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The effects of forest burning and logging toward regeneration ability of Sowang (*Xanthostemon novaguineense* Valet.) in Cycloop Mountain, Jayapura, Papua

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ABSTRACT

Wilujeng S (2010) The effects of forest burning and logging toward regeneration ability of Sowang (Xanthostemon novaguineense *Valet.) in Cycloop Mountain, Jayapura, Papua. Biodiversitas 11: 194-199.* Sowang (*Xanthostemon novaguineense* Valet.) is an endemic plant of New Guinea Island, which is threatened by human activities through land conversion, forest burning and logging. This research aims to know the Sowang developmental phase and stem branching, seedling dominance level, and effect of environmental factor alteration towards the amount of Sowang seedlings at burning and logging areas, and natural forest as control parameters. Sowang stem, derived from shoot of burning area, grows branchy from the lower part of stem. Sowang stem derived from seed grows monopodially. Sowang seedling, derived from stem shoot of burning area, have already started flowering phase that occurs all seasons. Individual of Sowang, derived from seed of logging area and natural forest, flowers on the tree level once a year. Sowang seedling became dominant species at burning area. Environmental factors affect Sowang seedling population density were crown covering and light intensity.

Key words: population, Sowang, *Xanthostemon novaguineense*, branching, flowering, domination.

INTRODUCTION

Papua is one of Indonesia's islands that have a high biological diversity and endemic level. Papua is estimated contains almost half of the Indonesia's biological diversity assets. Papua's endemic species, which is mostly used by the local people, is vascular plant species, e.g. Sowang (*Xanthostemon novaguineense* Valet.) (Figure 1). Sowang is a fire-resistant plant, and its wood quality belongs to the category of sea wooden gimlet resistant. Until now, scientific information about Sowang is still rare. This is supported by statement of Wilson and Pitisopa (2007) that *X. novaguineense* is an endemic plant of western Papua New Guinea Island with limited available site data.

Sowang's habitat area in Jayapura exists at Cycloop Mountain. Sowang grows at the west, south, east, and is an endemic plant of New Guinea Island. Cycloop Mountain lies alongside at the north of Jayapura. Sowang's habitat is lowland at 15-450 meters above sea level. That is why Sowang are found abundant at the foothill of Cycloop Mountain or at another area except natural preserve area. The wide of those Sowang's habitats then decrease because of land conversion and forest yield exploitation, and the rest of it are still being a traditional forest that is authorized by traditional citizens.

Traditional people lives at the west of Cycloop Mountain. Their activities in the forest include repeatedly burn and log trees. Meanwhile, south to east area of Cycloop Mountain is a forest product exploitation and land conversion area. It is causing the south to east side of Cycloop Mountain undergoes land damage and conversion that make it become no longer conducive for Sowang population. Yepasedanya (2004) wrote that traditional citizens and society has divided Cycloop area become the zones of residential, farming, forest yield collecting area, and traditional restriction (natural forest).

Sowang's resistant toward fire is a form of self-defense to survive in ecosystem. This self-defense effort affects Sowang branching and developmental phase. In this case, Sowang branching and developmental phase is tightly related with the regeneration ability. Besides qualitative methods above, there is a need of quantitative indicator to show Sowang population ability of self-defense to survive from extinction. The threat to extinction particularly comes from the disruption activities by local people through forest burning and logging. The indicator explained above was a dominance level, which was analyzed using Importance Value Index (IVI) of seedling and an affect of environmental factor toward individual amount of Sowang seedling. Environmental factor, which were observed, are crown covering, light intensity, air temperature, soil temperature, humidity, soil moisture, and soil pH.

A

B

C

D

Figure 1. *Xanthostemon novaguineense* Valet. A. Regenerant in the burning area (three years old), B. Flower, C. Fruits, D. Leaf. Bar = 5 cm.

