

Biodiversity enrichment in KHDTK Wanadipa forest based on agarwood plants (*Auricularia malaccensis* Lamk)

Jafron W Hidayat^{1,2}, Sri Puryono KS^{2,3}, Yayuk Astuti⁴, Pratama J. Wibowo⁴

¹) Department Biology, Faculty Science and Mathematic Diponegoro University, Semarang

²) Kantor KHDTK Wanadipa, Diponegoro University Semarang, wasiqjep@gmail.com

³) Postgraduate School, Diponegoro University Semarang

⁴) Chemical Department of Science and Mathematics, Diponegoro University, Semarang

Abstract. Forests have enormous functions for life, unfortunately continue to experience a decline in quality. The condition of biodiversity also continues to be under pressure. On the other hand, Diponegoro University, Undip as a research university considers to prepare environmental concern instruments as educational forest. The aim of the research is to determine the biological richness of tree stands in Kawasan Hutan Dengan Tujuan Khusus (KHDTK). It is also to study the physical and chemical conditions, especially as a basis for vegetation enrichment with a valuable agarwood plants. The results of the study showed that the species that had great importance value in terms of seedlings and trees were *Dalbergia* (72%), *Leucaena* (44.109%) and *Cassia siamea* (13.199%). These species have very high reproduction rates and adaptability, since enable to produce many seeds. Indigenous forest tree, especially teak, have low important value because they have illegal logged before. There was no agarwood species or relative species found here. The soil and terrain conditions for enrichment with agarwood, are very suitable, although the slope is not really ideal. Slopes related to erosion and lead to poor soil nutrition. Alignment of planting through intercropping farming has great prospects for farmer, especially in relation to ecological and economic benefits.

1 Introduction

Forests have enormous functions and values for life, both in economic, ecological and social aspects. Forest provide habitat for biodiversity, natural service, food sources, education instrument, ect [1][2]. Unfortunately, forest areas continue to experience a decline in quality, both due to management capacity and increasing change in land usage. So far, the relationship between forestry authorities and the surrounding community is still not harmonious, so that the interaction that has developed has not provided benefits for both. The condition of biodiversity, therefore, is also under pressure and requires more initiatives. The government has adopted a social forestry system in the forest, including through the management of KHDPK (Forest Areas with Special Management) and KHDTK (Forest Areas with Special Purposes). Community activities in this area are still focus on agricultural activities which tend to be unsustainable. The principles of KHDTK management are aimed at ensuring that

conservation aspects can be consistently maintained [2]. The institution which have the opportunity to propose this management involve universities, including Diponegoro University (Undip). As a best university, Undip need to contribute in developing a forest and environmental management instrument through research and development functions.

Undip obtained this area through the designation of a Special Purpose Forest Area (KHDTK) by the Minister of Environment and Forestry, as regulated in the Decree of the Minister of Environment and Forestry Number P.15/MENLHK/SETJEN/KUM.1/5/2018. This area functions as a laboratory to carry out research and development activities. These tasks include preserving natural resources, which have educational and research functions.

As far as management goes, there are obligations that must be carried out, including carrying out an inventory important resources in KHDTK, they are the richness of vegetations/flora. In the KHDTK area there are several stands of trees, including mahogany, gmelina wood and rosewood [3]. The other forest areas are still dominated by shrubs which require to be managed optimally. Development program at KHDTK are focus to maintain land sustainability by rehabilitation activity, including by enriching biodiversity, especially those related to land productivity. Among the potentially valuable commodity, namely the Gaharu or agarwood tree (*Alaucaria mollucana*). Agarwood is generally a valuable wood inhabitat in forests, including areas under canopy shadow [1;4]. In terms of conservation status, agarwood or gaharu is included in Appendix II (potentially threatening species) listed by CITES [4;5].

Agarwood produce a special resin which is used in the perfume and aromatic industries [5;6]). The chemical compounds produce are sesquiterpenes, 2-(2-phenylethyl)-4H-chromen-4-one derivatives (PECs), and aromatic compounds. These phytochemicals showed various pharmacological properties such as anti-inflammatory, cytotoxic, neuroprotective, anti-diabetic, anti-bacterial, etc.

