Innovations in healthy citrus garden management to reduce major pests and diseases and increase incomes of citrus farmers

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Abstract. Healthy citrus garden management is an effort to optimize citrus yields. The research aims to suppress major pests and diseases and increase yields and incomes of citrus farmers. The research was conducted in Kintamani, Bali in January 2017-December 2020. The study was conducted in pairs in the form of 1 block of garden technology innovation treatment of healthy citrus gardens and 1 block of farmers' existing gardens. Plant samples per block were determined by *purposive sampling*. The results showed that the treatment had a significant effect on the abundance of fruit fly populations, diplodia infection, crop yields and farm income. There was a decrease in fruit fly population abundance and diplodia infection by 9.20 and 33.60%, the average citrus fruit yield was 23.71 t/ha. / year, there is an increase in citrus farming income by 97.19%/ha/year due to the innovation of healthy citrus gardens. Based on the calculation results, the R/C ratio and MBCR values were 1.96 and 2.55 for innovations with components of healthy citrus garden management. It is concluded that the technological innovation of healthy citrus gardens is feasible to be developed with the same type of agroecosystem

1 Introduction

Horticultural products are commodities that have high economic value and market opportunities. Its contribution to the development of the agricultural sector shows a trend as a source of export, employment, and farmers' income [1]. One of the horticultural commodities that is the focus of development in 57 districts/cities in the development area is citrus [2]. [3] stated that citrus is one of the leading fruit commodities in Indonesia which are the most traded globally. Orange prices are relatively affordable with high nutritional content. [4] added that citrus are fruits that play an important role in the era of the covid pandemic.

Citruses contain lots of vitamins, minerals, fiber, and phytochemicals such as carotenoids, flavonoids, and limnoids which are important for the activities of the human body in maintaining health [5,6] and can be consumed in fresh form [7].

According to [8] citrus farming in Indonesia is still dominated by Siamese oranges, around 80%. Likewise with Bali, Indonesia. Siamese oranges are one of the leading citrus

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commodities in Bali, Indonesia with the dominant production center in Kintamani, Bangli Regency [9] Based on data from the Central Bureau of Statistics [9], in the last five years, Siamese citrus production in Bangli, Bali has fluctuated between 102,051 and 131,587 tons

per year. Increasing the production and quality of Siamese citrus fruit is needed to avoid economic losses in citrus farming. Various efforts have been made to increase the production and quality of Siamese oranges. However, pest and disease attacks remain a major obstacle. Based on the results [10], fruit flies and diplodia are one of the main pests and diseases that attack Siamese oranges in Kintamani-Bangli. According to [11] the intensity of fruit fly pests can reach 90%, if there is no control effort. [12] added that the damage caused by fruit flies is caused by their larvae causing the fruit to drop before the fruit is ripe.

Diplodia is the main disease affecting citrus associated with the fungus *BotryoDiplodia theobromae Pat*. [13] stated that this fungus is polyphagous and attacks various plants, therefore the source of infection will always be in the cropping environment. Diplodia disease in citrus plants can be observed by looking at the symptoms on the stems. Symptoms are characterized by yellow or foamy discharge and cracked skin due to pathogenic activity that causes stem rot. Diplodia disease or often referred to as Diplodia gummosis because it reacts to release gum [14]. Penetration causes plants to react by releasing yellow defense substances such as gummosis which are released by plants as a form of reaction after pathogen attack in tissues and are produced to localize and limit the growth of pathogens [15]. Gummosis that emerges from the surface of the skin of plant tissue indicates an advanced attack. In addition to attacking citrus plants, this fungus also attacks cashew nuts [16], and other horticultural crops [17].

Based on the problems mentioned above, research related to the control of major pests and diseases was carried out with the application of healthy citrus garden management. Healthy citrus garden management is an approach or way of thinking about plant management based on ecological considerations and economic efficiency in the context of managing agro-ecosystems that are environmentally sustainable. Through the introduction of healthy citrus garden technology, it is hoped that pest and disease attacks can be suppressed so that optimum production and farmers' incomes increase.

