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Increasing yield and quality of citrus by pruning and fertilization

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Abstract

Pruning and fertilization are factors that can determine the production and quality of citrus. The objective of this study was to determine the effect of pruning intensity and fertilizer doses of N (nitrogen), P (phosporus), and K (potassium) on citrus production and quality. The study was carried out in a citrus orchard in Central Java, Indonesia, over the course of two seasons, 2016-17 and 2017-18. The experiment was conducted as a two-factorial, completely randomized block design where the first factor was pruning intensity, namely 0, 5, 10, and 15 % of the total number of branches per tree while the second factor was doses of N, P, and K fertilizers, namely 0, 2, and 4 % of the weight of harvested citrus fruit in the previous season. The result showed that increasing doses of N, P, K fertilizers from 0 to 4 % increased fruit-set, harvested fruits, fruit size, content of vitamin C, sugar, and soluble solid. The highest fruit-set, weight of harvested fruits, and content of vitamin C were achieved by pruning intensity of 10 %.

Key words: *Citrus nobilis* L., pruning intensity, doses of N, P, K fertilizers, sugar

Introduction

Citrus (*Citrus nobilis* L.) is a familiar temperate fruit that contains a variety of vitamins, minerals, fiber, and phytochemicals such as carotenoids, flavonoids, and limonoids, which appear to have biological activities and health benefits (Berk, 2016). There is considerable evidence that citrus fruit has antioxidant and antimutagenic properties and a positive association with the health of bones, cardiovascular and immune systems (Codoňer-Franch and Valls-Bellés, 2010). Citrus consumption might improve indices of antioxidant status, and possibly cardiovascular health and insulin sensitivity (Turner and Burri, 2013).

One of the most important ways to maintain the health of a tree is pruning because it effects the tree's health and structure (Clark and Matheny, 2010). Pruning can improve photosynthesis by improving sunlight penetration (Taiz and Zeiger, 2010; Sharma *et al*., 2006), so it can produce more flowers and fruits (Ghosh *et al*., 2016; Santoso, 2012; Willaume *et al*., 2004). Pruning is a cultivation technique that allows a farmer to form and arrange the plant canopy to effectively produce flowers and fruits (Santoso, 2012). Not only does sunlight influence flowering and fruit-set, but it also influences fruit quality and color development (Dhaliwal *et al*., 2014; Abobatta, 2019). Pruning application is important to control the shape and health of tree and to stabilize fruit production (Dhillon and Thakur, 2014). There are not many studies on appropriate pruning intensity for citrus. Susanto *et al*. (2019) said that the objective of pruning is to increase the sunshine penetration on the inner side of the canopy by at least 30 %. This sunshine penetration was achieved by pruning 10 % of the total number of branches in every tree. Based on the total number of branches, the branches were pruned from the top to the inner side, allowing sunlight to penetrate better to the inner side of the shoot.

According to Abobatta (2018), fertilization is a cultivation technique used to improve soil nutrient availability in order to maximize yield. Fertilization will directly affect the growth, fruit-set, retention yield and quality improvement and sustainable production of Kinnow orchards (Huang *et al*., 2014; Yasseen and Manzoor, 2010). Macronutrients, particularly N, P, and K, are needed by citrus plants in large quantities, and play an important role in fruit yield and quality (Srivastava and Singh, 2009). Generally, farmers apply the fertilizer to citrus trees based on common recommended dose, not yet based on the lost nutrients due to harvesting. Sutopo (2011) stated that one of the aims of applying fertilizer is to replace lost nutrients at harvest. The average dose of fertilizer application for citrus (*C. nobilis* 'Pontianak') is 2-3 % of the weight of harvested citrus fruit and added nutrients are in the form of 10 N: 7 P_2O_5: 2 K_2O. The objective of this research was to identify the best pruning intensity and doses of N, P and K fertilizers for higher yield and quality of citrus.