Before implementing enrichment, however, it is very important to identify community structure of vegetative resources as well as physical- chemical conditions, especially in supporting gaharu introduction. In doing biodiversity enrichment, the stage is very long and must be carried out carefully to avoid ecological side effects. Based on experience from other enrichment in previous localities and places; enrichment of agarwood does not cause significant ecological impact [7]. Therefore, it is necessary to adopt the success of other locations, ie in KHDTK. Therefore, initial studies and research must be carried out, especially the critical environmental factors related to the life suitability of agarwood plants, as done by [1;2;5].

The aim of the research is to determine the biological richness of tree stands in KHDTK. It is also to study the physical and chemical conditions of the environment, especially as a basis to support biological enrichment with agarwood plants. Increasing biodiversity and forest productivity can provide many benefits for community as well.

2 Research method

The research was observational and was carried out in May 2023. The location was carried out in the KHDTK area which was represented by observation points based on the vegetation covers (5 zones) that had been determined. The research was performed by sampling at five repetitions using systematic random sampling. Sample was taken by applying a transect line where plant biodiversity measurements were carried out using quadrants method (5x5 m). Physical and chemical factor measurements are also carried out both in-situ and ex-situ, including temperature, humidity, pH; while the nitrate, phosphate and potassium content was carried out in the Environmental Engineering laboratory Undip

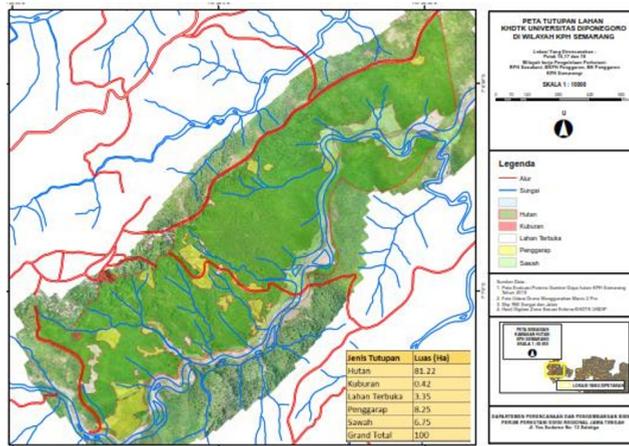


Fig. 1. Map of KHDTK based on vegetation cover

For vegetation analysis from the results of data collection in the field, the results of observations are recorded and enumerated to determine quantitative vegetation parameters such as: Density (K), Frequency (F), and Dominance (D) of the tree, pole, sapling and seedling strata. To determine the level of dominance of species in a plant community, the Important Value Index (INP) is used according to Odum [8]. The Important Value Index (INP) for the seedling and sapling levels is the total of the Relative Density (KR) and Relative Frequency (FR) values. Meanwhile, the Important Value Index for the pole and tree level is the sum of the Relative Density (KR), Relative Frequency (FR) and Relative Dominance (DR) values. The general formula is as follow:

$$\text{Species Density (K)} = \frac{\text{Total individu of species } i}{\text{Size of the plot}} \quad (1)$$

$$\text{Relative Density (KR)} = \frac{\text{Special Density}}{\text{Total Species Density} \times 100\%} \quad (2)$$

$$\text{Species Frequency (F)} = \frac{\text{Number of plot of } i \text{ species found}}{\text{Number of plot observe}} \quad (3)$$

$$\text{Relative Frequency (FR)} = \frac{\text{Species Frequency of } i \text{ species}}{\text{Total Species Frequency} \times 100\%} \quad (4)$$

$$\text{Species dominance (D)} = \frac{\text{Size of the canopy base}}{\text{Plot size}} \quad (5)$$

$$\text{Relative Dominance (DR)} = \frac{\text{Species dominance of } i \text{ species}}{\text{Total Species dominance} \times 100\%} \quad (6)$$

$$\text{Important Value Index (INP)} = \text{KR} + \text{FR} + \text{DR} \text{ (for tree and pole)} \quad (7)$$

$$= \text{KR} + \text{FR} \text{ (sapling and seedling)} \quad (8)$$

Determination of the feasibility enrichment with agarwood plants is carried out according to the criteria determined by Wahyudiono and Kurniawan [1], namely using 5 environmental indicators including land use, soil type, height, rainfall and slope. The criteria that can be used are divided into 3 qualifications, namely suitable, least suitable and not suitable. In terms of soil conditions, the determination is based on references, including Hamdan et al [5] and Mat et al [9].