MATERIALS AND METHODS

Time and area study

This research was performed in Doyo Baru, Sub District of Waibu and Maribu, and Sub District of Sentani Barat, District of Jayapura, Papua. The research location is kind of unfolded area of tropical forest ecosystem. The forest in Doyo Baru is a secondary forest that is deliberately burned repeatedly. The last burning was performed ± 3 years before this research. After the last burning, BKSDA (Nature Conservation Agency) of Papua planted *Podocarpus neriifolia* and *Anacardium occidentale* species as reforestation plants.

Because of its same unfolded area, species existed before the burning and logging were assumed alike with species at the natural forest. By the traditional society, forest at Maribu is divided into forest for logging activity and natural forest. Logging area is a natural forest which the pillars and the trees are cut selectively, so the crown covering still dense. Tree species that are cut are *X. novaguineense, Calophyllum* sp., *Pometia* sp., *Homalium foetidum* and *Intsia bijuga*. If the pillar and tree level of those species are totally cut in one area, logging activity will be moved to another area at the same forest. At the sampling location, the last logging was done ± 3 years ago.

Study design

The research was designed with quasi-experiment. Natural forest was assumed as control. Sample acquisition was performed in Kampung Doyo Baru to represent burning area, and at Kampung Maribu to represent logging area and natural forest. The sampling area has 85-142

meters above sea level, the height level was measured with altimeter while clinometer was used to measure the slope. The last time of burning and logging activities is ± 3 years.

Procedures

The methods of data collection for testing are categorized into three steps, (i) branching and development phase of Sowang, (ii) Importance Value Index (IVI), (iii) The effect of environmental factors towards Sowang seedling. In first step, branching and developmental phase of Sowang, observations branching and flowering period of Sowang were done. The observations that performed comprised were: (i) sowang branching from seed and stem shoot in the burning area, logging area, and natural forest; (ii) flowering phase and flowering frequency of Sowang individual from seed and stem shoot in the burning area, logging area, and natural forest.

The second step was to find the Importance Value Index (IVI). Sampling unit was a transect line with sampling plot sited crossly at the left and right parts of line, with 10 meters length between plot. Transect placing was done systematically with regarded of the border affect. Plot placing in the burning and logging areas were determined by the estimate of same land height and last time in logging and burning activity. Meanwhile, plot determination in natural forest was conducted based on the height level approximation of the same places.

Each sampling area was assumed homogeneous because there are a limitation in the last time of burning, logging, and the limitation of land height. Sampling size for each sampling area proportionally appropriated with the wide of each sampling area. It is estimated that the wide of burning area is 20 ha, logging area is 30 ha, and natural forest is 50 ha. There were two tracks of transect at the burning area, which each had a 110 meters and 100 meters length between tracks, 20 sample plots are obtained. Transect direction was upright of contour. At the logging area, there were three tracks of transect, which had a 110 meters length for each and entirely 30 sample plots. At the natural forest, there were five tracks with the length was 110 meters for each, 50 sample plots are obtained entirely. In the logging area and natural forest, transect direction was upright towards river stream direction. Tree community analysis of vegetation was done to gain the importance value for Sowang seedling population. Sampling technique was set by determine 2 meters x 2 meters, and bordered using measure tape. Data collection technique included individual and type census for every plot. Vegetations that been found were collected as herbarium, for identification requirement. Stand criteria for tree plants, which were, belong to the seedling class was ≤ 1.5 meter height.