Materials and methods

The experiment was conducted in a citrus orchard (60 m asl, 7.44° S and 109.43° E) in Kembangan Village, Bukateja District, Purbalingga Regency, Central Java, Indonesia. The study was conducted from June 2016 until June 2018. The average monthly rainfall was 142.15 mm, the average air temperature was 24-37 °C, and there were 7 sunshine hours per day (data from a local meteorological station). We used 36 four-year-old *C. nobilis* 'Pontianak' trees in both seasons. All trees had uniform growth, age, and cultivation techniques.

There were two factors arranged in a completely randomized block design. The first factor was pruning intensity, 0, 5, 10, and 15 % of the total number of tertiary branches per tree; the second one was doses of N, P, and K fertilizer: 0, 2, and 4 % of the weight of harvested citrus fruit per tree in the previous season (about 20 kg). There were 12 treatment combinations with three replications, so 36 trees in total.

At first, the total number of branches of every tree was counted. There was an average of 250 branches per tree. All treatments were adjusted for the same number of branches, and the selected tertiary branches (diseased, damaged, non productive, or structural unsound) were cut or pruned using shears. Branches were pruned in June of 2016 and 2017.

We applied N, P_2O_5, and K_2O as urea (PT Pupuk Sriwidjaja, Palembang, Indonesia), SP36 (PT Petrokimia, Gresik, Indonesia), and ZK (PT Petrokimia), respectively. For a 5 % fertilization dose, we added the following nutrients per tree: 20 kg × (0.05 × 10:19) or 526.32 g N, 20 kg × (0.05 × 7:19) or 368.42 g P_2O_5, and 20 kg × (0.05 × 2:19) or 105.26 g K_2O per plant. In the same way, 1,052.64 g N, 736.84 g P_2O_5, and 210.52 g K_2O were added for a fertilization dose of 10 %, and 1,578.96 g N, 1,105.26 g P_2O_5, and 315.78 g K_2O for a fertilization dose of 15 %. Initially, fertilizer was dissolved in 3 litres of water then poured on the soil surface around the base of the stem of each citrus tree. Fertilizer was applied twice: 50 % one month after pruning, and the remainder one week later. No serious pests or diseases were detected, so no control sprays were applied. Furrow irrigation was used to water citrus trees.

Several fruit yield variables were observed: 1) fruit-set (ratio between the number of fruits formed and the number of flowers of the same tree); 2) number of harvested fruits per tree; 3) weight of harvested fruits per tree; 4) fruit drop. The fruit quality variables observed were:1) average weight per fruit; 2) average fruit diameter; 3) content of vitamin C, which was measured using a titration method with 0.01 N iodine solution; 4) total acid was measured using a titration method with 0.1 N NaOH solution; 5) sugar content (^{o}Brix) was measured by a hand refractometer (Atago N-1, Saitama, Japan); 6) content of soluble solids, which was measured by an electrical conductivity method (TDS 6 + TDS/Temp, Eutech Instruments Pte Ltd., Singapore). Data was analyzed by ANOVA with SAS version 9. Means were separated through Duncan's Multiple Range Test at P=0.05.

Results and discussion

Immediately after pruning the branches, light intensity was measured at a depth of about 20 cm in the canopy for every pruning intensity with a LX-101 A light meter (Lutron Electronic Enterprise Co. Ltd., Taipei, Taiwan). Light intensity of 0, 5, 10, and 15 % pruning intensity was about 125, 465, 780, and 1550 μmolm^{-2} s^{-1}, respectively.

Fruit-set and fruit drop: Increasing the N, P, and K fertilizer doses from 0 to 4 % increased fruit-set for all pruning intensities (Fig. 1**).** This result indicates that a high dose of N, P, and K fertilizers is required for high fruit-set. When N, P, and K fertilizers were applied at a rate of 4 %, fruit-set increased by approximately 63.61 % as compared to when these fertilizers were not applied.This result is similar to Ramadhan *et al*. (2015) who reported that the highest fruit-set (93 %) of *C. sinensis* Osbeck was achieved by application of high dose of N, P, and K fertilizer (400 g per plant). Nainggolan (2007) stated that the increase of