3 Result and discussion

3.1. Tree biodiversity condition in KHDTK

The results of observations found that there were 60 species of trees found in KHDTK at various strata. The diversity of the trees here tends to be greater compare to other forest areas, such as in the Perhutani Gunung Karang Banten area which only reaches 40 species [10] or in the Ledug Tahura R Soerja forest which reaches 16-22 species [11]. This difference seems to be related to the enrichment done in KHDTK before that focused to MPTS (Multi Purpose Tree Species) plants based on social forestry regulation. When observing vegetation conditions, especially groups of woody trees, it is known that each growth level has a different important value (IP) for at least the three main dominant species. At the seedling level, the species that have the greatest importance are *Dalbergia latifolia* (72%), *Leucaena leucocephala* (44.109%) and *Cassia siamea* (13.199%). These three species have high reproduction rate, even *L. leucocephala* has become invasive [12]. They are belong to family Leguminocea that produces many seeds and some adaptive in hard/ dry condition. Beside, all three species are strong in competition, especially in denser conditions and shadow below the canopy. At the sapling strata, The first two species are still stand out and are followed by the Gamal (*Glerecidae* sp) as the third dominant reaching a value of 96,01; 47,51 and 42,24% respectively. Gamal also has strong regeneration manner, even by vegetative planting, and is resistant to competition. This plant is also often used as a weed repellent plant, due to its strong competition. This plant, however, is useful as a goat feed, so it is often pruned regularly and thus is resistant in growth.

At the level of pole strata, the species that have great importance IP are rosewood, gmellina and mahogany with index values respectively 72.609; 33,909 and 25,257%. Gmellina, a non-wood forest plant, is cultivated by Perhutani apart from mahogany and rosewood, to repel ilalang grass and feed stock for ruminant. Mahogany has the great ability produces a lot of seeds and to disperse close together. The seeds are equipped with wings, therefore increasing the spread and survival potential of the offspring. The high number of diversity is also due to reforestation activities to support conservation for many year before. These additional species include kluwih *Arthocarpus*, guava, mango, jackfruit and sengon wood

Plant diversity at the tree level is the lowest, compared to other plant strata where only 20 species were found, including forest wood and MPTS plants. This related to forest management by perhutani which select certain tree species. The forestry plants cultivated by Perhutani are mahogany, teak, rosewood and Gmellina., Teak is among a species with a relatively small population, due to illegal logging during the national reform period. However, there is an increased chance associated with the number of poles strata that grow from the remaining of the previous tree (*tunggak=jw*), as regeneration. Sengon is a species of forest tree, but it is cultivated by the community, it is not replanted by Perhutani. The non-timber forest plant cultivated by Perhutani is Gamal (*Gleresidae* sp), which was initially used as reforestation seed stock for various Perhutani locations. Currently it is no longer used for seeds stock, however, it is now a source of cattle feed for the community. This species is very resistant to survival and easy to propagate, so it needs to be managed both for its invasion potential and its benefits for livestock (bees and ruminants). This species is also can be produce to be charcoal with quite high heat (calorie); so that the pruning remaining can be potentially used as renewable fuel in the form of briquettes

Table 1. Biodiversity and Important Value (IV) of tree in KHDTK Wanadipa Undip, Semarang.