The last step was collecting data to determine the effect of environmental factor towards Sowang seedling. Data collecting was done in the sampling plots sized 10 meters x 10 meters at transect with no regarded to the border affect. Transect was placed at the burning area, logging area, and natural forest systematically in two tracks. The data, which were taken, were: (i) crown covering (%), which was measured by comparing the wide of crown opening area with the plot area. The crown covering percentage per plot is a unit data of experiment; (ii) light intensity (Wm^{-2}), the measurements were performed on land surface at 12.00-13.00 o'clock. The measurements used lux-meter in every corner and center of plots. The average of light intensity that was obtained per plot is a unit data of experiment; (iii) air temperature (ºC), with determinations of daily temperatures were done 2 times a day, 08.00 and 16.00 o'clock in every plot. The air temperature measurements were performed with thermometer placed under the crown (± 0.5 above land surface) in every corner and center of plots. The average of air temperatures per plot is a unit data of experiment; (iv) soil temperature (ºC), the measurements of soil temperature were performed in ± 30 cm depth with 3 times repetition in every plot. The average of soil temperatures per plot is a unit data of experiment; (v) humidity (%), the humidity measurements were performed 2 times a day, which were 08.00 and 16.00 o'clock in every plot. The measurements were done using hygrometer placed under the crown (± 0.5 m above land surface) in every corner and center of plots. The average of humidity per plot is a unit data of experiment; (vi) soil moisture (%), the measurements were performed by soil sampling in ± 30 cm depth compositely with 3 times repetition in every plot. The water content calculation was performed by gravimetric, using oven and weights. The percentage of soil moisture per plot is a unit data of experiment; (vii) soil pH, the measurements were performed directly by soil pH meter in ± 30 cm depth. Repetitions were done 3 times in every plot. The average of soil pH per plot is a unit data of experiment; (viii) population density (individual amount) of breeds, the calculations of individual amount of Sowang breed were performed in every plot. The amount of breed individual in every plot is a unit data of experiment.

Data analysis

To interpret the obtained data, the following tests were done: (i) branching and developmental phase of Sowang,. qualitative data of branching and developmental phase of Sowang from seed and stem shoot at the burning area, logging area, and natural forest was tested by descriptive analysis; (ii) Importance Value Index (IVI), IVI are counted with the formula IVI = Rd + Rf, with the components are Relative density (Rd) and Relative frequency (Rf). Rd is a proportion between the individual total of certain species with individual total of all species in sampling units. Rf is a proportion between certain species frequency with total frequency of all species in sampling units. The calculation of Rd and Rf values was performed toward each of tree plant species in sampling units. IVI values of all species were calculated in every burning area, logging area, and natural forest; (iii) the effect of environmental factor towards seedling population density, the difference of environmental factor in the burning area, logging area, and natural forest were showed by Analysis of Variance (ANOVA) and LSD α 0.05 through the model:

$$Yij = \mu + \rho i + \epsilon ij; \text{ and}$$

$$LSD\ \alpha\ .,05 = t\ \alpha\ 0.05\ (2\ s^2/r)^{1/2}$$

Multiple regression analysis was used to show the effect of environmental factor towards seedling population density. The equation model of doubled regression analysis is formulated as:

$$Y_i = b_0 + b_1x_{i1} + b_2x_{i2} + b_3x_{i3} + b_4x_{i4} + b_5x_{i5} + b_6x_{i6} + b_7x_{i7}$$

Multicollinearity test was used by correlation analysis of inter free variable. If multicollinearity occurred, one of the variables will be rejected.

RESULTS AND DISCUSSION

Branching and developmental phase of Sowang

Sowang includes in Myrtaceae family. Sowang is a type of plant, which shoot will be able to grow after its above-ground-stem is cut or burned. More than one shoots or branches will be growth from the trunk. This branching is not a monopodial type as the Sowang individual growth from seed because the primary stem stops the growth. According to research result of Wilson (2000), lateral bud or branch growth on the direct sun lighted plant are stimulated by activity of cytokinin hormone concurrently with sunlight stressing on the activity of auxin hormone to trigger the development of primary stem.

Myrtaceae has an amount of fire-resistant plant genus. Study results by Burrows (2002) show that genus of *Angophora, Eucalyptus,* and *Lophostemon* has an epicormic bud which able to produce stem and branch after burned. An epicormic shoot is a bud under the bark of a stem or branch of a plant, or a shoot (water sprout) growing from such a bud. Epicormic buds lie dormant beneath the bark, their growth suppressed by hormones from active shoots higher up the plant. Under certain conditions, they develop into active shoots such conditions may include damage to higher parts of the plant, or increased light levels following removal of nearby plants.

