INTEGRATION of QFD and LCA for SUSTAINABLE KENAF FIBER GROWTH

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ABSTRACT

The competitiveness and sustainability for kenaf fiber in Bonorowo field is not only concerned on the satisfaction of both customer request and quality preference but also related to the environment. This research proposed to find out the use of LCA on the evaluation of environmental consequences and the using of QFD due to improvement strategies related to kenaf plants growth until the kenaf fiber has been produced in the of bonorowo Laren-Lamongan. Based on the HoQ calculation there are 8 VoC attributes, 2 attributes on environmental aspects and 6 attributes on quality aspects. Two environmental aspects attributes came from the highest LCA results, while 6 quality attributes came from literature and discussions with farmer groups. There are 20 technical responses used as the basis for improvement. The technical response should be followed up by the kenaf farmer groups in the Laren bonorowo field is the use of organic fertilizers, conducting rebonery, drying kenaf fibers in the hot sun, providing indoor winds, weed control (use of herbicides or weeding), installing rat traps in the planting area, harvesting kenaf stalks on time, retting using microbial cultures, using closed tub colt, increasing the price of dry kenaf fiber by Rp. 100/ kg, employing Laren mothers during the retting process, the maximum diameter of kenaf stem ties is 20 cm during the retting process, and the use of personal protective equipment (mask / faceshield) when spraying pesticides and fertilizing.

Keywords*:* LCA, QFD, kenaf fiber, Bonorowo Laren Field

INTRODUCTION

At the time, the need for kenaf fiber is huge. Since, the kenaf fiber developed into a material substitute for Resin in the automotive world, kenaf fiber engaged in the automotive industry in the form of door trim and car interior components (Akil at al., 2011). Furthermore, if all the types of vehicles use kenaf fiber as a vehicle interior material, the demand for kenaf fiber will increase. As the existence of kenaf fiber in Indonesia is limited, some of kenaf fiber should be imported from abroad. Kenaf fiber is produced through the skin of the kenaf plants. So far, farmers have only planted kenaf as an alternative crop, especially for areas with sufficient water supply, such as the Bonorowo field in Lamongan. Kenaf plants are suitable to live in marsh areas that are submerged in water, but if the weather is too extreme, the kenaf plants cannot thrive anymore.

The Bonorowo Laren field is the largest seasonal flood area in east java. Since the seasonal floods are not suitable for growing food crops, farmers 'usually tilling the land by planting kenaf at the beginning of the rainy season. Being the largest producer for kenaf fiber in Indonesia brings Bonorowo Laren field reliable as an additional source of income for local farmers. However, there are several problems in the development of kenaf plants to become kenaf fibers, the amount of kenaf fiber is uncertain, since the plants is depending on the weather supply, planting of kenaf is done once a year, the harvest and retting process is still

ISSN: 2223-9944, e ISSN: 2223-9553

manual so it requires a lot of labor and water, and the use of chemicals in the growth process. kenaf plants so that it can pollute the environment. To achieve high quality kenaf fiber that is able to meet domestic and even foreign needs, farmers are required to overcome this problem.

Quality Function Deployment (QFD) is a method for measuring standard quality on producing process. The essence of the QFD method is the House of Quality (HoQ), which is a matrix of the relationship between customer expectations, technical responses, assessments and priorities. There are four phases in QFD, the phase of quality planning, parts deployment, process planning, and production planning (Fragnoli et al., 2018). However, the QFD using mostly do not use these four applications, but using quality planning for the initial design process (Vinayak and Kodali, 2013). The advantage of using QFD; the data is analyzed systematically and logically, quality improvement considers customer needs, knowing the strengths and weaknesses of the company, and strategic production planning (Jaiswal, 2012). QFD has been widely used in the world of agriculture, namely analyzing the problems of accidents as well as occupational safety in the agricultural sector (Lombardi and fargnoli, 2018), identifying the design and development of agricultural machinery (Kumarl et al., 2015), mapping consumer interest for the quality of olive oil so that improvements in olive cultivation practices (Sayadi et al., 2017) and many other studies.

Product competitiveness and sustainability are not only concern about the customer demand satisfaction and quality preference but also related to the environment. Since, the 90's there has been products development considering environmental requirements. This is a form of reducing environmental impact in the product life cycle (Bakker, 1995). One method for analyzing the environmental impact of a product's cycle is the Life Cycle Assessment (LCA). LCA is a standard methodology for assessing various categories of environmental impacts along the production chain. The LCA method has been accepted internationally and it is described in ISO standards. LCA has been used in many fields, included for the product in the agricultural world. LCA studies have been used to measure the environmental impact on agriculture in South America (Sa' et all., 2017), analyze the ecological dimensions from cultivation to processing of Amazonian fruits (Recanati, 2018), compare the environmental impacts of organic lettuce harvesting with traditional farming (Foteines and Chatzisymeon 2016), and analysis of the environmental impact of planting and processing kenaf (Fernando, 2013), and there are still many LCA studies in the agro-industrial sector.