No	Local Name	Latin Name	seedling		sapling		pole		tree	
			Total	IP	Total	IP	Total	IP	Total	IP
1	Sonokeling	<i>Dalbergia latifolia</i>	175	72,01	101	96,01	75	72,61	18	29,13
2	Akasia	<i>Acacia mangium</i>			1	1,62				
3	Akasia	<i>Acacia auriculiformis</i>					2	2,58	1	2,08
5	Cepokak	<i>Solanum torvum</i>			1	1,06				
7	Lamtoro	<i>Leucaena leucocephala</i>	119	44,11	61	47,52	5	5,88		
8	Johar	<i>Cassia siamea</i>	26	13,19	7	8,96	14	14,69	13	21,29
9	Mahoni	<i>Swietenia macrophylla</i>	17	11,87	13	11,82	21	25,25	52	66,57
10	Jati putih	<i>Gmelina arborea</i>	18	9,57	13	13,12	30	33,91	54	62,45
11	Gamal	<i>Glirisidea sepium</i>	21	8,96	45	42,24	7	7,25		
12	Mulwa	<i>Annona reticulata</i>	18	8,31	5	6,63	13	14,48		
13	Salam	<i>Syzygium polyanthum</i>	13	4,71	2	2,28	4	4,15		
15	Pulai	<i>Alstonia scholaris</i>	11	3,65	10	9,80	12	12,12		
16	Asam londo	<i>Pithecellobium dulce</i>					1	1,23		
17	Kenanga	<i>Cananga odorata</i>					3	5,48		
18	Kesambi	<i>Schleichera oleosa</i>	8	3,62			8	6,98		
19	Flamboyan	<i>Delonix regia</i>	6	2,56	2	2,29	6	6,73	11	15,29
20	Petai	<i>Parkia speciosa</i>			1	1,22			1	1,96
21	Ploso	<i>Butea monospera</i>	6	2,56						
22	Awar-awar	<i>Ficus septica</i>	2	1,06						
23	Duwet	<i>Syzygium cumini</i>	2	1,06			1	1,31		
24	Jambu air	<i>Syzygium aqueum</i>			1	1,11				
25	Jambu dersono	<i>Syzygium malaccense</i>					1	1,32		
26	Jambu klutuk	<i>Psidium guajava</i>	2	1,06						
27	Jarak	<i>Ricinus communis</i>	2	1,06						
28	Jati	<i>Tectona grandis</i>			3	1,33	13	14,27	15	21,59
29	Sengon Jawa	<i>Albizia chinensis</i>	2	1,06					3	13,49
30	Sengon Laut	<i>Paraserinathes falcataria</i>					5	5,79	4	4,65
32	Perdu	<i>Flacourtia sp.</i>	2	1,06						
33	Asam jawa	<i>Tamarindus indica</i>	1	0,84	2	2,92	2	2,89		
34	Kaliandra	<i>Calliandra calothyrsus</i>	1	0,84						
35	Kudo	<i>Lannea coromandelica</i>			1	1,17				
36	Jambu klutuk	<i>Psidium guajava</i>			1	1,38	2	2,61		

No	Local Name	Latin Name	seedling		sapling		pole		tree	
			Total	IP	Total	IP	Total	IP	Total	IP
37	Jambu mete	<i>Anacardium occidentale</i>			3	2.94	2	2.69		
38	Kedawung	<i>Parkia timoriana</i>			1	1.45				
39	Kepuh	<i>Sterculia foetida</i>			1	0,66				
40	Kesambi	<i>Schleichera oleosa</i>			4	5.21			1	2.21
41	Kaliandra	<i>Calliandra calothyrsus</i>					2	1.93		
42	Kersen	<i>Muntingia calabura</i>	1	0,84						
43	Kluwih	<i>Artocarpus camansi</i>					6	8.56	8	13.15
44	Kopi	<i>Coffea sp</i>					2	2.40		
45	Luwing	<i>Ficus hispida</i>			2	1,33	3	4.51		
46	Mangga	<i>Mangifera indica</i>	1	0,84	3	4.68	7	8.47	6	10.17
47	Mindi	<i>Melia azedarach</i>	1	0,84	1	1.34	3	3.94		
48	Nangka	<i>Artocarpus heterophyllus</i>			3	2,00	2	2.91	2	2.97
49	Alpukat	<i>Persia americana</i>			4	0.68	2	2.71		
50	Ploso	<i>Butea monospera</i>					2	2.53	2	4.94
51	Ragen.	<i>Lasianthus sp</i>					2	2.54		
52	Randu	<i>Ceiba petandra</i>			2	2.98	3	4.15	11	18.85
53	Rojo serut	<i>Streblus asper</i>			1	0,66				
54	Senu	<i>Melocia umbellata</i>	1	0,84	1	0,66			2	2.57
55	Sirsak	<i>Annona muricata</i>	1	24,51	2	2,00	2	2.44		
56	Siwil Kutil	<i>Pterocymbium javanicum</i>			2	1.40	1	1.34	1	2.02
57	Tanaman	<i>Leea javanica</i>	1	24,50						
58	Trengguli	<i>Cassia fistula</i>	1	24,51	1	1.32	2	2.71	1	2.08
59	Turi	<i>Sesbania grandifolia</i>			4	1.33	3	3.14	1	2.48
60	Waru	<i>Hibiscus tiliaceus</i>					1	1.42		

