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The effect of various types of forest fires on pine resin productivity in Gunung Walat University Forest, Sukabumi, Indonesia

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Abstract. *Prasetya CD, Syaufina L, Santosa G. 2017. The effect of various types of forest fires on pine resin productivity in Gunung Walat University Forest, Sukabumi, Indonesia. Biodiversitas 18: 476-482.* Gunung Walat University Forest (GWUF) of Sukabumi, Indonesia is one of pine resin producers that has 71 hectares of resin production area. The forest fire burned 7 hectares of resin production area in August 2015 was expected to affect the resin productivity. The aim of this study was to analyze the effect of each type of forest fire to pine resin productivity and analyze the correlation between the biophysic aspect and pine resin productivity after the fire. The types of forest fire were litter and shrub fire, stem fire, and crown fire. ANOVA test showed that the types of forest fire have significant effect to resin production with the value of F_{table} (3.12)<F_{test} (4.88) and P_{value} (0.006)<α (0.05). The Tukey test showed that the stem fire and the crown fire gave the most significant result to the resin production with the mean of resin productivity value (g/tree/day) respectively 24.54 and 21.698.

Keywords: Fire effect, pine resin, productivity

INTRODUCTION

A forest is an ecosystem unit in the form of an expanse of land filled with natural resources that are dominated by trees in their natural forms and their environment where they are inseparable from one another (President of the Republic of Indonesia 1999). Forests in Indonesia are highly prone to various disturbances, both natural disturbances and man-made disturbances. One most common form of forest disturbances is forest fires. Forest fires may cause economic, ecological, and social losses in the short and long terms (Syaufina 2008). A decrease in forest productivity could be caused by forest fires as the forest products decrease due to the damage to stands.

Non-timber Forest Products (NTFPs) are defined as everything that is in and originates from forests except for timber, including beneficial environmental services (FAO 1992). NTFPs are natural resources which have very good prospects to be developed in Indonesia. The harvesting of NTFPs is usually conducted sustainably without damaging the forest. One of the important NTFPs in Indonesia which brings many benefits for industries is pine resin. According to FAO (2010), Indonesia is the second largest pine resin producer in the world after China at 69,000 tons (10% of the total world production).

The resin produced by pine trees is classified as oleoresin which is a fluid consisting of resin acids which seep out when the resin vascular in the pine tree are injured (Kozlowski and Pallardy 1997). Rosin is the product of pine resin distillation which is also called gum rosin, pine rosin, or colophony. Rosin is a clear, pale yellow to dark yellow solid having a clear liquid side product called turpentine. The use of pine resin has rapidly developed, namely, as the main ingredient for varnish, as sizing material of soaps, as scrubbing material, as ink material, and as paint material in the paint industry. Turpentine is commonly used as paint material and varnish diluent, wax diluent, and an ingredient for synthetic camphor.

Gunung Walat University Forest (GWUF) which is located in Sukabumi District, West Java Province, Indonesia is a pine resin producer. GWUF has pines growing on ± 125 hectares. The area of the pine forest used for resin production is ± 71 hectares. Pine resin in GWUF is harvested from a number of pine species: *Pinus merkusii*, *Pinus oocarpa*, and *Pinus insularis* (syn. *Pinus kesiya*). In August 2015, there was a forest fire which struck 7 hectares of the pine stand area. This incident is believed to affect the production of pine resin for both short and long term. This study aimed to determine how far the three types of forest fire incident in the pine stand area affected the pine resin productivity.

