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Yield and yield components of superior cocoa (*Theobroma cocoa* L.) clones rejuvenated by ring budding technique

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Abstract

The ring budding technique gave a higher suitability for rejuvenation of cocoa plants compared to side cleft grafting it can be combined with the use of superior clones for optimal production. However, information related to this is still limited. The research aimed to determine the effects of ring budding technique on yield components and yields of three types of superior cocoa clones. The experiment was arranged in a Nested Design. The first factor is the type of vegetative propagation technique, consisting of side cleft grafting and ring budding. The second factor was clones, which consisted of clones KKM 22, RCC 70 and RCC 71. Clones were nested in vegetative propagation. The research was conducted from September 2020 to January 2021 at the Pagilaran Company. Observations were made on several yield component variables. The data were analyzed using Analysis of Variance (ANOVA) and continued with the Least Significant Difference Test (LSD) at the 5%. The results showed that the number of pods and the weight of beans per cocoa stand were significantly higher in the ring budding technique than the side cleft grafting. This condition caused the dry bean weight per hectare much higher as well. The three cacao clones, which were rejuvenated by ring budding, gave a good response and high yields. Meanwhile, only KKM 2 gave good response and high yield after treated with side cleft grafting technique, while RCC 70 and RCC 71 clones gave low yields. The KKM 22 clone is the best option in terms of rehabilitation with ring budding and side cleft grafting.

INTRODUCTION

Cocoa (*Theobroma cocoa* L.) is one of the mainstay commodities of cultivation which role is quite important for the nation's economy, especially as employment provider, source of income and country's foreign exchange. Moreover, cocoa also plays a role in improving the growth of regions and agro-industry improvement. In 2020, cocoa plant had provided employment and source of income for around 900 thousand families of framers, which most of them were located in the East Indonesia Region (EIR). It also supplies the biggest contribution of foreign exchange to these sub-sectors of cultivation after rubber and palm oil by the US $701 million (Departemen Perindustrian, 2007).

Within the period of 2015-2019, the average cocoa productivity in Indonesia only reached around 700kg/ha/year when it potentially can reach up to 3000kg/ha/year (Direktorat Jenderal Perkebunan, 2019). Several factors caused the low productivity of cocoa in Indonesia, such as planting material, not optimized fertilization, old stands, pest and disease infestation, and lack of quality of cultivation technology used (Wahyudi et al., 2008).

Ring budding is a technique of vegetative propagation by joining parts of two plants in a ring-like (circular) motion. This technique utilizes vigorous orthotropic shoot as root stock, which appears from the main stem. This helps trees to adapt and grow faster. Putra et al. (2012) mentioned that the ring

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budding of cocoa had success rate up to 91.38%. Furthermore, Aikpokpodion and Dongo (2010) stated that the production of cocoa seedlings by ring budding technique showed success rate up to 68.88% due to its technique covering wide entire cuts circling in the rootstock compared to other vegetative propagation techniques such as grafting (26–78%), shoot-tip grafting (38–62%), and cutting (24–52%). Another technique for rehabilitation is side cleft grafting. Limbongan (2007) mentioned that side cleft grafting technique is commonly applied by cocoa farmers who are unwilling to replace old stands with new one. This is because farmers still produce cocoa pod within the rehabilitation process.

Clone KKM 22 is a superior fine clone that belongs to the Trinitario. Indonesian fine cocoa is well known as Java Fine – Flavor Cocoa, one of the highest priced cocoas in the world. Though this fine cocoa has higher grade, it is one of those vulnerable cocoa when compared to bulk cocoa (Devy et al., 2018). Clone RCC 70 and RCC 71 are superior bulk clones that belong to the Forastero. Forastero is produced and sold higher compared to Criollo and Trinitario (Martono, 2014).

The utilization of superior planting materials and vegetative rejuvenation techniques are expected to improve the productivity and quality of cocoa stands. The success rate of attaching scion to rootstock in ring budding and side cleft grafting are determined by the ability of cell in producing new cells and functional tissues within wounded area. Tirtawinata (2003) mentioned that process of linking attached parts of stand started from responses of cells and tissues on the wound (grafted) area. The cutting on grafted tissue caused several parenchyma (on scion and rootstock sides) to damage and die, which then formed necrotic tissues. These necrotic tissues act as isolation layer that avoid contamination or infections on scion and rootstock. Other cells located below necrotic cells undergo hypertrophy. The cells experience division and enlargement until exceeding normal size, followed by hyperplasia or large number of cell divisions to form callus. Subsequently, vascular cambium forms callus, which develops inward to form xylem and outward to form phloem (Ramdhini et al., 2021). Zaubin and Suryadi (2002) state that grafting process requires energy. The role of main stem in photosynthesis determines success rate of ring budding and side cleft grafting. There has been limited information regarding the effects of grafting technique and clones on the yield components and yields of new stands. Therefore, this research was conducted to determine the effects of grafting technique and clones on the yield performances of cocoa stands.