This study proposed to find out the using of both using LCA method on environmental consequences and QFD to determine improvement strategies related to kenaf plants growth until kenaf fibers were obtained in the Laren-Lamongan bonorowo field.

METHODOLOGY

This study committed through 4 basic steps; introduction, data collection, data processing, and data analysis.

1. Introduction

Introduction step start by first identification through literature review related to kenaf plants growth until obtained the kenaf fiber, QFD, and LCA. Then, determine the problem and purpose of the study as well as identified the needed data. The object of this study is the kenaf plants cultivation located in the Bonorowo laren lamongan.

2. Data collection

This study applied both secondary and primary data. The data required in the QFD process are quality attributes, technical response determination, level of importance, satisfaction and goals. Regard with the quality attributes and technical response determination toward kenaf plants growth into kenaf fiber, the author committed literature as well as discussions with the

ISSN: 2223-9944, e ISSN: 2223-9553

chief of Bonorowo Laren farmer group. Whereas, the satisfaction level Assessment, interests and goals revealed through filling out questionnaires by consumers. The one who acts as a consumer in this study is the chief of Bonorowo Laren farmer group. The determination of environmental aspect attributes is obtained from LCA processing using SimaPro software. The data used for LCA process is the same data during kenaf planting cycle until produce kenaf fiber, 2019/2020.

3. Data processing

Data processing is the determination toward Voice of custumer (Voc) which consisted of environmental and quality aspects distributing questionnaires, HoQ development, and formulating the improvements in the growth process to become kenaf fibers. The determination of environmental aspect attributes is revealed through the output of LCA method by SimaPro software. The purpose of the LCA method is to determine the environmental impact since the growth process until kenaf fiber is obtained. The LCA stage consists of the goal and scope phases, Life Cycle Inventory (LCI), Life Cycle Impact Assessment (LCIA), and Interpretation. The needed data on LCA method is the amount of water for the growth process to immersion, chemicals, raw materials, the use of transportation and the energy required, the flow of the growth process until the kenaf fibers shipped to collective merchant, and the amount of kenaf fibers produced. The data required in calculating the LCA as a whole is secondary data obtained from the Bonorowo Laren land farmer group. After obtaining the criteria for environmental impact aspects, it is necessary to determine the aspects of the impacts that must be addressed. The two highest environmental impacts were selected as attributes of environmental aspects that need to be improved.

The determination of the quality aspect attributes obtained from literature studies related to the growth process of kenaf plants to become ideal kenaf fibers and then discussed with the leader of farmer group Bonorowo Laren. Filling out a questionnaire by the leader of farmer group regarding the level of interest, satisfaction and goals, is used as the basis for HoQ development. The results of the questionnaire were used as input for the planning matrix in the HoQ. HoQ development started by filling the VoC space. The VoC attribute is filled based on the quality and environmental aspects. The second space of the HoQ section is the planning matrix which listed columns for importance to customer, current satisfaction performance, goals, improvement ratio, raw weight, and normalized raw weight. The third space is the technical response which is revealed from the literature and discussions with the leader of the farmer group. The fourth and fifth space are relationship matrix and technical correlation. The determination of the value on the relationship matrix and technical correlation is filled by the leader of the farmer group. The last space of the HoQ that needs to be filled is the technical matrix. the percentage contribution of each technical response is obtained based on the value of the relationship matrix and the normalized raw weight. From the calculation results in the technical matrix, it can be seen that the priority of the technical response in designing the improvement of kenaf plants growth until it becomes kenaf fiber is sent to collectors.

4. Data analysis

After received the HoQ processing data, all the data analyzed and conclude based on the applied method.