MATERIALS AND METHODS

Study area

Gunung Walat University Forest is located in Sukabumi District, West Java, Indonesia, and geographically is located at 6°54’23”-6°55’35” S and 106°48’27”-106°50’29” E (Figure 1). The study was conducted in the unburned *P. merkusii* production forest and nine months post-fire in the Tanabe block in the Gunung Walat University Forest

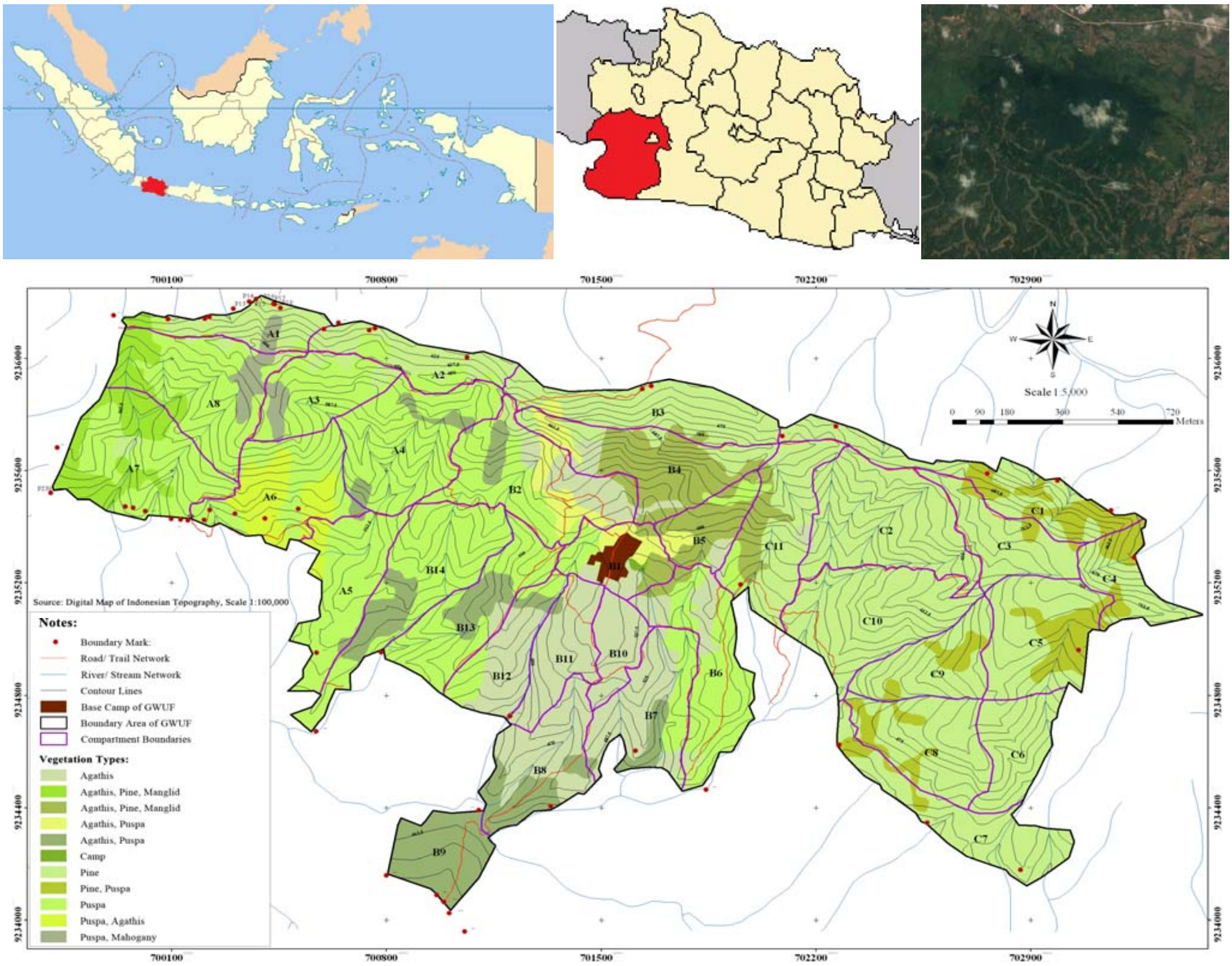

Figure 1. Map of Gunung Walat University Forest in Sukabumi District of West Java, Indonesia

(GWUF), Sukabumi, West Java, between May and June 2016.

Procedures

Equipment and materials

The material used was ETRAT stimulant. The equipment used in this study were cameras, tally sheets, nails, hammers, 1 kg plastic bags, sprayers, permanent markers, tree tags, aluminum spouts, labels, digital scales, a thermohygrometer, and a densitometer.