2 Methodology

2.1 Place and time

The research was carried out at the Tabeng Sari Farmer's Group, Beluhu Village, Kintamani District, Bangli Regency, from January 2017 - December 2020.

2.2 Implementation of activities

The activity was carried out on a farmer's land area of 1 ha, divided into 2 blocks, namely 1 block of gardens with technological innovation treatment of healthy citrus gardens and 1 block of farmers' existing gardens. The innovative treatment for healthy citrus gardens includes fertilization, pruning, and controlling pests and diseases, especially fruit flies and diplodia, according to standard operating procedures for managing healthy citrus gardens. Existing farmers is the treatment according to the habits of farmers. Sample plants per block were determined by *purposive sampling* namely: deliberately based on certain considerations. The number of plants per block is 100 trees. The application begins with the application of 40 kg/tree of fermented cow dung organic fertilizer mixed with 1 kg of dolomite lime/tree, 1 kg of NPK/tree and 0.02 kg of ZA/tree by immersing it under the edge of the canopy as deep as 20 cm. Pruning is done by cutting branches / twigs and shoots that grow at the base of the rootstock and cutting the former fruit stalks so that flower buds grow on the twig. To overcome the lack of micro elements, micro fertilizers are applied by spraying them on the leaves according to the recommended dose. Fruit fly pest control is carried out with garden sanitation, namely collecting rotten fruit on trees and fallen fruit and installing yellow traps. The traps were set as many as 20 traps per hectare and placed by hanging from the canopy of citrus plants as high as 1.5m from the ground. The control of diplodia was carried out by application of a sulfur-calcium suspension. The materials used to make the sulfur-calcium suspension were powdered sulfur (Indosulfur Mitra Kimia, Indonesia), calcium hydroxide in the form of lime (Petrokimia, Indonesia), and clean water with a concentration of 1:2:10 in each mixture. To make a suspension, the sulfur powder is boiled and then added with lime until it is homogeneous. The final suspension product is reddish yellow in color. Application of sulfur-calcium suspension in the field is done by first cleaning the trunk, branches, and twigs of tree plants where the sap occurs by peeling the skin to facilitate the application of calcium-sulfur suspension. Applications are made at the beginning and end of the rainy season.

2.3 Observation parameters

Initial observations were made to determine the abundance of fruit fly imago and the intensity of diplodia disease. Parameters of late fruit fly imago abundance, number of sample plants affected by late diplodia disease, intensity of late diplodia attack, number of new shoots, number of young fruits, yield, and analysis of citrus farming were carried out during the last study. Data on the abundance of fruit flies was obtained by counting the number of fruit flies trapped in the yellow trap. The intensity of the attack of diplodia is calculated based on the formula:
In addition, the disease intensity was determined with:

$$DI=\frac{\Sigma_{i=0}^{i} ni.vi}{NV} x100\% \quad (1)$$

Where DI = diseases intensity; Σ = the sum of the number attacked leaves multiply by the score of each category; ni = number of leaves attacked in each category; vi = score in each category; N= highest score in each category; V = number of total leaves observed.
To measure the diseases' intensity the following score or scale of each category was used:
0 = no attack at all
1 = very mild attack (0-10% of steam surface was attacked)
2 = mild attack (10-30% of steam surface was attacked)
3 = moderate attack (30-50% of steam surface was attacked)
4 = severe attack (50-75% of steam surface was attacked)
5 = very heavy attack (75-100% of steam surface was attacked)

2.4 Data analysis

Agronomic observation data were analyzed using t test, while farming analysis used *Return of Cost* (R/C) and *Marginal Benefit Cost Ratio* (*MBCR*) analysis. R/C analysis compares gross revenue (sales proceeds) and total costs incurred. *MBCR* is used to measure the feasibility of new/introduced technology compared to farmer technology which can be formulated as follows

$$MBCR=\frac{\text{Gross receipts (I) - Gross receipts (P)}}{\text{Total cost (I) - Total cost (P)}} \quad (2)$$