Dormant axillary buds allow plants to repair minor damage to their canopies. In woody plants, these buds subsequently develop into epicormic structures that may allow vegetative recovery after major disturbances. All investigated Myrtaceae species had an excellent meristem reserve for recovery of photosynthetic capacity after minor canopy damage and for developing epicormic structures for sprouting after more severe damage (Burrows et al. 2008).

In this territory, all burning residual stem able to grow shoot. Sowang derived from this stem shoot are able to flowering despite still on the seedling size. Resultant flower can produce fertile seed. Flowering phase is occurred all seasons. Small and light seed ejected from fruit split on the tree reinforces the assumption that seeds are spread by wind. Due to the statement of Sera and Sery (2004) that the plants that produce much seeds with relatively small size generally spread the seeds by wind.

Sowang is much more found in gardening zone. Gardening zone is an area which undergoes repeated burning. It cause Sowang never grow to be adult phase in gardening zone. This is congruent with result of the research of Hoffmann et al. (2003) which shows that individual productivity of tropical forest is about 2 times compared with savanna individual, but need longer time to reach production maturity in successive forest burning if the interval of burning time is short.

Maribu is a sampling area for logging area and natural forest. Here, logging activity is selectively performed to take woods based on needs. Sowang wood is taken only for special concern such as for house pillars of tribal chief. Logging activity is impossible to be performed if the wood wants to be taken in the tree dimension, so the tree should first be downed by burning its root. Therefore, there is no trunk remained from Sowang tree for shoot to grow. In the natural forest, none of the individual of Sowang is found derive from shoot, all of them are derived from seed.

In the logging area and natural forest, pillar sized Sowang and Sowang tree derived from seed are not in flowering. Flowering frequency is occurred once a year. This is due to the observation of Australian National Botanic Gardens (2003) that *X. verticillatus* natural flowering time is spring, but in the glasshouses at the Australian National Botanic Gardens it flowers all year round with masses of flowers all summer. Flowering is enhanced with warmth and high light intensity.

Branching of Sowang, which is derived from side-widen stem shoot at low-level land, is placing Sowang seeds on growth media (soil) which appropriate with germination requisite of Sowang seed. At that condition, plus with the frequency different of flowering, Sowang from stem shoot produces more seedlings than Sowang from seed. Seed from Sowang derived from seed has low probability to stick on appropriate and 'desired' growth media in the case of its mild weight and dependence on wind direction.

Importance Value Index (IVI)

Analysis resulted eight tree species, which had highest seedling IVI at each sampling area. Analysis results then compared by tabulation with dominance level of Sowang seedling in Table 1. Table 1 indicates that Sowang seedling population at burning area was dominance population in its community. In the burning area and natural forest, Sowang seedling was not included into dominance population, moreover, not found in the logging area.

Ex-burning area is a suitable environment for Sowang germination and seedling live, proved by Sowang seedling's high IVI. Only certain plant can live after burning event. This phenomenon shows that environmental factors in this area fulfill the needs for Sowang germination, also for its seedling growth and branch out. A certain species can be dominant if it able to use the environmental factor so that affect community. According to Richards et al. (2003), *Xanthostemon* belongs the genus that has the low photosynthesis activity, high transpiration rate, and needs high concentrate Mn. *X. formosus* species needs water in great amount, for that reason this species easily found in the riverside. Meanwhile, *X. chrysanthus* can grow under various environments, although it is naturally found in riparian rain forest. On the other hand, Woinarski et al. (2000) report *X. paradoxus* in Australia has its best habitat in open forest.

Table 1. Highest seedling IVI of tree species and Sowang seedling IVI in the burning area, logging area, and natural forest.