Determination of the types of fire

Determination of the types of fire in this study was conducted based on the field conditions observed in a preliminary survey. The results of the preliminary survey at the observation site revealed that there were three types of fire that had happened: (i) Litter and shrub fire: the litter and shrubs around the observed trees showed evidence of being burnt. (ii) Stem fire: part of or the entire trunk of the observed trees showed evidence of being burnt. (iii) Crown fire: the entire tree up to the crown of the observed trees showed evidence of being burned.

Determination of the fire severity and fire intensity

The measure of fire severity and fire intensity is important to measure the effect of fire on pine resin productivity. DeBano et al. (1998) classified the fire severity in three groups, which were:

Based on soil resource responses: (i) Low fire severity: Low soil heating, or light ground char, occurs where litter is scorched, charred, or consumed by fire, but the duff is left largely intact, although it can be charred on the surface. Woody debris accumulations are partially consumed or charred. Mineral soil is not changed. Fire severity in forest ecosystems is considered low when the litter and duff layers are scorched but not altered over the entire depth. The surface is mostly black in a shrubland or grassland ecosystem, although gray ash can be present for a short time. Soil temperature at 1 cm is less than 50^{o}C. Lethal temperatures for soil organisms occur down to the depths of about 1 cm. (ii) Moderate fire severity: Moderate soil heating, or moderate ground char, occurs when the litter on forest sites is consumed, and the duff is deeply charred or consumed, but the underlying mineral soil surface is not visibly altered. The light color of ash is present. Woody debris is mostly consumed, except for logs, which are deeply charred. On scrubland or grassland sites, gray or white ash is present and char can be visible in the upper 1 cm of mineral soil, but the soil is not altered. Soil temperatures at the 1 cm depth can reach 100 to 200^{o}C. Lethal temperatures for soil organism occur down to depths of 3 to 5 cm. (iii) High fire severity: High soil heating or deep ground char occurs where the duff is completely consumed and the top of mineral soil is reddish or orange on severely burned sites. The color of the soil below 1 cm is darker or charred from organic material. The charred layer can extend to a depth of 10 cm or more. Logs can be consumed or deeply charred, and deep ground char can occur under slash concentration or burned-out logs. Soil texture in the surface layers changed and fusion showed by clinkers can be observed locally. All shrub stems are consumed and only the charred remnants of large stubs may be visible. Soil temperatures at 1 cm are greater 250^{o}C. Lethal temperatures for soil organisms occur down to depths of 9 to 16 cm.

Based on the percentage of the total area that burned: (i) Low fire severity: Less than 2% of the area is severely burned, less than 15% is moderately burned, and the remainder of the area is burned at a low severity or unburned. (ii) Moderate fire severity: Less than 10% of the area is severely burned, but over 15% is burned moderately, and the remainder is burned at low severity or unburned. (iii) High fire severity: More than 10% of the area has spots that are burned at high severity, more than 80% moderately or severely burned, and the remainder is burned at a low severity.

Based on damage on the burned trees: (i) Low fire severity: At least 50% of the trees exhibit no visible damage, with the remainders have scorched canopy, dead shoot (died on the shoot tip but able to sprout), or dead root (died on the root tip and unable to sprout); over 80% of the fire-damaged trees survive. (ii) Moderate fire severity: 20-50% of the trees exhibit no visible damage, with the remainders are fire-damaged; 40-80% of the fire-damaged trees survive. (iii) High fire severity: Less than 20% of the trees exhibit no visible damage, with the remainders are fire-damaged, and have mostly dead roots ; less than 40% of the fire damage trees survive.

The measure of fire intensity is using Byram's intensity (I) which is measured by fire line intensity. The fire line intensity has been related empirically to flame height (h). This equation is often simplified for field use as:

$$I\ (kW/m) = 300h^2$$

Determination of pine resin productivity

Initial preparations for this study were preparing the equipment and materials, conducting a site survey, and collecting secondary data on the general condition of the study location, on the history of the forest fire in GWUF, and on resin production of the stands before being scorched by fire. The samples were 80 trees; 20 trees of unburned *P. merkusii*, 20 trees with burned litter and shrub, 20 trees with damaged stem from the fire, and 20 trees with scorched crown from the fire. The tree samples were marked with tree tags.