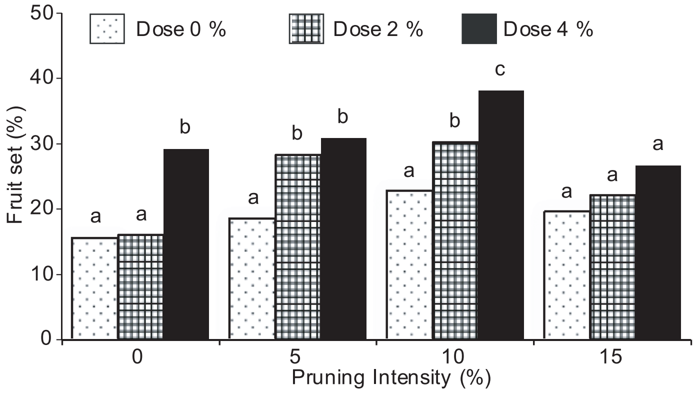

Fig. 1. Fruit-set as affected by the dose of N, P, and K fertilizers at different pruning intensity. Each value is the mean of three replicates. Mean values with the same letter are not significantly different at P=0.05 by the Duncan's Multiple Range Test

fertilization doses from 0 to 3 % (based on weight of harvested fruits per tree in the previous season) increased the yield of citrus fruits. It means that increasing fruit-set by improving nutrient status in the plant through fertilizer application. According to Iglesias *et al*. (2007), nutritional status influences flower formation and development, and thus citrus fruit-set. Patil *et al*. (2018) added that increased fruit-set could be due to increased flower production. Pruning with a 10 % intensity increased fruit-set by 49.55 % when compared to pruning with a 0 % intensity. According to Dhillon and Thakur (2014), one of the goals of pruning is to increase fruit-set. Susanto *et al*. (2019) reported that pruning by leaving 4 and 8 pairs of leaves increased fruit number by 85.22 and 50.74 %, respectively, compared to control plants that only produced 20.3 fruits per plant. According to Willaume *et al*. (2004), sunlight received by pruned apple plants increased so it could stimulate the growth of new shoots. Fig. 2 shows that the increase in doses of N, P, and K fertilizers decreased the fruit drop of citrus. Application of 4 % N, P, and K fertilizers reduced

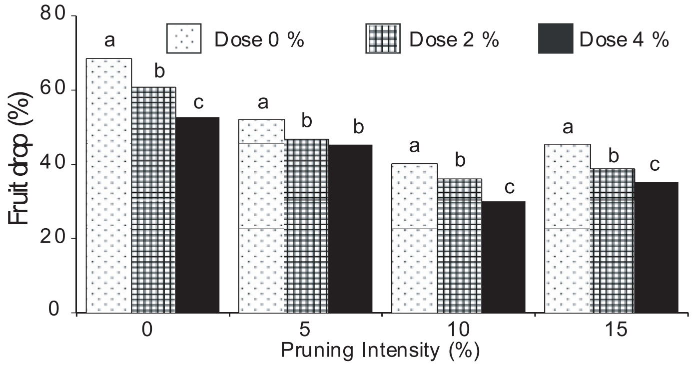

Fig. 2. Fruit-drop as affected by the dose of N, P, and K fertilizers at different pruning intensity. Each value is the mean of three replicates. Mean values with the same letter are not significantly different at P=0.05 by the Duncan's Multiple Range Test

fruit drop to 19.51 % compared to no application of N, P, and K fertilizers. Saleem *et al.* (2005) recorded minimum fruit drop in trees of *C. reticulata* Blanco fertilized of N, P, and K with a higher dose in two splits (3.0 kg).