MATERIALS AND METHODS

This research was conducted from September 2020 to February 2021 at Production Unit of North Segayung, Pagilaran Company, Batang Regency, Central Java Province. The research was arranged in a nested design. There were two factors tested, consisting of grafting techniques and cocoa clones. Grafting techniques include side cleft grafting and ring budding, while cocoa clones include KKM 22, RCC 70, and RCC 71. The cocoa tree used in this research is rejuvenated cocoa tree with age of 10 years. Thus, the observations were made only on a few yield component variables and not plant growth. The observed variables include the percentage of flowers into harvested pod, total number of pods per stand, weight of beans per stand, weight of 100 beans, and beans weight per hectare. Percentage of flowers into harvested pod could be obtained from the number of pods per stand divided by total flowers per stand, which was then multiplied by 100. Total number of pods per stand were calculated based on yields achieved by each stand. As for weight of beans per stand, harvested fruits were each sliced open in half and dried until it reached more or less 7.5% of water content. The dried beans were then weighed. The weight of 100 beans were obtained by collecting 100 beans randomly from total of all existing beans yielded by stand and then weighed. Finally, bean yield per hectare was obtained by multiplying weight of bean per stand with total number of stands per hectare. Meanwhile, the soil fertility variables consist of soil chemical properties. Soil chemical properties consist of organic C, pH, content of total N, P, K, Ca, Mg, B and content of available of P.

The yield components and yield data were analyzed by Analysis of Variance (ANOVA) and continued with the Least Significant Difference Test (LSD) at the 5% level if there was a significant difference between treatments. Data analysis was performed using the PROC GLM and PROC MIXED with the SAS 9.4 Software.

RESULTS AND DISCUSSION

Percentage of flowers into harvested pod (%)

According to Table 1, the percentage of flowers into harvested pod was not affected by rehabilitation technique. Rejuvenated cocoa trees through ring budding technique had similar percentage of flowers into harvested pod if compared to side cleft grafting. The occurrence of fertilization causes the ovary to develop into fruits and ovule into seeds. The zygote within a seed also develops into the embryo. At the same time, flower undergoes changes, which leads to the development of ovary into fruit (Hidayat, 1995). Bigger percentage of flowers into harvested pod means more pods are formed. Rejuvenation techniques create a good attachment between upper and lower stem. After the attachment is stable, the cocoa tree shows high possibility to produce high content of gibberellic acid (GA3), which play important roles in maintaining the juvenile characteristics of plants (Lu et al., 2022). Some roles of gibberellin are cell division triggering, flowering, and development of fruits. According to Mog et al. (2019), gibberellin plays a role in mobilizing carbohydrate in plants and can also transform carbohydrates into glucose. The advantage of ring budding is that it can be done in meristematic tissue, whereas the side cleft grafting only can be done in mature tissue. This condition makes the attachment formed in ring budding tissue produce more gibberellin than in side grafting. The better production of gibberellin makes the plant become healthier and mature faster. Ring budded cocoa trees produce more branch and leaves than side cleft grafted cocoa trees. The higher number of productive branches means higher photosynthetic capacity of the trees. This effect is shown in the percentage of flowers into pods (Table 2), number of pods, bean weight, and productivity.