The tapping method employed on the 80 sample stands was the Quarre method. The shrubs surrounding the tree bark were cleared and the tree bark was scraped off using a cleaver; the groove was 3 mm deep and 20 cm wide (the starting point of the tapping groove was 20 cm above the ground). A tapping spout was then affixed to the bottom of the groove using a nail and a 0.5 kg capacity plastic bag was attached to collect the resin. The groove in the trunks of each sample stand was then sprayed with the liquid stimulant ETRAT for as much as 0.5 mL/groove (one spray). ETRAT 1240 is a product used in pine tapping which consists of 100 ppm ethylene and 150 ppm citric acid. The resin was harvested every 3 days which was followed by renewing the Quarre at a height of 0.5 cm and spraying the liquid stimulant ETRAT at a dose of 0.5 mL/groove/3 days (the harvesting was conducted ten times). The yield was weighed every time harvesting was conducted for the ten harvests using a digital scale.

Data analysis

The analysis of data was conducted with a Complete Randomized Design where the response was obtained from the unburned (control) and burned based on the types of fire, namely litter and shrub fire, stem fire, and crown fire. This study used 80 sample trees selected randomly then classified into 20 trees for each fire type. The determination of the number of trees referred to the experiment design guidelines in Walpole et al. (1993) where each fire type in the experiment design had at least three repeats.

Each fire type was analyzed using the analysis of variance (ANOVA) with the Complete Randomized Design model. The analysis of variance was conducted to discover if the fire types had an effect on the increase in pine resin productivity. The results of the ANOVA were then followed up with the Tukey test or the Honest Significant Difference (HSD). The hypothesis in this study was that each of the types of fire had a different effect on pine resin productivity at a significance of 95%.

RESULTS AND DISCUSSION

Pine resin productivity

This study classified tree samples into four groups, namely litter and shrub fire, stem fire, crown fire, and control. The classification of stands based on the types of fire was meant to identify the types of fire that have a significant effect or are significantly different from the control. The average resin production (g/tree/day) in the control stands was 12.78 g/tree/day, which was the lowest average resin production amongst the other three fire types. The highest average resin production was found in the stem fire at 24.45 g/tree/day (Table 1).

The lowest resin productivity was found in the stands in the control plot and highest in the stands in the stem fire plot. After the sixth to the eighth harvests, resin production in all the fire types declined, and this was caused by the rise of precipitation at the study location, causing the temperature and sunlight intensity to drop, which was followed by a decrease in resin productivity (Figure 2).

Testing the response of resin productivity using ANOVA was conducted to demonstrate statistically if different types of fire had a significantly different effect at a 95% confidence interval. Based on the ANOVA test, it could be seen that $P_{value} < F_{count}$, so that the Ho hypothesis that stated that different types of fire had a significant effect on resin productivity at a 95% confidence interval was rejected (Table 2). And then a follow-up test in the form of the Tukey/Honest Significant Difference (HSD) test to discover which type of fire had the most significantly different effect on resin productivity. Based on the results of the Tukey test, it was concluded that the stem fire and crown fire were very significantly different from the control, whereas the litter and shrub fire was not very significantly different from the control and the stem fire and crown fire (Table 3).

The biophysical aspect

The resin productivity response in each fire type tended to be similar. This similar response was assumed to be caused by the fire that occurred at the study site did not have a significant effect on the biophysical conditions in each of the plots that were still in one land area. Biophysical conditions could affect resin productivity and change the land cover. The biophysical aspects included temperature, humidity, and canopy cover (Table 4). The results of the measurements revealed that the three measured parameters in each fire type tended to be similar, leading to a similar response of pine resin production in all the fire types.