Where, *I* was technology introduction and *P* was existing technology

Theoretically, the decision to adopt a new technology is feasible if MBCR > 1. That is, the additional revenue gained from implementing the new technology must be greater than the additional cost

3 Results and discussion

3.1 Existing conditions

The area of land cultivated by citrus farmers ranges from 0.30-2.00 ha. Planting is done by intercropping between oranges and vegetables (chili, cabbage, sweet potatoes, and beans). The age of citrus plants ranges from 4-10 years, spacing of 3 x 4 m. The average citrus population per hectare is 833 trees. In general, farmers have been cultivating citrus crops for a long time, but they do not fully understand the correct citrus cultivation technology in accordance with *good agricultural practices* (GAP). Based on the results [10], fruit flies and diplodia are one of the main pests and diseases that attack Siamese oranges in Kintamani-Bangli. Dominant farmers use chemical pesticides to control pests and diseases that attack citrus plants individually. This condition will cause pests and diseases to always exist in the field. Farmers have done pruning, but the part that is trimmed is not quite right. Farmers only use makeshift organic and inorganic fertilizers according to their respective abilities.

3.2 The results of the study

The results of the analysis showed that the technological innovations of healthy citrus gardens were different and not significantly different from the observed parameters. The abundance of late fruit flies, number of plants attacked by late diplodia, intensity of attack of late diplodia, number of new shoots, young fruit, and yields were significantly different, while abundance of early fruit flies and intensity of early attack were not significantly different (Table 1-3).

The abundance of final fruit flies in farmers' existing gardens (99.40) was higher than technological innovations in healthy citrus gardens (91.05), or in other words, technological innovations in healthy citrus gardens were able to suppress fruit fly abundance by 9.20% (Table 1).

Table 1. Average early, late fruit fly abundance and percentage of plants affected by diplodia

Treatment	Fruit fly abundance (early/tails)		Fruit fly abundance (late/tails)		Plants attacked by diplodia (early/trees)	
Innovation	106.53	a	91.05	b	100.00	a
Existing	99.79	a	99.40	a	100.00	a
	t count =	1.49	t count =	2.48	t count =	0.99
	t table =	1.68	t table =	1.68	t table =	1.68

Note: For each sample, means within each column followed by a different letter are significantly different

The intensity of diplodia attacks at the end of the farmers' existing gardens (10.75) was also higher than the technological innovation gardens (7.13%). In other words, technological innovations in healthy citrus gardens were able to reduce the intensity of diplodia attacks by 33.6% (Table 2).

Table 2. Average intensity of initial diplodia attack, number of affected plants late diplodia and late diplodia attack intensity

Treatment	Early diplodia attack intensity (%)		number of late diplodia attack plants (trees)		Late diplodia attack intensity (%)	
Innovation	10.75	a	100.00	a	7.13	b
Existing	9.94	a	100.00	a	10.75	a
	t count =	1.56	t count =	0.99	t count =	12.04
	t table =	1.65	t table =	1.65	t table =	1.65

Note: For each sample, means within each column followed by a different letter are significantly different

The number of new shoots, young fruit and yields in the innovation treatment of healthy citrus gardens was higher than that of existing farmers. The number of new shoots due to technological innovation was 34.08 stems or 31.04% higher than the existing farmers. Likewise, young fruit (90.15) and yield (28.46) were 19.26 and 13.98%, respectively, higher than existing farmers (72.79 and 24.48) (Table 3).