Table 1 shows there is no significant difference effect of ring budding and side cleft grafting in all clones on the number of fruits formed. This condition could happen due to the side cleft grafting technique, in which although many cherelles were formed, many eventually wither and did not develop into fruit. The development of cherelles is affected by the chemical properties of the soil. The micronutrients status in the field experiment is high to very high, whereas the macronutrients status varies. Total nitrogen and phosphorus in the soil is low, whereas the content of potassium, calcium, magnesium, and sulfur is high. Ovaries failure to become fruit is most likely due to low nitrogen and phosphorus content in the soil. Nitrogen and phosphorus are important for plants to carry out photosynthesis and distribute energy for fruit formation. In accordance with research conducted by Lokhande et al. (2015), the higher N and P content in the soil led to an increase in yield in coriander plants. Phosphorus is a vital component of ATP, the energy unit of plants. ATP forms during photosynthesis, has phosphorus in its structure, and processes from the beginning of seedling growth through to the formation of pods and maturity (Nurafiza et al., 2017). The condition of low availability of phosphorus is aggravated by the possibility of low auxin hormone in plant tissue. According to Rismunandar (1988), the reduction or absence of auxin production by endosperm can cause cell tissues formation located between pedicel and tree branch which produce layers separating both sides. Abscission layer cut connection between stand (branches) with pods, causing dwarf fruits and gradually dries out and dies.

Amaru (2013) showed that sprouting had very close relation with fruits. Tutiliana (2014) states that

Table 1. The percentage of flowers into harvested pods of some cocoa clones which had been rejuvenated by both ring budding and side cleft grafting techniques

Treatments	Rejuvenation techniques	
Clone	Ring budding	Side cleft grafting
KKM 22	17.60 a	20.59 a
RCC 70	29.62 a	14.85 a
RCC 71	25.73 a	17.05 a
Average	24.32 a	17.50 a
Coefficient of variance (%) = 32.80		

Remarks: means in one column followed by similar letters show no significant differences among treatments (LSD test at α = 5%). Data were transformed into $\sqrt{(x+0.5)}$.

fruit is organ that requires most assimilate support to grow and develop. The more flower means the more fruits set, which also means more competitors to get assimilate and nutrient to form fruits. Both rejuvenation techniques have similar respond, which gives no impact toward stand. Flower forming into fruits were not proportional toward carrying capacity of plants. Limited amount of assimilate was not available for fruit growth, causing flower drop. There were no data recorded for any physiological activity of rejuvenated plants, including photosynthetic and net assimilation rate to support this condition.

According to Table 1, the percentage of flowers into harvested pod in on all tested clones was almost the similar in both rejuvenated by side cleft grafting and ring budding technique. These results identify that all tested clones in this research had an equivalent capacity value of the percentage of flowers into harvested pod. Aneja et al. (1999) mentioned that rate incidence of flower transforming into pod on cocoa reached only up to 0.5–5%, identified as very low percentage. Moreover, Citrosupomo (1989) and Pangaribuan (2004) explained that cherelle wilt could reach up to 70–80% from the whole total of formed fruits. Schnappinger et al. (2003) and Prawoto (2014) reported that only 32.9% of flowers became harvested pod. Possible concerns to increase the percentage of flowers into pods were pest infestation, cocoa fruit and peel borer, as well as pathogen as cause of diseases such as rotten fruit from the *Phytophthora palmivora*.

The high rate of failure in developing flowers into pods begins from the failure of its flower development into ovary, where cocoa flowers have relation with incompatibility behavior. Pollen from cocoa stands owns characteristics of resinous, sticky, and hidden within staminode. Cocoa flower is protogynous, meaning that pollen ripens and blooms earlier than pistil. These flowers of cocoa do not contain honey and are odorless, causing difficulties in attracting pollinator insects. In addition, the position of these flowers is facing downwards with its pistil-tip higher than the staminode, which gives small chance for pollen to fall onto stigma (Prawoto, 2014).

Total number of pods per stand

Table 2 shows that technique of rejuvenation gives impact on the number of fruits per stand. Ring budding technique caused cocoa stand capable to produce higher number of pods per stand compared to side cleft grafting. This indicates that cocoa stands produced by ring budding technique have better capacity in producing pods. The higher number of pods in ring budded cocoa trees are in accordance to high content of soil potassium (Table 3). High amount of potassium can increase cocoa yields because it helps translocate sugars and starches to the pods. Potassium application can increase the number of fruits and the weight of Japanese pear (Shen et al., 2016). As addition, ring budded cocoa trees mature early and possibly has higher amount of gibberellin hormones. Gibberellin produced by ring budded cocoa trees is used for flowering initiation and mobilization of carbohydrates.