Discussion

Since being established as educational forest in 1969, GWUF has land width of about 359 hectares. About 75% land cover in GWUF are even-aged forest that had been planted since 1958. The even-aged forests in GWUF are damar (*Agathis dammara*), pine (*Pinus merkusii, Pinus oocarpa, Pinus caribaea,* and *Pinus insularis*), rasamala (*Altingia excelsa*), and puspa (*Schima wallichii*). Even aged pine forest area in GWUF is about 125 hectares and the pine resin production area is about 71 hectares. The forest fire in August 2015 occurred on 7 hectares of the pine resin production area, this occurrence may affect the pine resin productivity considering the wideness of burned area which was about 10% of pine resin production area. The forest fire in the last five years in GWUF at Cimenyan blocks happened on September 1, 2012 and August 14, 2015. Those incidents were caused by the same activity namely land preparation of cultivation activity by society surrounding GWUF. Cultivation activities done by society surrounding GWUF were assumed to cause the fire in GWUF pine area. The area making border with society land has a slope with average declivity of 30^{o} which is categorized as sheer land and also has high wind velocity. Dominating vegetation in that area is grass, shrubs, and pine trees. Abundant availability of those fuels may be the factor that stimulates the occurrence of the fire started by human activity in land preparation.

The study was conducted in the Gunung Walat University Forest (GWUF) that had ±125 hectares of pine trees, in Tanabe Block, the block that had been burned in August 2015. The fire at the observation location was classified into three types of fire, namely litter and shrub fire, stem fire, and crown fire. The study was conducted to observe if there were any differences in response to each type of fire nine months after the fire burning down the trees. The

Table 1. Pine resin productivity in Gunung Walat University Forest, Sukabumi District, West Java, Indonesia

Harvesting period	Control (g)	Litter and shrub fire (g)	Stem fire (g)	Crown fire (g)	Mean (g)
1	8.27	10.12	12.00	12.87	10.82
2	4.27	5.56	9.19	10.30	7.33
3	7.12	12.74	17.98	18.59	14.11
4	11.81	17.09	20.93	21.43	17.81
5	15.30	23.12	27.45	26.08	22.99
6	18.15	26.02	29.24	25.04	24.61
7	22.29	25.32	31.47	25.68	26.19
8	15.41	25.35	33.41	27.14	25.33
9	12.86	25.64	30.85	24.45	23.45
10	12.35	27.23	32.03	25.41	24.26
Total	127.85	198.19	244.55	216.98	
Mean	12.78	19.82	24.45	21.70	

Table 2. Analysis of variance (ANOVA) test of pine resin productivity in Gunung Walat University Forest, Sukabumi District, West Java, Indonesia

Source	Degree of freedom (DF)	Sum of Square (SS)	Mean of Square (MS)	F_{test}	P_{value}
Fire types	3	744.3	248.10	4.88	0.006
Error	36	1828.7	50.80		
Total	39	2573.0			

Table 3. Tukey test/ Honest Significant Difference (HSD) test

Fire type	Mean of productivity (g/tree/day)
Control	12.785^{b}
Litter and shrub fire	19.818^{ab}
Stem fire	24.54^{a}
Crown fire	21.698^{a}

Note: The different superscript character in "Mean of productivity" column shows the significant difference result (P<0.05)

Table 4. Biophysical aspect in Gunung Walat University Forest, Sukabumi District, West Java, Indonesia

Mean	Control	Litter and shrub fire	Stem fire	Crown fire
Temperature (°C)	28.14	29.05	28.77	27.57
Humidity (%)	80.17	77.30	78.10	80.53
Canopy cover (%)	43	32	34	33