FINDING AND DISCUSSION

Kenaf farmer group in Bonorowo Laren producing kenaf plants into kenaf fiber conventionally. As a first step, farmers spread kenaf seeds manually. The distribution of kenaf seeds is carried out for 2 weeks before the rice harvest. After the seeds grow into kenaf

ISSN: 2223-9944, e ISSN: 2223-9553
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plants, farmers take care by applying fertilizers and pesticides. At the age of 130-140 days or if 50% of all plants are flowering, the kenaf plants can be harvested. Harvesting is done traditionally by cutting the base of the kenaf stem with a sickle. The collected kenaf stems are then immersed in a pool of water, this process is called retting. The retting process aims to break down the bark into strands of fibers. This process lasts 14-20 days depends on the area where the kenaf stalks are soaked. When the kenaf fibers are easily removed from the stem, the workers then removing the strands. As the alignment process is still done manually, the process requires a lot of workers. Workers must enter the immersion pool, remove the kenaf fibers from the stems and wash the kenaf strands thoroughly. Then, the clean kenaf fibers are dried in the hot sun. If the weather is favorable, the kenaf fibers dry within 1-2 days, but if the weather is unstable, it is needed within 3-5 days. The dry fiber is then rolled into a ball and ready to be sent to collectors using colt.

In the process of growing kenaf plants, raw water, chemicals, raw materials, transportation and energy are needed. The using raw water comes from the Bengawan Solo river and rainwater. In the process of kenaf growth, urea and pesticides are needed to meet the nutritional needs of plants and kill pests. In addition to chemicals, the process of transporting kenaf fiber requires transportation in the form of colt which uses oil as fuel. All data on the use of raw water, chemicals, colt as well as fuel oil in the kenaf plants growth process until the kenaf fiber is sent to collectors becomes input for data processing at SimaPro.

Products

Outputs to technosphere: Products and co-products	Amount	Unit	Quantity	Allocation	Waste type	Category	Comment
Serat_Kenaf	1179000	kg	Mass	100 %	not defined	Agricultural	
Add							

Outputs to technosphere: Avoided products	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
Add							

Inputs

Inputs from nature	Sub-compartmer	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
Water, lake	in water	4200000	m3	Undefined				
Sand and clay, unspecified, in ground	in ground	3930000	kg	Undefined				
Add								

Inputs from technosphere: materials/fuels	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
Cotton seed, at regional storehouse/US U	4930	kg	Undefined				
Urea, as N, at regional storehouse/RER U	128000	kg	Undefined				
Organophosphorus-compounds, at regional storehouse/RER U	10,5	kg	Undefined				
Transport, van <3.5t/RER U	8775	tkm	Undefined				
Diesel, at regional storage/RER U	552,5	kg	Undefined				
Add							

Figure 1. Input data at SimaPro

Based on the table 1 about the characterization impact, the biggest environmental impact is the loss due to gas energy sources (fossil fuels) due to the use of urea fertilizer. Otherwise, the lowest environmental impact is the ozone layer. Furthermore, the biggest environmental impact category is the use of fossil fuels become input for VoC attributes in HoQ development.

Table 2. Environmental impact on kenaf plants growth until produce kenaf fiber

	Total	*Cotton seed*	*Urea*	*Organophosphorus*	*Transport*	*Diesel*
Carcinogens	1,16E-6	3,65E-8	1,09E-6	3,31E-10	3,67E-8	6,71E-10
Respiratory organic	1,47E-8	7,29E-11	1,28E-8	2,73E-12	1,78E-9	5,49E-11
Respiratory inorganics	1,66E-5	9,49E-8	1,58E-5	2,78E-9	7,55E-7	1,64E-8
Climate change	5,2E-6	2E-8	4,98E-6	9,38E-10	1,99E-7	3,22E-9
Radiation	5,08E-8	1,45E-10	4,62E-8	4,26E-11	4,46E-9	4,47E-11
Ozone layer	3,51E-9	6,52E-12	3,35E-9	6,8E-13	1,37E-10	1,48E-11
Ecotoxicity	2,41E-6	6,94E-9	2,33E-6	5,01E-10	7,21E-8	9,58E-10
Acidification/Eutrophication	1,84E-6	1,59E-8	1,75E-6	1,95E-10	7,19E-8	1,35E-9
Land use	1,83E-6	1,05E-6	6,95E-7	1,6E-10	8,39E-8	3,38E-9
Minerals	2,43E-6	9,6E-9	2,32E-6	2,6E-10	1E-7	2,74E-10
Fossil fuels	1,08E-4	1,7E-7	1,04E-4	2,03E-8	3,11E-6	4,01E-7

HoQ development is required as the repairment plan through below steps;

1. Voice of Customer (Voc)

There are two aspect of Voc Attributes; Quality and Environment. Determined environment aspect attributes which is derived from LCA method has the biggest impact on the use of fossil fuels and respiratory inorganics. Whereas, the 6 determined quality aspects is the result of literature and discussion with the leader of farmer group of Bonorowo laren. VoC attribute display as below.