Pods were results of pollination process. In process of pods formation, besides pod sets, some parts of flower grow along and become part of pod. Directly after fertilization, parts of flower (apart from ovary) will wither, dry and fall off (Ramdhini et al., 2021). The availability of Zn and B nutrients were very high in research site (Table 3), which were optimally absorbed by roots to be then utilized to form cocoa pods. Providing multi-micro (including those consisting Zn and B nutrients) NAA can decrease amount of cherelle wilt, maintain the number of healthy ovaries and increase the number of seed per pod, increase weight of 100 dry beans, increase dry bean yield per

Table 2. Number of fruits from several cocoa clones rejuvenated by ring budding and side cleft grafting techniques

Treatments	Rejuvenation techniques	
Clone	Ring budding	Side cleft grafting
KKM 22	48.00 a	40.00 a
RCC 70	36.00 a	20.00 b
RCC 71	54.67 a	24.00 b
Average	46.22 a	28.00 b
Coefficient of variance (%) = 25.08		

Remarks: means in one column followed by similar letters show no significant differences among treatments (LSD test at α = 5%). Data were transformed into √(x+0.5).

Table 3. Chemical properties of cocoa plant soil by rejuvenating ring budding and side grafting

Test parameters	Value in ring budding block	Category	Value in side grafting block	Category
pH	5.36	Slightly sour	5.46	Slightly sour*
Organic C (%)	1.25	Currently	1.20	Currently*
Total N (%)	0.17	Low	0.19	Low*
P Availability Bray (ppm)	2.57	Very low	6.87	Low*
CEC (cmol(+)kg^{-1})	13.29	Low	13.48	Low*
Total Potassium (ppm)	413.01	Very high	261.17	Very high*
Calcium Total (%)	0.045	Very high	0.09	Very high*
Total Magnesium (%)	0.04	Very high	0.05	Very high*
Total Iron (ppm)	40009.57	Tinggi	42116.06	High*
Total Manganese (ppm)	533.51	Very high	957.41	Very high*
Total Zinc (ppm)	46.36	Very high	55.29	Very high*
Total Copper (ppm)	33.39	Very high	38.01	Very high*
Total Sulfur (%)	Tt	Tt	0.05	Very high*
Total Boron (ppm)	47.91	Very high	53.08	Very high*

Remarks: *) Categories are based on Soil Research Institute (2009).

hectare, and increase the number of cocoa pods per stand that could be harvest. On the other hand, gibberellin, one of hormones also gave impact on fertilization. According to Pardal (2001), addition of gibberellins accelerated crops to grow more pods (Puslitkoka, 2010).

Table 2 also shows that the number of cocoa pods produced are influenced by cocoa clones, especially the stands rejuvenated by side cleft grafting technique. Meanwhile, rejuvenation of each tested clones by ring budding technique was able to produce same number of fruits per stand. KKM 22 clones produced a higher number of cocoa pods per stand compared to RCC 70 and RCC 71 clones. According to Rismunandar (1988), reduction or absence of auxin production by endosperm can cause cell tissues formation located between pedicel and branch, which produce layers separating both sides. Abscission layer between branches and pods causes dwarf fruits, which and gradually drys out and die.

Weight of 100 dry beans

Table 4 shows that weight of 100 dry beans are not affected by rehabilitation technique. Rejuvenated cocoa stand by ring budding technique had same weight of 100 dry beans to those rejuvenated by side cleft grafting. This indicates that growth capacity of weight of 100 dry beans were similar in both ring budding and side cleft grafting techniques. Seeds are main reproduction tool because they contain potential new seedling within them. Generative or reproductive growth starts from formation of flower growing into a pod. Seeds are formed along with growth of pod (Lakitan, 1997). According to Sutara (2016) and Ramdhini et al. (2021), seeds are developed from ovules.

Table 4. Weight of 100 dry beans from several cocoa clones rejuvenated by ring budding and side cleft grafting techniques

Treatments	Rejuvenation techniques	
Clone	Ring budding	Side cleft grafting
KKM 22	88.91 b	88.83 a
RCC 70	106.85 a	91.21 a
RCC 71	75.43 c	83.21 a
Average	90.40 a	87.75 a
Coefficient of variance (%) = 7.30		

Remarks: means in one column followed by similar letters show no significant differences among treatments (LSD test at α = 5%). Data were transformed into $\sqrt{(x+0.5)}$.

