The Influence of Strangulation and Dormancy-Breaking Agent Aplication on Fruit set, Flower and Fruit Drop of Chokun Citrus (*Citrus reticulata*)

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Abstract. Chokun citrus plants (*Citrus reticulata*) are known for their sweet taste and distinctive aroma. Citrus production in Indonesia fluctuates annually. This research aims to investigate the effects of strangulation and dormancy-breaking agent application on fruiting, flower drop, and fruit drop in Chokun citrus. The study was conducted at the exfarm of Universitas Jenderal Soedirman from July 2023 to January 2024 using a Completely Randomized Design (CRD) with two main treatments: strangulation (without strangulation, single strangulation, double strangulations) and dormancy-breaking agent application (without dormancy breaking agent, KNO3 250 ppm, Etephon 150 ppm), involving a total of 27 citrus trees as research subjects. Strangulation involved wrapping a 1.5 mm diameters wire around the lower stem, which was removed after three months. Dormancy-breaking agents were applied after wire removal. Results indicated that strangulation increased flower and fruit numbers, flower and fruit drop, and leaf carbon content at 32 days after treatment (DAT). Dormancy-breaking agent application did not affect all variables. Interaction between strangulation and dormancy-breaking agents affected flower and fruit numbers, leaf carbon content at 64 DAT, and C/N ratio. This study demonstrates that combining strangulation techniques and dormancy-breaking agent applications can enhance Chokun citrus plant production.

1 Introduction

Horticultural commodities play a crucial role in national economic development. One of the important horticultural commodities is fruit. Chokun citrus, commonly known as Thai honey citrus, is a type of lowland citrus with a sweet taste. Citrus contain high levels of vitamin C; every 100 grams of sweet citrus contains 49 mg of vitamin C, 190 IU of vitamin A, 0.08 mg of vitamin B1, 33 mg of calcium, 11.2 g of carbohydrates, 0.4 mg of iron, 87.2 g of water, 0.2 g of fat, and 3 mg of phosphorus [1]. Citrus juice is very

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beneficial for the body as it can help against infection and colds also stimulate the immune system [2]. These benefits have led to an increase in citrus consumption in Indonesia every year. In 2020, the average citrus consumption in Indonesia was 3.301 kg per capita, in 2021 it was 4.269 kg per capita, and in 2022 it was 4.826 kg per capita [3].

Production of citrus in Indonesia fluctuates each year. In 2019, production reached 2,444,518 tons. In 2020, there was an increase to 2,593,384 tons. However, in 2021, production fell to 2,401,064 tons. Then, in 2022, production increases again to 2,551,999 tons [4]. Therefore, it is necessary to implement cultivation techniques to ensure the annual increase in citrus production.

One of the method to accelerate citrus fruit production is strangulation. Strangulation is a technique to induce flowering or stimulate flower formation in citrus plants. The process involves tying the stem with wire of a certain diameter [5]. The application of strangulation in pomelo citrus significantly affects the total number of leaves per plant and the diameter of the upper stem [5]. Generally, strangulation only induces flowering but does not promote the development of flowers, thus requiring a combination with dormancy-breaking agents such as KNO_3, ethephon, and Purin (BAP) [6]. Ethephon, BAP, and KNO3 are synthetic chemicals that can act as accelerators for breaking dormancy in buds and forming flowers [7] Research showed that the application of dormancy-breaking agents (DBA) only affects the number of new buds per Siam citrus tree [8]. Therefore, a combination of dormancy-breaking agents and strangulation is needed to improve fruit quality.

2 Research Methods

The research was conducted at the Experimental Farm of the Faculty of Agriculture, Universitas Jenderal Soedirman, and the Soil Science Laboratory. The research period was from July 2023 to January 2024. This research used four-years-old Chokun citrus plants. This study employed a factorial experiment with a completely randomized design (CRD) involving two main treatments: strangulation (without strangulation, single strangulation, double strangulations) and the application of dormancy-breaking agents (without dormancy- breaking agent, 250 ppm KNO_3, 150 ppm Ethephon). Thus, there were 27 citrus trees as the research subjects.

The observed variables included the number of fruits, flower drop, fruit drop, fruit set, carbon (C) content at 32 and 64 days after treatment (DAT), nitrogen (N) content at 32 and 64 DAT, and the C/N ratio. Samples for carbon and nitrogen content analysis were taken from healthy leaves, then oven-dried and blended to the desired particle size. Sampling for this analysis was conducted twice, at 36 and 64 days after treatment (DAT). Nitrogen analysis used the Kjeldahl method, which includes digestion, distillation, and titration processes. The Kjeldahl method is used to determine nitrogen content in a compound [9]while leaf carbon content was determined using spectrophotometry at a wavelength of 587. The C/N ratio is the relationship between the mass ratio of carbon (C) to nitrogen (N) in a substance [10]. The C/N ratio is calculated after determining the C and N content in the leaves using the formula:

$$C/N\ Ratio = \frac{Carbon\ content\ \ (C)}{Nitrogen\ content\ (N)} \quad (1)$$

3 Results and Discussion

The results of the F test at a 5% error levels (Table 1) indicate a significant effect on several observed variables in the strangulation experiment and the application of dormancy-breaking agents. Strangulation treatment showed a significant impact on the number of flowers, number of fruits, flower and fruit drop, and increase leaf C content at 32 days after treatment (DAT). In this experiment, the dormancy-breaking agent treatment didn't show a significant difference in several research variables. This means that the use of dormancy-breaking agents didn't have a significant effect on reducing flower and fruit drop or on increasing fruit set and nitrogen in Chokun citrus plants.