Table 3. Average number of new shoots, young fruit, and yield/tree

Treatment	Number of new shoots (stems)		young fruit (fruit)		yield/tree (kg)	
Innovation	34.08	a	90.15	a	28.46	a
Existing	23.50	b	72.79	b	24.48	b
	t count =	19.47	t count =	18.6	t count =	6.68
	t table =	1.65	t table =	1.65	t table =	1.65

Note: For each sample, means within each column followed by a different letter are significantly different

The comparison of soil quality between existing and innovated conditions is shown in Table 4. The table provides an overview of the effect of technological innovations for fertilization of healthy citrus orchards on several soil quality parameters. The three main macronutrients namely Nitrogen (N), Phosphorus (P) and Potassium (K), soil organic carbon, electrical conductivity and soil pH, Nitrogen (N), Phosphorus (P) and Potassium (K) composition increases with the addition of organic fertilizers. and inorganic. The organic carbon component of the soil as well as the electrical conductivity at the site was increased after the fertilization treatment. Soil pH increases with the addition of organic fertilizers combined with dolomite.

Table 4. Soil quality comparison between conventional and innovation treatment.

Soil Parameters	Existing	Innovation
Ph	5.8	6.7
Electric Conductivity (mmhos/cm)	0.66	1.75
C-Organic (%)	3.57	12.53
N-Total (%)	0.25	0.49
P-Available (ppm)	31.78	604.00
K-Available (ppm)	145.79	954.44

Notes:
Existing *(Fertilization conventional way)*
Innovation *(Fertilization innovation)*

Overall, the technological innovation treatment of healthy citrus gardens gave better soil and plant performance compared to the use of chemicals. This condition is caused by the effect of regular pruning and fertilization combined with garden sanitation, yellow trap installation and calcium-sulfur suspension treatment.[18] states that pruning will increase the plant's ability to form flowers and fruit. Shaded leaves will not be optimal in photosynthesis so that it interferes with flowering and fruiting. Proper pruning accelerates the emergence of new shoots and more shoots. New shoots will appear and develop into new leaves. It is also said that pruning can break the apical dominance of the shoot and encourage the growth of lateral shoots, so that the direction of shoot growth is to the side. The higher the number of shoots initiated, the higher the citrus fruit production [19]. [20] stated that the application of open pruning was making the canopy more open and reducing land occupation. Pruning also affects the attack of anthracnose on citrus plants. The results of the study [21] showed that pruning can suppress anthracnose attack by 33% on mature plants and 60% on immature plants.

Fertilization is an effort to add organic matter into the soil which functions to improve soil properties, including physical, chemical and biological properties. The properties of soils that are in good condition can stimulate plant growth and development because they can stimulate root growth, increase nutrient availability for plants, and increase soil microbial populations [22]. [23] and [24] stated that the combination of inorganic and organic fertilization can increase crop yields. [25-28] added that fertilization is not only done through the soil but also the leaves. Giving fertilizer through the leaves is important, especially to overcome the lack of micro elements. [29] stated that the application of foliar fertilizer containing Zn and Cu to citrus plants was able to increase photosynthetic activity. [30] and [31] stated that the element potassium can increase the level of fruit sweetness because this element helps plants translocate sugar to parts of plants that need it. Furthermore [32] added that phosphorus is needed by plants in the generative phase to increase yield and quality. [33] and [34] stated that together with phosphorus, potassium played a role in increasing the percentage of finished fruit.

Sanitation of rotten fruit on trees and fallen fruit combined with yellow traps is an effort to prevent the expansion of fruit fly attacks. Rotten fruit is a shelter for fruit flies and yellow traps are a means of attracting male fruit flies. By cleaning the rotten fruit and trapping male fruit fly insects, the fruit fly's life cycle will be cut off and the population will decrease.

Calcium and sulfur are both nutrients for plants. Calcium is required to hold together and maintain the integrity of plant cell walls and offer growth support to tissues. While sulfur, is one of the building blocks of protein and is easily absorbed by plants. The combination of calcium-sulfur suspension provides the essential elements needed for plants and soil with compost able to provide optimal support for plant growth so that plants grow healthy and diplodia attack is controlled. Research related to the use of calcium-sulfur suspension has also been carried out by [35]. The results of the study [36] showed that the application of sulfur lime coupled with the addition of Mycosin and environmental sanitation was able to reduce Diplodia in apple plants by about 73%.