Table 4 informs that weight of 100 dry beans is affected by clone types, especially those rejuvenated by ring budding technique. Yet, rehabilitation by side cleft grafting technique caused not significant difference in weight of 100 dry beans in all three tested clones. Within ring budding technique, RCC 70 clone had higher weight of 100 dry beans compared to KKM 22 and RCC 71 clones due to difference capability of clones in optimizing each growth. It also showed that pod growth tended to be more optimal in RCC 70 compared to in other two clones. Puslitkoka (2006) states that RCC 70 is one of bulk cocoa clones with high potential of dry bean/pod. This is a reason why RCC 70 clone have higher growth of pods.

Bean weight per stand

Table 5 shows that bean weight per stand is impacted by rehabilitation technique. Rejuvenated cocoa trees by ring budding technique produced more bean weight per stand than those rejuvenated by side cleft grafting. This indicates that the growth capacity of bean weight per plant was higher by ring budding than by side cleft grafting technique. Dry bean weight per stand was total of several dry seeds per pod. The weight of dry beans describes assimilate content converted into secondary metabolism adjusted accordingly to each need of cocoa beans.

Nutrients provided in planting media, especially K, affected beans quantity. Planting media of both of rejuvenation technique have very high K nutrient content, but the ring budding research site has higher number than that of the side cleft grafting. Potassium can increase yield of carbohydrates and accelerate rate of translocation. The role of potassium in solute translocation is related to contributions on potential osmotic and ATP synthesis, which provide energy to load photosynthesis. Potassium plays a positive role in loading phloem and accelerating solute transfer. Secer (1978) states that potassium affects growth of cocoa bean sizes because it promotes photosynthesis translocation as well as protein mobility stored in leaves, stem, pods, and seeds. Thus, the positive effect of high potassium content in soil was shown in the bean weight of ring budded cocoa trees.

Table 5 shows that bean weight per stand is affected by clones, especially those rehabilitated by side cleft grafting technique. KKM 22 clone was able to produce more bean weight per stand when

Table 5. Bean weight per stand from several cocoa clones rejuvenated by ring budding and side cleft grafting techniques

Treatments	Rejuvenation techniques	
Clone	Ring budding	Side cleft grafting
KKM 22	1459.1 a	1096.9 a
RCC 70	1364.7 a	591.5 b
RCC 71	1330.3 a	537.7 b
Average	1384.7 a	742.1 b
Coefficient of variance (%) = 13.64		

Remarks: Means in one column followed by similar letters show no significant differences among treatments (LSD test at α = 5%). Data were transformed into √(x+0.5).

Table 6. Yield per hectare from several cocoa clones rejuvenated by ring budding and side cleft grafting techniques

Treatments	Rejuvenation techniques	
Clone	Ring budding	Side cleft grafting
KKM 22	1.6 a	1.2 a
RCC 70	1.5 a	0.7 ab
RCC 71	1.5 a	0.6 b
Average	1.5 a	0.8 b
Coefficient of variance (%) = 24.00		

Remarks: means in one column followed by similar letters show no significant differences among treatments (LSD test at α = 5%). Data were transformed into √(x+0.5).

compared to other two clones. Rejuvenated by ring budding technique, all three clones produced similar bean weight per stand, indicating similar growth capacity of bean. Bean weight per stand was total of several seeds per fruit from a stand. More bean weight per stand resulted in higher yield per hectare.

According to Indonesian National Standard (SNI), weight of dry bean/pod is one of quality parameters to determine bean grade. Moreover, weight of dry bean describes assimilate content converted into secondary metabolism adjusted accordingly to each need of cocoa beans. Seed weight per fruit is one of parameters in observing grade and quality of cocoa beans (Kusumadati et al., 2002; Fujita et al., 2003).

Yield per Ha

Table 6 shows that yield of rehabilitated cocoa stands are affected by grafting techniques. Rehabilitated cocoa by ring budding technique had more yield than those by side cleft grafting (Table 4.74). This indicates that ring budding technique could produce more pods per stand. Higher yield of cocoa stand rejuvenated by ring budding technique compared to those by side cleft grafting was seen on the total number of pods per stand (Table 2). The yield increased along with increase of land resources quality. The number of available potassium content in the soil affected the number of cocoa pods and the weight of its beans. These two variables are the component of yield. Potassium plays role in increasing root growth, activate important enzymes in photosynthesis, translocate sugars and starch into beans, and also improve the quality of the beans (Habberman et al., 2019).

Nutrient availability also affects productivity. More nutrients provide more pods. Zahrah (2011) said that lack or excess of nutrition (includes N, P, and K) could give bad impact to crop growth and production.