Sampling area	Species	Rd (%)	Rf (%)	IVI (%)
Burning area	*Podocarpus neriifolia*	33	37	70
	Xanthostemon novaguineense	30	37	67
	Stenocarpus beccari	27	7	34
	Decaspermum fruticosum	4	3	7
	Gordonia papuana	1	3	4
	Anacardium occidentale	1	3	4
	Rhodomyrtus sp.	1	3	4
	Casuarina rumphiana	1	3	4
Logging area	*Pometia pinnata*	6	6	12
	Mallotus sp.	7	5	12
	Calophyllum sp.	5	6	11
	Intsia bijuga	6	5	11
	Rhodomyrtus sp.	6	5	11
	Alstonia scholaris	5	5	10
	Eugenia sp.	4	5	9
	Syzygium sp.	6	4	10
	Xanthostemon novaguineense	0	0	0
Natural forest	*Calophyllum* sp.	15	15	30
	Litsea sp.	23	1	24
	Rhodomyrtus sp.	4	5	9
	Xanthostemon novaguineense	4	3	7
	Canarium sp.	4	3	7
	Diospyros sp.	3	4	7
	Pometia pinnata	2	4	6
	Elaeocarpus sp.	2	4	6

Although Sowang breed is able to compete with introduced *Anacardium occidentale*, it is not yet able to equal the domination. *Podocarpus neriifolia* is also introduced as a greening plant. The worry that *Podocarpus neriifolia* become the threat for Sowang domination can be occurred, as it is happened in *X. verdigonianum* and *X. philippinensis* in Philippines. Baguinon et al. (2003) explained that *X. verdigonianum* and *X. philippinensis* are endemic species in Philippines. These species grow unhealthy on ultrabasic land. Ultrabasic land is not optimum environment for those species. It is worried that those endemic species cannot compete with an introduced exotic species. The introduced species is a reforestation plant that has a wide tolerant interval toward environmental factor.

In addition, there was a different of seedling species, which dominated burning area, logging area, and natural forest. If assumed that natural forest is a control area, environmental change resulted of human behavior and activity was occurred in the burning and logging area. This is congruent with the research by Bischoff et al. (2005) concerning secondary succession caused by forest logging in Dipterocarpaceae Kalimantan forest. The research results show that logging can cause the secondary succession. Secondary succession in the lowland of Dipterocarpaceae Kalimantan rainforest is affected by conversion sequence of primary forest after reforestation. The succession process that is happened depends on the composition of remain plant species and the invasion of plant species from outside. These situations show the uncertainty of which type of forest will be growth.

Table 1 also shows that difference of dominant breed species is much more found in burning area if it is compared with control area, which was natural forest. This phenomenon is supported by the statement of Stolle and Lambin (2003) that the influence of flamed forest is greater than logging activity, which fire negatively affects species diversity. However, in long-term condition, the remains of unfired forest can be used as one of the source for tree species spreading which locally extinct by burning event. This is supported by statement of Platt and Connel (2003), that the consequence of fire disruption has a similar effect to natural disturbances. This disruption will cause significant changes that will form the natural variability in species composition.

The effect of environmental factor towards the amount of Sowang seedling

ANOVA and LSD α 0.05 results for the effect of environmental factor towards the amount of Sowang seedling are showed in Table 2.

Percentage decreasing of crown covering in the burning area is followed by increasing of light intensity, air temperature, and soil temperature, and decreasing of humidity. Soil moisture in these three sampling area are not show significant different, environmental factor of underground plant generally has changed with relative slow fluctuation. The change of soil pH which burning and logging area's pH is lower than at natural forest was caused by decreasing of humus partly washed by burning event, included alkali cations. An observation by Handayani and Prawito (2002) on post deforestation land in Bengkulu, Sumatra, showed there are significant differences between the post combustion logging soil and the forest soil pH. Post combustion logging soil pH is 5.48, lower than forest soil pH, 6.4. This is appropriately fit to the research result of Markewitz et al. (2004) which said need a long time to increase soil pH to the initial state in Amazonia secondary forest after burning.