3.3 Analysis of citrus farming business

The highest expenditure components in the cost structure of citrus farming, both citrus gardens with technological innovation and existing farmers include expenditures for fertilizers, labor, and medicines (Table 5).

In Table 5, the application of technological innovations in healthy citrus gardens has an impact on crop production. Cash expenditures on healthy citrus gardens incur cash costs of 60,419,000.00 IDR while in the existing garden the production cost per hectare of citrus farming is 41,900,000.00 IDR with an abundance of 91.05 fruit flies per trap and 7.13% of diplodia infection and the use of such inputs, the resulting citrus productivity is 2,370,718.00 t/ha for healthy citrus gardens and 2,039,184.00 t/ha for existing farmers. If judged by the selling price of oranges, it turns out that the selling price of healthy oranges is 5,000.00 IDR/kg while the existing 3,500.00 IDR/kg, then the total revenue of healthy citrus farmers is 118,535,900.00 IDR/year, while the existing plantation is 71,371,440.00 IDR/year. After deducting the cost of farming, the farmer in the healthy citrus garden earns a profit of around 58,116,900.00 IDR/hectare/year while the existing garden is 29,472,440 IDR/hectare/year.

Table 5. Analysis of citrus farming (per hectare) in Subak Tabeng Sari

Production Facilities	Unit	Technology innovation			Existing		
		Volume	Price	Value	Volume	Price	Value
inorganic fertilizer							
- NPK	kg	920.00	15,000.00	13,800,000.00			
- ZA	kg	17.00	7,000.00	119,000.00			
- Urea	kg				850.00	7,000.00	5,950,000.00
organic fertilizer	kg	34,000.00	1,000.00	34,000,000.00	17,000.00	1,000.00	17,000,000.00
micro fertilizer	l	34.00	25,000.00	850,000.00	34.00	25,000.00	850,000.00
Dolomite	kg	850.00	1,000.00	850,000.00			
pesticide	l				50.00	90,000.00	4,500,000.00
Labor							
- fertilization	day	64.00	50,000.00	3,200,000.00	48.00	50,000.00	2,400,000.00
- pest control	day	40.00	50,000.00	2,000,000.00	64.00	50,000.00	3,200,000.00
- pruning	day	48.00	50,000.00	2,400,000.00	64.00	50,000.00	3,200,000.00
- weeding	day	64.00	50,000.00	3,200,000.00	96.00	50,000.00	4,800,000.00
Total cost				60,419,000.00			41,900,000.00
production							
- Amount	t	2,370,718.00				2,039,184.00	
- Price	IDR/kg	5,000.00				3,500.00	
Reception	IDR	118,535,900.00				71,371,440.00	
Income	IDR	58,116,900.00				29,472,440.00	
R/C ratio		1.96				1.70	
MBCR		2.55					

The value of the R/C ratio received by both healthy and existing citrus gardens gives a value above 1 which means that citrus farming is feasible to develop, but it will be more profitable to apply healthy citrus gardens. The MBCR (*marginal benefit cost ratio*) value from the application of this technological innovation is 2.55, which means that every additional cost in implementing new technological innovations is 1,000.00 IDR it can increase revenue by 2,550.00 IDR. Citrus is feasible and profitable to be developed in a wider area with relatively the same type of agroecosystem.

4 Conclusion

Siamese citrus has the potential to be developed in Kintamani-Bali, Indonesia. Judging from the results, the technological innovation of healthy citrus orchards with regular pruning and fertilizing combined with sanitation, yellow trapping and treatment of calcium-sulfur suspension gave better results than the existing conditions. Treatment of healthy citrus gardens can suppress fruit fly and diplodia attacks as well as increase yields and income of citrus farming. Financially, Siamese citrus farming is feasible. An R/C ratio value of more than one is good for the existing condition and innovation of healthy citrus gardens, but it is more profitable if implementing healthy citrus gardens is seen from the MBCR (*marginal benefit cost ratio*) value.

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