Although the dormancy-breaking agent treatment individually didn't show a significant impact, the interaction between strangulation and dormancy-breaking agent treatments had a significant effect on the number of flowers, number of fruits, leaf carbohydrate content, and C/N ratio. This indicates that the combination of both treatments can change the plant metabolism, particularly in the distribution and storage of carbohydrates.

Table 1. Recapitulation results of analysis variance for all observed variables in Chokun citrus plants.

No	Observation variables	Treatment		SxP
		Strangulation (S)	Dormancy Breaking Agent (P)	
1	Number of fruit	**	ns	**
2	*Fuit-set (*%)	ns	ns	ns
3	Flower drop *(*%)	*	ns	ns
4	Fruit drop *(*%)	*	ns	ns
5	Leaf nitrogen content 32 hsp	ns	ns	ns
6	Leaf carbon content 32 hsp	**	ns	ns
7	C/N Ratio	ns	ns	ns
8	Leaf nitrogen content 64 hsp	ns	ns	ns
9	Leaf carbon content 64 hsp	ns	ns	**
10	C/N Rasio	ns	ns	*

Note: hsp = days after treatment; ns = not significant; * significant; ** highly significant

3.1 Effect of Strangulation

Table 2 show that strangulation significantly increases the number of fruits. This is related to the increased carbon content in the leaves of the plants. Strangulation can increase carbohydrates in the plant due to the inhibition of the translocation of photosynthates from the canopy to the roots, leading to carbohydrate accumulation in the canopy [11]. However, strangulation also affects flower and fruit drop. This occurs because the plant cannot sustain the flowers for a long period, resulting in no significant effect on fruitset.

Table 2. The effect of strangulation on the number of fruits, fruit-set, flower drop, fruit drop, carbon content, nitrogen content, and C/N ratio at 32 and 64 DAT.

Variable										
S	Number of Fruit	Fruit-set (%)	Flower drop (%)	Fruit drop (%)	32 DAT			64 DAT		
					C	N	C/N	C	N	C/N
S0	26,56 a	36,80 a	26,00 a	18,04 a	40,04 a	2,09 a	24,04 a	39,39 a	1,68 a	23,57 a
S1	45,13 b	49,88 a	40,22 b	29,49 a	48,25 b	1,91 a	26,65 a	39,30 a	1,62 2 a	24,68 a
S2	52,61 b	42,22 a	46,66 b	43,95 b	49,13 b	1,91 a	26,71 a	36,85 a	1,57 a	23,92 a

Note : without strangulation (S0), single strangulation (S1), double strangulations (S2), days after treatment (DAT)

3.2 Effect of Dormancy-Breaking Agents

Table 3 shows that the application of dormancy-breaking agents does not result in significant differences in the number of fruits, fruit set, flower drop, fruit drop, carbon content, nitrogen content, and C/N ratio. This is because some plants had already flowered before the application of the dormancy-breaking agents. The application of dormancy-breaking agents such as KNO_3, ethephon, and BAP did not have a significant effect on any variables because some plants had already flowered before the application of these agents [11].

Table 3. Effect of dormancy-breaking agents on the number of flowers, fruits, fruit set, flower drop, fruit drop, and C, N, and also C/N ratio at 32 and 64 days after application

Variable										
P	Number of Fruit	Fruit-set (%)	Flower drop (%)	Fruit drop (%)	32 DAT			64 DAT		
					C	N	C/N	C	N	C/N
P0	44,00 a	44,44 a	33,78 a	31,62 a	48,18 a	1,91 a	26,90 a	36,81 a	1,66 A	22,48 a
P1	37,33 a	45,07 a	46,01 a	31,33 a	46,91 a	1,90 a	25,06 a	38,98 a	1,60 A	24,46 a
P2	54,06 a	39,39 a	33,10 a	28,55 a	48,33 a	1,93 a	25,44 a	39,75 a	1,61 a	24,84 a

Note : Without dormancy-breaking agent (P0), KNO3 250 ppm (P1), Ethepon 150 ppm (P2), day after treatmen (DAT).

3.3 Effect of Dormancy-Breaking Agents

The effects of the interaction between strangulation and dormancy-breaking agents on the number of fruits, leaf carbon content at 64 days after treatment, and leaf C/N ratio at 64 DAT are presented in Tables 4 and 5. Table 4 also indicates that strangulation affects the

number of fruits, influenced by dormancy-breaking agents. While strangulation itself can increase the number of fruits (P0), strangulation with Ethepon (P2) is more effective than the only strangulation treatment. The higher fruit yield is due to the increased number of flowers in the interaction treatment of strangulation and Ethepon.