In multicollinearity analysis between freedom variables, there are correlation coefficient score 0.923, 0.590, and 0.501 between crown covering with light intensity, air temperature with humidity, and air temperature with soil temperature. In the case of its effect is assumed equal, further analysis will use light intensity and air temperature variables. Analysis results are showed in Table 3.

Table 3. Multiple regression coefficient of the effect of environmental factor towards the individual amount of Sowang seedling.

Variables	B	Sig.
Constant value	17.683	0.610
Light intensity	0.015	0.000
Air temperature	−1.394	0.244
Soil pH	3.342	0.283

Regression equation obtained is: $Y = 17.683 + 0.015x_2 - 1.394x_3 + 3.342x_7$, $R^2 = 0.404$. In the degree of confident 99%, light intensity and crown covering affect the

Table 2. Crown covering average, light intensity, air temperature, soil temperature, humidity, soil moisture, and soil pH in the burning area, logging area, and natural forest.

Environmental factor	Burning area	Logging area	Natural forest
Crown covering (%)	20.526±6.06 b	72.143±12.48a	68.000±20.46a
Light intensity (Wm^{-2})	1542.105±208.44a	357.143±175.04b	555.556±399.62b
Air temperature (ºC)	31.737±0.85a	28.571±0.73b	29.333±0.86b
Soil temperature (ºC)	29.105±1.06a	26.143±0.35b	26.000±0.38b
Humidity (%)	53.368±2.92b	68.000±6.90a	65.444±4.31a
Soil moisture (%)	35.084±2.46a	35.447±9.99a	33.292±9.44a
Soil pH	6.000±0.36b	5.786±0.50b	6.678±0.32a

Note: that average values followed by same letter at the same row is not significant at LSD α 0.05

individual amount of Sowang seedling. The individual amount of Sowang seedling will rise if an escalation of light intensity is occurred. On the other hand, the increase of crown covering causes the decrease of Sowang seedling amount. Franklin et al. (2005) noted that light intensity is amongst the most important environmental cues regulating plant development. In addition to light quantity, plants measure the quality, direction and periodicity of incident light and use the information to optimize growth and development to the prevailing environmental conditions. The research results of Pearson, et al. (2002) also showed that the percent germination of seeds of pioneer plants in Panama is influenced by light intensity and seed's mass but not influenced by fluctuations in the surrounding temperature.

Environmental and genetic factors give a large influence in population growth of certain species. The principle of Berryman (2003) said that every population grows with the constant rate logarithmically, except if it is influenced by other power or energy in its environment. Dynamic prediction of population is defined as a deviation of function value from biotic factor, abiotic factor, and genetic trait. This fact is occurred in *Acacia rigens*, *A. wilhelmiana*, *Triodia scariosa*, and *Eucalyptus* sp., mainly by the environmental influence. The research results by Cohn and Bradstock (2000) show that the frequency increase of low precipitation with weeds consumption interaction by herbivore decreases the germination ability of species seeds. This event causes rareness of the former species in latest 8 years. In the remains of burning area at the foothill of Cycloop Mountain, that event is not occurred in Sowang species. It shows that the environment with the post-burning environmental factor is an optimum environment for the germination of Sowang seeds.

CONCLUSIONS

Sowang branching derived from shoot in the burning area shows halted growth of primary stem. Sowang stem derived from seed grows monopodially. Sowang seedling and stake derived from stem shoot in the burning area has entered the flowering phase, which are occurred all seasons. Sowang derived from seed in the logging area and natural forest is flowering in the tree level for once a year. Sowang seedling's IVI in the burning area is higher than in logging area and natural forest. Environmental factors, which affect the amount of Sowang seedling were light intensity and crown covering. The amount of Sowang seedling will rise if the increase of light intensity is occurred. On the other hand, the increase of crown covering causes the decrease of Sowang seedling amount.

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