The number and weight of harvested fruits: The application of higher doses of N, P, and K fertilizers increased fruit-set, which was followed by an increase in the number of harvested fruits (Fig. 3) and weight of harvested fruits (Fig. 4). Our results are similar to the results of Dubey and Yadav (2003), who showed that the highest yield (163.3 kg per tree or increased 150 % compared

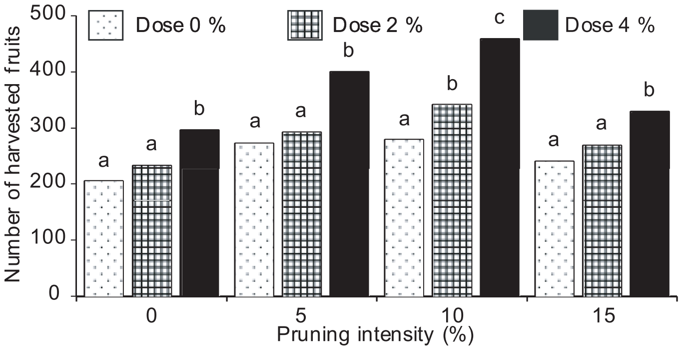

Fig. 3. Number of harvested fruits as affected by the dose of N, P, and K fertilizers at different pruning intensity. Each value is the mean of three replicates. Mean values with the same letter are not significantly different at P=0.05 by the Duncan's Multiple Range Test

to control) of 'Khasi' mandarin was obtained at high doses (110 kg of pig manure + 750 g of N + 650 g of K_2O). Nainggolan (2007) showed that the highest yield (60.10 kg per ha) of citrus *cv.* Siam Madu was obtained at a dose of 3 % of the weight of harvested fruits per tree in the previous season. Amina *et al.* (2018) reported that the more 'Kinnow' mandarin fruits per tree was achieved by a higher dose of fertilizers (250 g P_2O_5 + 150 g K_2O; 200 g P_2O_5 + 250 g K_2O). Li *et al*. (2017) found that the fruit yield of *C. grandis* 'Longanyou' was positively correlated with leaf nutrients of N, P, and K with a correlation coefficient of 0.472, 0.529, and 0.727, respectively. This study found that applying 4 % N, P, and K fertilizers increased the number and

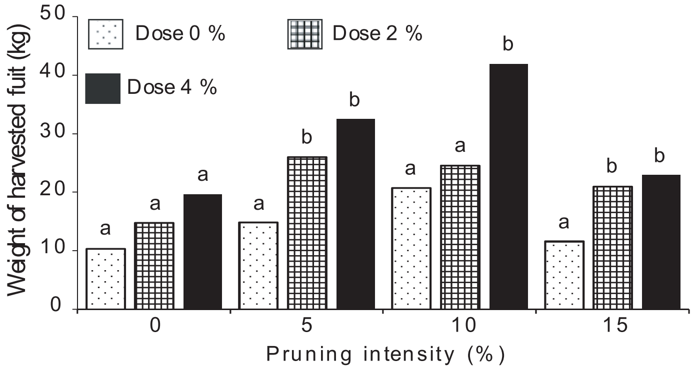

Fig. 4. Weight of harvested fruits as affected by the dose of N, P, and K fertilizers at different pruning intensity. Each value is the mean of three replicates. Mean values with the same letter are not significantly different at P=0.05 by the Duncan's Multiple Range Test

weight of harvested fruits by 49.01 and 102.89 %, respectively, when compared to not applying these fertilizers.Application of 10 % pruning intensity increased the weight of harvested fruit by about 94.72 % compared to control (without pruning).

Fruit size: Increase in dose of N, P, and K fertilizers increased weight per fruit (Fig. 5) and fruit diameter (Fig. 6) for every pruning intensity. Dhillon and Thakur (2014) stated that pruning not only influences flowering and fruit-set but also enhances the fruit quality such as fruit size and content of sugar by increasing the photosynthetic surface. Astiari *et al*. (2019) added that pruning increased weight per fruit and total sugar content because there are more allocated photosynthate for growth and fruit development. By application of 4 % N, P and K fertilizers in this research, weight per fruit and fruit diameter was increased by about 31.17 and 37.90 %, respectively.