Increased number of flowers and fruits aligns with [11] who stated that strangulation can increase the number of flowers and fruits in citrus plants compared to other treatments (control, prohexadione-Ca, and paclobutrazol). Strangulation treatment on 'Kristal' guava plants can produce a higher number of flowers compared to without strangulation treatment [12]. Ethepon at 100 ppm also found significantly affects the number of male flowers in watermelon plants, while Ethepon at 200 ppm can enhance female flower formation in watermelon [13].

Table 5 shows that there is an interaction effect between strangulation and dormancy-breaking agents on leaf carbon content at 64 days after treatment. In the non-strangulation treatment (S0), the carbon content with KNO_3 (P1) and Ethepon (P2) shows significant differences. In single strangulation (S1) and double strangulations (S2) treatments, the carbon content didn't show any significant differences with or without dormancy-breaking agents. Strangulation of Siompu citrus plants leads to inhibition of carbohydrate translocation from leaves to other plant organs [14]. This inhibition causes carbohydrate accumulation in the strangulation area, while in non-strangulated plants, there is no such a accumulation.

The C/N ratio represents the ratio of carbon (C) to nitrogen content in an organic material [10]. Table 5 shows that there is an interaction effect between strangulation and dormancy- breaking agents on the C/N ratio. In non-strangulation treatment (S0), dormancy-breaking agents affect leaf carbon content. In single strangulation (S1) and double strangulations (S2), dormancy-breaking agents didn't affect leaf carbon content. In non-strangulation treatment (S0), the highest number of flowers were achieved from Ethepon (P2), while in single strangulation treatment (S1), the highest number of flowers were achieved with KNO_3 (P1).

Strangulation is an effective method to induce flowering in pomelo citrus plants, as indicated by higher carbohydrate levels in the canopy, which can enhance the C/N ratio [15].

Table 4. Effect of dormancy-breaking agents on the number of flowers, fruits, fruit set, flower drop, fruit drop, and C, N, and also C/N ratio at 32 and 64 days after application

Number of fruit			
Treatment	Dormancy-breaking agents		
Strangulation	P0	P1	P2
S0	15,00a A	54,33b B	10,33a A
S1	55,67a B	42,67a A	70,33a B
S2	61,33b B	15,00a A	81,50b B

Note : Numbers in a column followed by different uppercase letters indicate significant differences in the DMRT 5% post hoc test; numbers in a row followed by different lowercase letters indicate significant differences in the DMRT 5% post hoc test

Table 5. The effect of interaction between strangulation and dormancy-breaking agents on carbon content and C/N ratio at 64 days after treatment (DAT)

Leaf carbon content 64 DAT				C/N Ratio		
Treatment	Dormancy breaking agent			Dormancy breaking agent		
Strangulation	P0	P1	P2	P0	P1	P2
S0	32,80a A	41,73b B	43,63b B	19,10a A	24,37b AB	27,26b A
S1	41,52a B	40,05a AB	36,32a A	23,48a AB	27,42a B	23,14a A
S2	36,09a AB	35,17a A	39,30a AB	24,85a B	21,59a A	24,11a A

Note : Numbers in a column followed by different uppercase letters indicate significant differences in the DMRT 5% post hoc test; numbers in a row followed by different lowercase letters indicate significant differences in the DMRT 5% post hoc test.

This study shows that Chokun citrus plants can be induced to flower through the application of strangulation and ethephon. Strangulation can inhibit the transfer of photosynthetic products from the upper parts of the plant to the roots, which can lead to an increase in carbohydrate accumulation in the canopy. Ethephon acts as a dormancy-breaking agent, which helps to induce flower bud formation. This success is consistent with the research by [13] which demonstrated that the application of ethephon at a concentration of 100 ppm significantly affected the number of male flowers in watermelon plants, and the application of ethephon at a concentration of 200 ppm increased the formation of female flowers in watermelon plants.

The increase in the C/N ratio is due to the high carbon content and low nitrogen content. According to [11], this is caused by strangulation, which inhibits the transfer of photosynthetic products from the upper parts of the plant to the roots. This inhibition causes the roots to lack photosynthates and decreases root respiration, disrupting the roots' ability to absorb nutrients and water, thus inhibiting vegetative growth and increasing carbohydrate content in the leaves. This is consistent with [15] which states that strangulation treatment can increase carbohydrate content in the plant canopy, and eventually increasing the leaf C/N ratio. Additionally, [12]strangulation can increase carbohydrate content and the C/N ratio.

4 Conclusion

1. Strangulation has a positive effect on increasing the yield variables of Chokun mandarin oranges, with the best treatment being double strangulation for the variable of fruit number and leaf carbon content at 32 days after treatment (DAT).
2. The application of dormancy-breaking agents does not affect any of the observed variables
3. The combination of double strangulation and the dormancy-breaking agent ethephon at 150 ppm is the best combination for increasing the number of fruits.

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