Table 5 shows that rejuvenation of KKM 22, RCC 70, and RCC 71 clones give the same yield regardless the ring budding technique. This indicates that all tested clones have same capacity of yield when rejuvenated by ring budding technique. Meanwhile, KKM 22 clone showed higher yield when compared to RCC 71 when rejuvenated by side cleft grafting. KKM 22 is in group of Trinitario, while RCC 70 and RCC 71 both are Forastero (Prawoto and WInarsih, 2010).

CONCLUSIONS

The number of pods and bean weight per cocoa stand were significantly higher in plants rejuvenated by ring budding technique due to high content of available potassium in the research site. Rejuvenation with ring budding technique gave a good response with high yield in all tested clones. All clones were suitable for rejuvenation by ring budding technique. Meanwhile, in the side cleft grafting technique, the KKM 22 cocoa clone only gave a good response with high yield potential. Meanwhile, the cocoa clones RCC 70 and RCC 71 had discrepancies that resulted in low yields.

REFERENCES

Aikpokpodion, P.E., and Dongo, L.N. (2010). Effects of fermentation intensity on polyphenols and antioxidant capacity. *Int. J. Sustain. Crop Prod*., 5(4), pp. 66–70.

Amaru, K., Edy, S., Nurpilihan, B., Fitri, P.A. (2013). Kajian kelembaban tanah dan kebutuhan air beberapa varietas hibrida DR UNPAD. *Jurnal Keteknikan Pertanian*., 1(1), pp. 107–115.

Aneja, M., Gianfagna, T., and Ng, E. (1999). The roles of abscisic acid and ethylene in the abscission and senescence of cocoa flowers. *Plant Growth Regulation*, 27(3), pp. 149–155

Citrosupomo, G. (1989). *Taksonomi tumbuhan: (spermatophyta)*. 11th ed. Yogyakarta: Gadjah Mada University Press, pp. 477.

Departemen Perindustrian. (2007). *Gambaran sekilas industri kakao.* Jakarta: Departemen Perindustrian, pp. 5–8.

Devy, L., Anita-Sari, I., Susilo, A.W., Wachjar, A., Sobir. (2018). Genetic diversity and indirect selection of fine cacao (*Theobroma cacao*) based on bean color. *Biodiversitas*, 19(6), pp. 2385–2392.

Direktorat Jendral Perkebunan (2019). *Statistik perkebunan Indonesia 2018-2020.* Jakarta: Sekretariat Direktorat Jenderal Perkebunan, pp. 7.

Hidayat, E.B. (1995). *Anatomi tumbuhan berbiji*. 1st ed. Bandung: ITB Press, pp. 151.

Fujita, K., Okada, M., Lei, K., Ito, J., Ohkura, K., Adu-Gyamfi, J.J., and Mohapatra, P.K. (2003). Effect of P-deficiency on photoassimilate partitioning and rhythmic changes in fruit and stem diameter of tomato (*Lycopersicon*

esculentum) during fruit growth. *Journal of Experimental Botany*, 54(392), pp. 2519–2528.

Kusumadati, W., Sutardi., and Kartika, B. (2002). Kajian penggunaan berbagai metode pengeringan dan jenis mutu biji kakao lindak terhadap sifat-sifat kimia bubuk kakao. *Gama Sains*, 4(2), pp. 102–111.

Lakitan, B. (1997). *Dasar-dasar klimatologi*. 2nd ed. Jakarta: Raja Grafindo Persada. pp. 65.

Limbongan, J. (2007). Percepatan inovasi teknologi pertanian spesifik lokasi mendukung kemandirian masyarakat kampung di papua. *Prosiding Seminar Nasional Balai Pengkajian Teknologi Pertanian Papua*, pp. 377–384.

Martono, B. (2014). Karakteristik morfologi dan kegiatan plasma nutfah tanaman kakao. *Inovasi Teknologi Bioindustri Kakao*, 1(2), pp. 15–27.

Mog, B., Janani, P., Nayak, M.G., Adiga, J.D., and Meena, R. (2019). Manipulation of vegetative growth and improvement of yield potential of cashew (*Anacardium occidentale* L.) by paclobutrazol. *Scientia Horticulturae*., 257, pp. 108748.

Pangaribuan, N. (2004). Peranan auksin dalam usaha menekan kelayuan buah muda kakao *(Theobroma cacao* L.). J*urnal Matematika, Sains dan Teknologi*, 5(1), pp. 31–38.