Fruit nutrition: content of vitamin C (Fig. 7) and sugar (Fig. 8) increased by application of N, P, and K fertilizers. The application

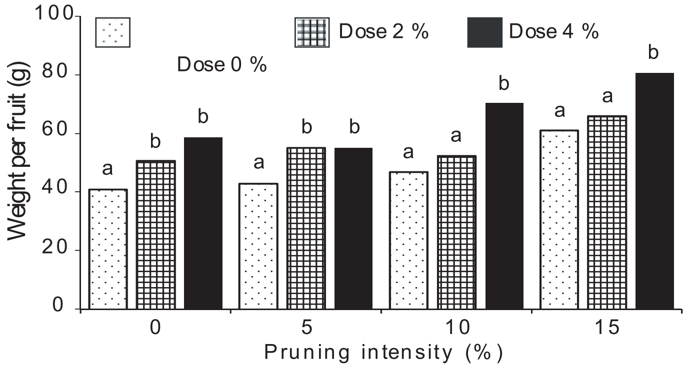

Fig. 5. Weight per fruit as affected by the dose of N, P, and K fertilizers at different pruning intensity. Each value is the mean of three replicates. Mean values with the same letter are not significantly different at P=0.05 by the Duncan's Multiple Range Test

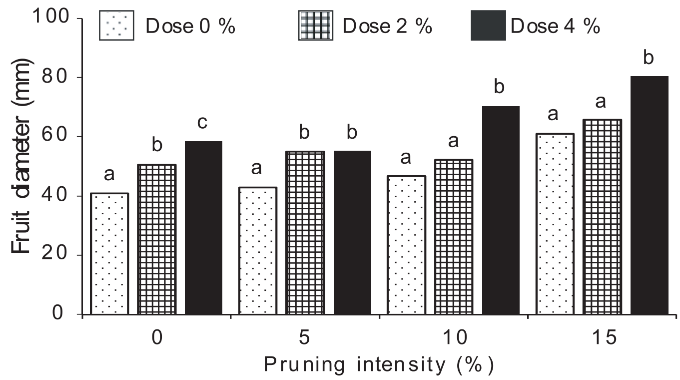

Fig 6. Fruit diameter as affected by the dose of N, P, and K fertilizers at different pruning intensity. Each value is the mean of three replicates. Mean values with the same letter are not significantly different at P=0.05 by the Duncan's Multiple Range Test

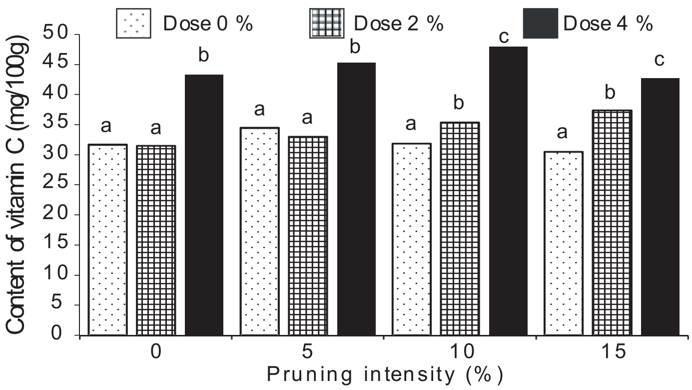

Fig. 7. Content of vitamin C as affected by the dose of N, P, and K fertilizers at different pruning intensity. Each value is the mean of three replicates. Mean values with the same letter are not significantly different at P=0.05 by the Duncan's Multiple Range Test

of 4 % N, P, and K fertilizers increased the content of vitamin C and sugar by 28.27 and 12.43 %, respectively, when compared to no N, P, and K fertilization.These increases are similar to those reported by Han *et al*. (2008), where proper application of N, P, and K fertilizers can significantly increase the content of sugar by 15-30 % and vitamin C by 13-57 %.

Lee and Kader (2000) reported that cultural practices such as pruning can influence the nutritional composition of fruits. Li *et al*. (2017) reported that the content of vitamin C and total sugar was positively correlated with leaf nutrients, particularly K, with a correlation coefficient of 0.380 and 0.451, respectively. According to Aular *et al*. (2017), K was the element that had the greatest influence on fruit characteristics. Aular *et al*. (2010) reported that

