control)	98.50 c	84.75 c	13.27 a	6.99 c
U_1 (5 ml/l)	104.00 b	95.00 b	10.71 a	8.40 b
U_2 (10 ml/l)	107.42 b	102.08 ab	7.10 b	9.68 a
U_3 (15 ml/l)	118.50 a	106.50 a	5.09 b	9.99 a
BNT 0,05	**8.44**	**8.73**	**2.85**	**0.78**
Guano Fertilizer (G)				
G_0 (0 g/ tree) (control)	99.50 a	84.75 c	13.47 a	7.01 b
G_1 (1000 g/ tree)	104.00 a	95.00 b	8.87 b	7.98 b

G_2 (2000 g/ tree)	107.42 a	102.09 ab	6.10 b	9.68 a
G_3 (3000 g/ tree)	108.50 a	106.50 a	4.18 b	10.09 a
BNT 0,05	**8.44**	**8.73**	**2.85**	**0.78**

Note: The average value followed by the same letter in the same treatment and column means that it is not significantly different at the 5% BNT test level.

The increase in yield in this case is the weight of harvested fruit per tree supported by the increase in yield components such as the number of harvested fruits per tree, weight per fruit, fruit diameter, number of flowers and the number of fruits formed per tree due to guano fertiliser which is an effective organic material for soil fertiliser, can improve the physical, chemical and biological properties of the soil so as to affect the growth and development of roots in the soil. Apart from being a soil fertiliser, it also contains high phosphorus (P) and nitrogen (N) elements. Plant height increase, growth and development of roots and leaves are strongly influenced by the availability of nitrogen in the soil. Better growth in fertilised with guano fertiliser is related to increased relative water content (KAR) of leaves and chlorophyll content of leaves. Leaf KAR at the G_3 fertilizer level was 86.78%, 16.39% higher than the control which was only 74.56%. The higher KAR indicates that fertilization with guano fertilizer can increase tissue water content so that it has a positive effect on the physiological processes that occur, which is indicated by increased chlorophyll formation and better ability to absorb nutrients. Leaf chlorophyll content in G_3 (78.56 SPAD) was significantly higher than the control (61.88 SPAD). The increase in leaf KAR, leaf chlorophyll content causes the metabolic process in plants to increase, which is indicated by the content of total sugar, reducing sugar and sucrose in leaves at the G_3 fertilization level which is higher than G_1 and control. Table 3 shows that the total sugar, reducing sugar and sucrose content of leaves in G_3 were 23.38%, 9.22% and 14.16%, in G_1 were 14.57%, 6.52% and 8.05%, while in G_0 were 13.48%, 6.32% and 7.16%. Better metabolic processes caused the number of fruits per tree, fruit weight per tree and weight per fruit in plants treated with guano fertilizer to be higher than the control. In addition, the best fruit quality was also shown by the total soluble solids value at the guano fertilization level of 3000 g/tree (G_3) which was 10.09 ^{0}Brix, significantly higher by 43.94% compared to the control which was only 7.01 ^{0}Brix. The better fruit quality in G_3 is related to the better photosynthesis process because the highest content of chlorophyll so that the photosynthate produced is greater, which is indicated by the highest content of total sugar, reducing sugar and sucrose in G_3 leaves. With better carbohydrate content status, the allocation of photosynthate to the fruit in G_3 is higher so that in addition to increasing yield, it also improves the quality of fruit yield. These results are in accordance with the results of research [35] on the fruit of the genus *Cucumis* that the increase in carbohydrates produced by the leaves causes the quality of the fruit to also increase. Supported by [36] states that the phosphorus element contained in guano fertilizer which is a macro nutrient that plays an important role in various life processes such as photosynthesis, respiration, energy transfer and storage, cell division and enlargement, and carbohydrate metabolism in plants. (37) states that the element P contributes to the growth of roots, flowers and fruits. The effect on the roots is to improve the root structure so that the plant's absorption of water and nutrients is better. Phosphorus is used to stimulate the flowering process. The growth and development of roots in the soil must be good so that the absorption of water and nutrients can run normally so that it can support above-ground growth optimally such as chlorophyll formation, protein synthesis and assimilates produced increase and those stored in storage organs, especially fruit, also increase, so as to reduce fruit loss. In addition to phosphorus and nitrogen, the potassium element contained in guano fertiliser also has the function of preventing flower and fruit loss and improving fruit quality. This can be proven in the variable of the percentage of fallen fruit, where the 3000 g/tree dose of guano fertiliser (G_3) gave the lowest percentage of fallen fruit at 5.09% and the highest was obtained in G_0 reaching 13.27%. [38]; [39] stated that nitrogen is the mineral element most widely used by citrus trees to produce leaves, flowers, and fruit, although Ca and K are also used in large quantities. Nitrogen is a key component in mineral fertilizers applied to citrus orchards, having a greater influence on fruit growth, appearance and production/quality than any other mineral element. Nitrogen affects the uptake and distribution of almost all other elements, and it is particularly important for trees during flowering and fruit formation. [11] states that the role of nitrogen, phosphorus and potassium elements for plants is to stimulate overall plant growth, especially stems, branches and leaves. Therefore, these elements are needed in large quantities when growth enters the vegetative phase, especially increasing the number of twigs, developing leaf area, root development, flower and fruit formation.