Pardal, S. J. (2001). Pembentukan buah partenokarpi melalui rekayasa genetika. Balai Penelitian Bioteknologi Tanaman Pangan. *Buletin AgroBio*, 4(2), pp. 45–49.

Prawoto, A.A. and Winarsih, S. (2010). *Mengenal tanaman kakao.* In: Lukito, A.M., Buku Pintar Budidaya Kakao. 1st ed. Jakarta: Agro Media Pustaka, pp. 11-41.

Prawoto, A. A. (2014). Dinamika pertunasan, layu pentil dan ketepatan taksasi produksi beberapa klon kakao. *Pelita Perkebunan,* 30(2), pp. 100–114.

Pusat Penelitian Kopi dan Kakao. (2006). Pengendalian hama PBK pada tanaman kakao. *Balai Pengkajian Teknologi Pertanian Maluku (BPTP Maluku)*, pp. 31–36.

Pusat Penelitian Kopi dan Kakao (2010). *Buku pintar budidaya kakao*. 1st ed. Jakarta: Agromedia Pustaka, pp. 271-291.

Putra, E.T.S., Ngadiman, Riyantono, E. (2012). Evaluasi keberhasilan beberapa teknik sambung pada program rehab di kebun kakao unit produksi Segayung Utara. *Laporan Kegiatan Operasional Kebun. PT. Pagilaran. Yogyakarta: PT.Pagilaran*, pp. 150

Ramdhini, R.N., Manalu, A.I., Ruwaida, I.P., Isrianto, P.L., Panggabean, N.H., Wilujeng, S., Erdiandini, I., Purba, S.R.F., Sutrisno, E., Hulu, I.L., Purwanti, S., Utomo, B., Surjaningsih, D.R. (2021). *Anatomi Tumbuhan*. 1st ed. Medan: Yayasan Kita Menulis.

Rismunandar. (1988). *Hormon tanaman dan ternak.* 1st ed. Jakarta: Penebar Swadaya, pp. 54–55.

Riza, A. (2009). Pengaruh pemberian kadar air terhadap pertumbuhan tanaman jagung (*Zea mays*). *Journal Unbara*., 1(1), pp. 41.

Salisbury, F.B., and Ross, C.W. (1995). *Plant Physiology*. 1st ed. California: The Banjamin/Cummigs Publishing Company Inc., pp. 581.

Schnappinger, D., Sabine, E., Martin, I., Voskuil., Yang, L., Joseph, A., Mangan., Irene, M., Monahan., Gregory, D., Brad, E., Philip, D., Butcher., Carl, N., Gary, K., and Schoolnik. (2003). Transcriptional adaptation of Mycobacterium tuberculosis within macrophages : Insights into the phagosomal environment. *Journal of Experimental Medicine,* 198(5), pp. 693–704.

Secer, M. (1978). Effect of potassium on nitrogen metabolization and grain protein formation in spiring wheat. *Kali-Briefe*, 14(6), pp. 393–402.

Sutara, P.K. (2016). *Struktur dan anatomi tumbuhan*. pp. 1–28. Available at:https://simdos.unud.ac.id/uploads/file_pendidikan_1_dir/bcac4e1615491798d8066dc0a362fd46.pdf. [Accessed 11 December 2021].

Tirtawinata, M.R. (2003). Kajian anatomi dan fisiologi sambungan bibit manggis dengan beberapa anggota kerabat Cluciaceae. Dissertation. IPB University.

Tutiliana. (2014). Aplikasi zpt auksin , seng dan boron untuk mengendalikan layu pentil (*Cherelle wilt*) pada tanaman kakao. *JESBIO*, 3(4), pp. 1–8.

Wahyudi, T. Panggabean, T.R.P., Pujiyanto. (2008). *Panduan lengkap kakao: Manajemen agribisnis dari hulu hingga hilir*. 1st ed. Jakarta: Penebar Swadaya, pp. 351–358

Zahrah, S. (2011). Respon berbagai varietas kedelai (*Glycine max* (L.) Merril) terhadap pemberian pupuk NPK organik. *J. Teknobiologi*, 2(I), pp. 65–69.

Zaubin, R. and Suryadi, R. (2002). Pengaruh troping jumlah daun dan waktu penyambungan. *Jurnal Litri*., 8(2), pp. 55–60.