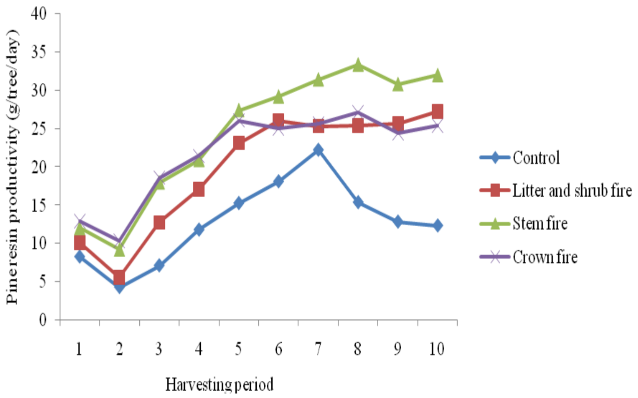

Figure 2. Pine resin productivity from each type of fire in Gunung Walat University Forest, Sukabumi District, West Java, Indonesia

most dominant pine species in the study location was *P. merkusii* and *P. oocarpa,* but data were only collected from *P. merkusii*. The species *Pinus merkusii* is an endemic species of Aceh, North Sumatra, and Jambi. This species is also planted in West Sumatra, Java, South Sulawesi, North Sulawesi, and South-East Sulawesi. Indonesia is the third largest pine resin producer in the world after China and Portugal (Wiyono et al. 2006) and it contributes to an approximate 8% of the world pine resin market (Fachrodji et al. 2009). Pine resin is a secondary metabolic product in the form of a clear, viscous, and sticky liquid. Pine resin contains terpenoids, hydrocarbons, and other compounds. Distillation of pine resin will produce rosin and a distillate called turpentine oil (Sukadaryati and Dulsalam 2013).

The fire types in this study are classified based on the type of fire only. Tree samples were given stimulant (Matangaran et al. 2012). There are various stimulants used in pine tapping activities, but the main ingredient is sulfuric acid and nitric acid which are strong oxidizers (Yusnita et al. 2001). The application of a stimulant on pine stands post-fire is expected to increase the resin production. The application of the stimulant ETRAT which contains ethylene and citric acid could increase resin productivity by activating the ethylene in the plant which will stimulate exudation of resin (Santosa 2011). The study conducted by Spanos et al. (2010) used a stimulant paste which consisted of sulfuric acid, water, and kaolin to increase resin productivity. However, the factor that strongly determines resin productivity is the tree's optimum ability to produce pine resin (Sukadaryati and Dulsalam 2013).

Based on soil condition, the fire on the research site was measured as low severity fire, where the soil heating was low, the shrub charred or consumed but the duff is left largely intact, the soil surface was black and gray on short time. Based on total burned area, the fire has burned 7 hectares out of 71 hectares pine resin production area or about 10% of total resin production area. Therefore, based on total burned area, it was categorized as low severity fire, where <10% area was severely burned, >15% was moderately burned and the remainings were burned at low severity or unburned at all. Based on fire damage on trees, it was categorized as low severity fire, where 50% of the trees exhibit no visible damage, and the remainings are either with scorched crowns, dead shoots, or dead roots, and over 80% of the fire-damaged trees survive. Overall, the former fire in GWUF on August 2015 was categorized as low-severity fire. Based on fire height, the fire reached 12 m on the tree stem, and it obtained fire intensity with the amount of 43,200 kW/m and was categorized as high-intensity fire and potentially caused fire spot in surrounding area whenever the wind speed and the fire were high.

Pine resin productivity in one area could also be different because of genetic variability between individuals on the location which would affect the tree's ability to produce pine resin (Sukarno et al. 2015). Pine resin productivity is also very much influenced by the size, distribution, and a number of resin ducts in the pine trunk and a number of parameters can be used in analyzing the anatomy and morphology of resin ducts (Reid and Watson 1966). Zanski (1970) reported that resin productivity is influenced by a number of factors: soil, climate, the use of chemicals, tree age, silvicultural treatments, and tree genetics. Spanos et al. (2010) found a low correlation between the height of trees and the amount of resin productivity at a value of R^2=0.315. Therefore, it could be concluded that the height of a tree does not have a correlation to its resin productivity.