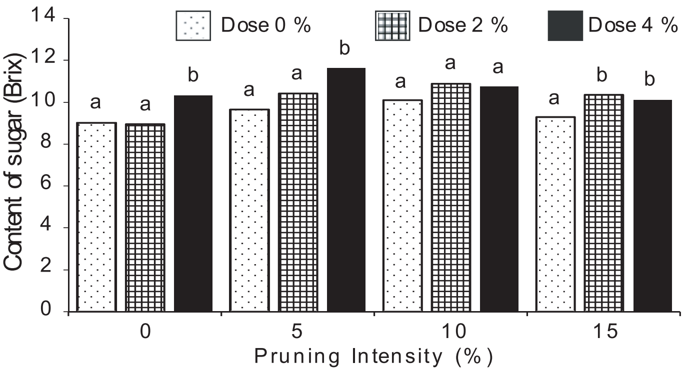

Fig. 8. Content of sugar as affected by the dose of N, P, and K fertilizers at different pruning intensity. Each value is the mean of three replicates. Mean values with the same letter are not significantly different at P=0.05 by the Duncan's Multiple Range Test

soil and leaf K content were associated with rind, fresh mass, and juice percentage. Obreza (2003) stated that potassium is necessary for basic physiological functions such as formation of sugars and starch, synthesis of proteins, and cell division and growth. This research also shows that application of 10 % pruning intensity increased the content of vitamin C by about 7.50 % compared with control.

The increase in content of vitamin C and sugar by application of 4 % N, P, and K fertlizers was followed by the increase in content of soluble solids (Fig 9). A similar result was reported by El-Aidy *et al*. (2018). Application of N, P, and K fertilizers increased the content of soluble solid compared to control. Nitrogen and

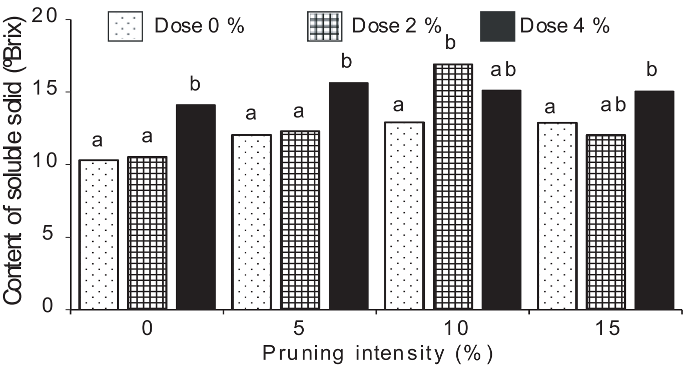

Fig. 9. Content of soluble solid as affected by the dose of N, P, and K fertilizers at different pruning intensity. Each value is the mean of three replicates. Mean values with the same letter are not significantly different at P=0.05 by the Duncan's Multiple Range Test

potassium play an important role in the process of carbohydrate storage, so they increase the content of soluble solids.

Fertilizer doses of N, P and K, as well as pruning intensity, had no effect on the total acid. Amina *et al*. (2018) noticed that total soluble solids/acid ratio were not affected by fertilizer dose. Application of pruning of 0, 5, 10, and 15 % gave content of total acid of 0.16, 0.15, 0.14, and 0.14, respectively. Li *et al*. (2017) noted that total soluble solid (TSS) and total acid content were not significant correlated with leaf nutrient N, P, and K rate. Moreover, Susanto *et al*. (2019) reported that TSS and total acid content in guava were not affected by pruning.

Overall, this study shows that application of appropriate pruning intensity and dose of N, P, and K fertilizers increased the yield and quality of citrus. Similarly to what Li *et al* (2019) found, N, P, and K fertilizer, as well as their interaction, have a significant impact on citrus yield and quality. Saleem *et al*. (2005) added that application of fertilizer significantly affected leaf N, P, and K content. Fertilizer application is very important for improving the nutrient status of citrus trees (Alva *et al*., 2006; Zhao *et al*., 2013).

Increasing doses of N, P and K fertilizers from 0 to 4 % increased fruit-set, harvested fruits, fruit size; content of vitamin C, sugar, and soluble solid. The highest fruit-set, weight of harvested fruits, and content of vitamin C were achieved by pruning intensity of 10 %. Pruning intensity and doses of N, P, and K fertilizers did not influence the content of total acid.

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