Table 3 Effect of liquid organic fertilizer treatment from cow urine waste (U) and guano fertilizer dose (G) on leaf relative water content, leaf chlorophyll content, total leaf sugar content, leaf reducing sugar content and leaf sucrose content

Treatment	Relative water content of leaves (%)	Chlorophyl content leaf (SPAD)	Total sugar content of leaves (%)	Leaf reduction sugar content (%)	Leaf sucrose content (%)
Cow Urine Liquid Organic Fertilizer (U)					
U_0 (0 ml/l) (control)	73.31 b	60.80 c	12.48 c	5.02 c	7.46 c
U_1 (5 ml/l)	74.89 b	62.85 c	12.65 c	5.12 c	7.53 c
U_2 (10 ml/l)	85.55 a	75.33 b	19.76 b	9.84 b	9.92 b
U_3 (15 ml/l)	87.65 a	79.89 a	22.54 a	10.77 a	11.77 a
BNT 0,05	**4.24**	**4.16**	**2.34**	**0.86**	**1.52**
Guano Fertilizer (G)					
G_0 (0 g/ tree) (control)	74.56 b	61.88 d	13.48 c	6.32 c	7.16 d
G_1 (1000 g/ tree)	77.80 b	67.45 c	14.57 c	6.52 c	8.05 c
G_2 (2000 g/ tree)	84.99 a	73.78 b	19.64 b	7.53 b	12.1 b1
G_3 (3000 g/ tree)	86.78 a	78.56 a	23.38 a	9.22 a	14.16 a
BNT 0,05	**4.24**	**4.16**	**2.34**	**0.86**	**1.52**

Note: The average value followed by the same letter in the same treatment and column means that it is not significantly different at the 5% BNT test level.

4. Conclusion

Base on the results showed that the interaction between the concentration of liquid fertilizzer of cow urine waste and the dose of guano fertilizer had no significant effect on all variables observed. Liquid organic fertilizer from cow urine waste increased the yield and quality of Siam citrus fruits in the off-season, reflected by the higher weight of harvested fruits per tree and weight per fruit at the 15 ml/l level (13.20 kg and 126.32 g), or an increase of 81.32% and 28.14% compared to the control (7.28 kg and 98.58 g). While in the Guano fertilizer treatment, the weight per fruit and harvest weight per tree were highest at the 3000 g/tree level (118.50 g and 12.64 kg), or increased by 10.05% and 33.33% compared to the control (107.68 g and 9.48 kg).

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare no conflict of interest.

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