In relation to enrichment based on agarwood plants, the research by Mulyaningsih and Marsono [15] showed that in the agarwood ecosystem area, there are 144 species of plants with high biodiversity. This indicates that agarwood can be planted in areas with various types (polycropping). The main vegetation composition of the agarwood tree ecosystem includes *Cocos nucifera*, *Annona pinnata*, *Mangifera indica*, *Theobroma cacao*, *P. javanicum*, *Arthrocarpus heterophyllus*, *G. versteegii*, Ficus group, *Mangifera sp.*, *Anacardium ocentale* and *E. orientalis* [15]. These species, especially *Annona* spp, *M indica*, *Anacardium* and various species of ficus also grow a lot in KHDTK, so that direct and indirect interactions in enrichment of Agarwood plants are quite safe to do [14]. However, a series of other bio-ecological studies are need to be carried out, both in-situ and ex-situ.

3.2. Physical and chemical condition toward agarwood enrichment.

From the results of observations, as mentioned in the data above, it is known that there is no species of Agarwood or relatives have been found in KHDTK, either in farmer area/ plots or forest plots. Agarwood plants have not been planted in this area and technically have not been taken into account by Perhutani before. This plant has valuable value, so it can be an alternative for biodiversity enrichment [4]. In doing so, the stage is very long and must be carried out carefully to avoid ecological side effects, aware to physic and chemicap factors as well.

According to the East Java Provincial Forestry Service[6] *Aquilaria* sp. can grow well on podzolic soil, altitudes from the lowlands to 850 meters above sea level (some report 300-750 meters above sea level), temperatures between 20-33 °C, rainfall 1000-2500 mm/year, humidity ranging from 77-85%, hilly soil, light intensity between 56-75%, as well as fertile soil, porous and good drainage. Based on these conditions, the KHDTK Wanadipa Undip area has a similar range of environmental factors. Environmental conditions at KHDTK are as shown in Table 02. The altitude of the location is already at 250 m above sea level, the land is hilly with a slope predominantly of 15-25% (rather steep). Rainfall tends to be high, reaching an average of 2,314 mm/year. In terms of slope, the land tends to be more stepper

Table 2. Physical and chemical conditions of soil in KHDTK

No	Soil Condition	value	references
1	Altitude (m swl)	100 – 250	300 -750*
2	Temperature (°C)	21-35	20-33*
3	Rainfall (mm/ year)	2.314	1000-2500*
4	Humidity (%)	45 - 80	77-85*
5	pH	6-7	5,95-6,67**
6	Ligh Intensity (%)	50-85	56-75*
7	Soil type	Clay	Podzolic*
8	Nitrate (%)	0,012 -0,147	0,09 -0,11**
9	Phosphate (%)	0,004 – 0,012	4-5** (mg /kg)
10	Kalium (%)	0,002- 0,041	3-7 (%)** Potassium
11	Soil Organic (%)	0,821 – 8,059	1,32 - 1,62**

Notes : * Dinas Kehutanan Jawa Timur (2002) ** : Hamdan et al (2021)

in sloping, which triggers critical and barren land due to greater erosion by run-off water. Nutritionally, the conditions for nitrate, phosphate and potassium tend to be low, in this case the values were respectively between 0.012-0.147; 0.004- 0.012; 0.002- 0.041%. The low level of nutrition is related to the slope of the land which stimulates the strong run-off of water to carry away fertile soil layers. According to Tuhehay et al [15] and Suntoro et al [20] land erosion often triggers the formation of critical land that is least fertile. This can be overcome by conservative intercropping of food or feed crops [11]. Forage plants tend to have their green parts pruned while the roots and base can continue to grow

The agarwood growth in a geographical position is influenced by soil factors. Based on land suitability, as stated by Wahyudiono and Kurniawan, [1]; which accompany at least 5 feasibility indicators/ parameters, namely land use, soil type, altitude, rainfall and slope. Based on these parameters, according to Wahyudiono and Kurniawan[1], KHDTK area is categorized in the suitable to plant agarwood tree and qualified at score 2. The only potentially least suitable parameter is slope, which is much broader than 25%, some even reaching 45%. This can be accomplished by selecting the area under the tree forest which is tend to be more stabile. Agarwood is a type of wood that is suitable for planting under tree canopy even if the light level is only 50%, and is not even suitable to be grown in open areas

without shade [117]. Based on chemical factors, especially soil nutrition, it shows that the land is still less fertile, compared to Hamdani et al[5] and the East Java LHK Service [6].