Resin productivity is strongly influenced by the tree's optimum ability in producing pine resin. The tree's ability is influenced by the resin canal system in the tree itself. The resin canal system is a complex metabolism which functions as the pine tree's defense against various disturbances such as taping, insects, and fire (Alfaro et al. 1997). If the cross-section of the tree is observed, the resin canals are positioned longitudinally in the xylem and produce resin when connected to the radial resin canals located between the xylem and phloem (Wu and Hu 1997). Napp-Zinn (1966) classified 4 types of resin canals based on their position in the pine trunk: (i) hypodermic canals; (ii) canals surrounded by chlorenchyma; (iii) canals that are in the vessel sheath in the chlorenchyma; and (iv) canals in the vessels inside the vessel sheath. There was a positive correlation between resin productivity and the density of axial resin canals (Blanche et al. 1992). A number of researchers, including Alfaro et al. (1997), discovered that the number, size, and density of resin canals in the xylem or phloem have a positive correlation to resin productivity.

Resin tapping with the Quarre method is conducted by peeling the pine bark without harming the wood tissue. However, the problem that might arise is the attacks of pests due to the exposed bark. Two insect species that are partial to turpentine in the south-eastern parts of America are *Dendroctonus terebrans* and *Buprestis apricans*. These insects place their eggs and larvae in parts of trees that are injured by tapping, and these insects are extremely destructive and can decrease resin productivity (William 1996). However, after being wounded (mechanical, animal, fire, and other disturbances), some types of pine produce more resin canals than in normal conditions.

Resin productivity in each fire type underwent a decline after the second harvest because of the traumatic response of the stands after the first tapping. Resin productivity began to rise at the third and subsequent harvests because there were no more traumatic responses on the wood, but the injury (tapping) in the wood became a stimulus for the wood to activate the ethylene hormone which will produce resin for healing the injury (Figure 2). Resin productivity is also affected by the biophysical conditions in the field. These biophysical conditions could increase or decrease resin productivity. The biophysical aspects included temperature, humidity, and canopy cover (Table 4). The results of the measurements revealed that the three parameters measured in each fire type had a tendency to be similar, so the responses tended to also be similar in all fire types.

The results of the ANOVA test which showed that the fire types had a significant influence on resin production were then followed up with the Tukey test to see which type of fire having the most significant effect. The results of the Tukey test revealed that the fire types that had the most significant influence on resin production were stem fire. The average resin productivity in trees surviving the stem fire was 24.54, which was the highest among the other fire types (Table 1). Table 3 showed the results of Tukey test on resin productivity

Based on the ANOVA and Tukey tests, it still could not be concluded how many burnt tree is needed to increase resin productivity. The factors that strongly influenced the results of this study were weather, human disturbances, and animal disturbances. The forest fire in GWUF has caused a change in the microclimate. According to Mutke et al. (2005), climate change had a negative effect on non-timber forest products, including pine resin, in Central Spain. Climate has different effects on resin productivity. The research by Pardos et al. (1976) stated that there was a direct effect on resin productivity, for example temperature which can affect resin fluidity, while Genova et al. (2014) stated that there was an indirect effect on resin production, for example, resin and water stress have a strong influence on the anatomic structure of trees and the biosynthesis process of resin and secretion. The human disturbances were in the way like people having a picnic or riding motorcycles in the forest and the path used by people is the right place for a study. Other disturbances included animal disturbances, especially from wild pigs which tracks were found around trees). They did damage to the resin collection vessels of a certain tree

On several temperate countries, the use of fire in the pine forest is for various reasons, such as forage improvement and hunting. Sometimes, the fire was originated from agriculture activities that spread to pine forest. Prescribed burning as one of forest management and conservation tools in a tropical forest is not applied widely. Whereas, prescribed burning can provide habitats for a number of vegetation and animal species. Unfortunately, in most countries with tropical pine ecosystem, the important role of fire is not understood and prescribed fire is not an accepted ecosystem management tool because to sprout up new vegetation is not hard, so the using of fire to stimulate the growth of new species is not necessary. According to Seijo et al. (2015), fire is a useful ecosystem management tool. The most important perceived utility is a tool to improve fertility and clear shrubs or trees from arable land. Fire is also a useful tool for improving habitat for hunting species. Based on those research, prescribed burning may provide some benefit for forest ecosystem, but its utilizing need some regulation.

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