Table 2. Suitability parameter for agarwood planting (Wahyudiono dan Kurniawan, 2016)

No	Parameters	Suitable (S1)	Least suitable (S2)	Not suitable (N)
		Score 2	Score	Score
1	Land use	Forest, Thicket, Moor, Garden, Pasture		Water Bodies, Residential Settlements
2	Soil type	Podzolic	Podsol, Latosol, Uluvial, Organosol	-
3	Altitude	<800 m dpl	900 - 1000	> 1000
4	Rainfall	1000-2500	2500-3600	3600-4800
5	slope	0 - 25 %	25 – 45 %	> 45%

This nutritional deficiency can be compensated for by implementing polyculture practices, where plants will be combined in intercropping way with grass as feed and food crops. The culture of such commodities can encourage farmer to apply fertilizer to the land, while the grass can prevent the potential for land erosion. In general, farmers will fertilize cultivated plants, so that they can also increase soil nutrition for tree growing including for agarwood plants.

4 Conclusion

The condition of plant biodiversity in KHDTK were still high in richness with important species, namely rosewood, gmelina and Glerecidae. The dominance of these three species were associated with the type's reproductive patterns and high competitive adaptability, apart from human intervention.

Enrichment with Agarwood plants in KHDTK is feasible, especially by managing the slope of land that is prone to aridity with nutrient enrichment from composting in accordance with intercropping farming

5 Recommendation

Further step to implement agarwood enrichment research should be undertaken in the field of KHDTK, it is useful not only on the bio-ecological aspect but also its farming practice .

References

1. S. Wahyudiono, Y.A. Kurniawan, *Jurnal Wana Tropika*, **6**, 2 (2016)
2. Permen LHK, Peraturan Menteri Lingkungan Hidup Dan Kehutanan Nomor 7 Tahun 2021 tentang Perencanaan Kehutanan, Perubahan Peruntukan Dan Fungsi Kawasan Hutan, Serta Penggunaan Kawasan Hutan (2021)
3. Universitas Diponegoro, *Pembangunan Kawasan Hutan Dengan Tujuan Khusus (KHDTK) Hutan Penggaron Sebagai Hutan Penelitian Dan Pengembangan*, Dokumen Proposal Universitas Diponegoro (2020)

4. Y. Sumana, *Budidaya Jenis Pohon Penghasil Gaharu*, Departemen Kehutanan badan Penelitian Dan Pengembangan Kehutananpusat Litbang Produktivitas Hutan bogor (2012)
5. M. S. S. Hamdan, M. A. H. Ismail, S. H. N. Shaarani, S. N. Tajuddin, *Material Science Forum*, **1025** (2021)
6. Dinas Kehutanan Provinsi Jawa Timur, *Gaharu (*Aquilaria malaccensis*)* <https://uptpth.dishut.jatimprov.go.id/gaharu-aquilaria-malaccensis/>, (2002)
7. I. K. Surata, Soenarno, , *Jurnal Species dan Konservasi*, **8** (2011)
8. N. Mat, S.A. Rahman, N. Ngah, K. Mahmud, A. Rosni, A. Rahim, *Journal of Nuclear and Related Technologies*, **9** (2012)
9. Y. Hidayat, *Wana Mukti Forestry Research Journal*, **11** (2010)
10. A. Rahadianoro, *Prosiding Biologi Achieving the Sustainable Development Goals with Biodiversity in Confronting Climate Change*, **7**, 1 (2021)
11. P. Sharma, A. Kaur, D. R. Batish, S. Kaur, B. S Chauhan, *Depan. Agron*, **4** (2022)
12. T. Mulyaningsih, D. Marsono, *Ekologi Gaharu *Gyrinops Versteegii* (Gilg.) Domke Di Hutan Lombok Barat*, (Unpublish), Universitas Gadjah Mada (2015)
13. Destri, Z. Mutaqien, A.H. Rozak, **9**, 1 (2020)
14. K. Tuhehay, P. H. Gosal, W. Mononimbar, *Jurnal Spasial*, **6**, 3 (2019)
15. M. A. Suntoro, D. Astiani, W. Ekyastuti, *Jurnal Teng kawan*, **9**, 1 (2019)
16. L. S. Yenti, Adiwirman, Department of Agrotechnology, Faculty of Agriculture University of Riau, *JOM FAPERTA*, **3**, 1 (2016)