Table 3. VoC attribute

Attribute code	Attribute
CR1	Total Kenaf fiber
CR2	Kenaf fiber condition (wholeness and color)
CR3	dryness level of Kenaf fiber
CR4	Shipment process to Collective merchant
CR5	Total employer for retting process
CR6	Kenaf fiber selling price
CR7	Inorganic respiration disorders
CR8	Using of urea fertilizer

2. Importance Customer

The importance customer value is revealed from the average value of the importance of the questionnaire results, with a scale of 1-5. The level of importance that has the highest value is the amount of kenaf fiber, the condition of the kenaf fiber (integrity and color), the dryness level of the kenaf fiber, the transportation of the kenaf fiber to collective merchant, total employer for retting process, and the selling price of kenaf fiber.

ISSN: 2223-9944, e ISSN: 2223-9553
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Table 4. Importance Customer

Attribute Code	Attribute	Importance to Customer
CR1	Total Kenaf fiber	5
CR2	Kenaf fiber condition (wholeness and color)	5
CR3	dryness level of Kenaf fiber	5
CR4	Shipment process to Collective merchant	5
CR5	Total employer for retting process	5
CR6	Kenaf fiber selling price	5
CR7	Inorganic respiration disorders	4
CR8	Using of urea fertilizer	4

3. Current satisfaction performance

Current satisfaction performance is the consumer satisfaction toward production process that has been running so far. The satisfaction level assessment was completed by the leader of the Laren farmer group. Teendagi satisfaction level of kenaf growth process until kenaf fiber is obtained is the selling price of kenaf fiber.

Table 5. Current satisfaction performance

Attribute Code	Attribute	Current Satisfaction Performance
CR1	Total Kenaf fiber	3
CR2	Kenaf fiber condition (wholeness and color)	3
CR3	dryness level of Kenaf fiber	3
CR4	Shipment process to Collective merchant	3
CR5	Total employer for retting process	3
CR6	Kenaf fiber selling price	2
CR7	Inorganic respiration disorders	3
CR8	Using of urea fertilizer	3

4. Goal

Goal describes the level of improvement that farmer groups will make. The highest goal values were the attributes of the amount of kenaf fiber, the degree of dryness of the kenaf fiber, respiratory inorganics disorders, and the use of chemical fertilizers.

Table 6. Goal

Attribute Code	Attribut	Goal
CR1	Total Kenaf fiber	5
CR2	Kenaf fiber condition (wholeness and color)	4
CR3	dryness level of Kenaf fiber	5
CR4	Shipment process to Collective merchant	3
CR5	Total employer for retting process	4
CR6	Kenaf fiber selling price	4
CR7	Inorganic respiration disorders	5
CR8	Using of urea fertilizer	5

5. Improvement Ratio

The kenaf fiber selling price attribute has the highest improvement ratio value. In the selling price attribute of kenaf fiber, the value of current satisfaction performance is 2, while the goal

ISSN: 2223-9944, e ISSN: 2223-9553
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value to be achieved is 4, which means that the level of satisfaction felt by the company towards the kenaf growth **process to produce kenaf fiber is still low.**

Table 7. Improvement Ratio

Attribute Code	Attribute	Improvement Ratio
CR1	Total Kenaf fiber	1,666666667
CR2	Kenaf fiber condition (wholeness and color)	1,333333333
CR3	dryness level of Kenaf fiber	1,666666667
CR4	Shipment process to Collective merchant	1
CR5	Total employer for retting process	1,333333333
CR6	Kenaf fiber selling price	2
CR7	Inorganic respiration disorders	1,666666667
CR8	Using of urea fertilizer	1,666666667

6. Raw Weight

the kenaf fiber selling price of 10 become the highest raw weight value. Whereas, the Shipment process to Collective merchant of 5 become the lowest raw weight value.

Table 8. Raw Weight

Attribute Code	Attribute	Raw Weight
CR1	Total Kenaf fiber	8,333333333
CR2	Kenaf fiber condition (wholeness and color)	6,666666667
CR3	dryness level of Kenaf fiber	8,333333333
CR4	Shipment process to Collective merchant	5
CR5	Total employer for retting process	6,666666667
CR6	Kenaf fiber selling price	10
CR7	Inorganic respiration disorders	6,666666667
CR8	Using of urea fertilizer	6,666666667

7. Normalized Raw Weight

Normalized raw weight is the percentage of raw weight, it is counted based the dividend of each raw wight toward total raw weight.

Table 9. Normalized Raw Weight

Attribute Code	Attribute	Normalized Raw Weight
CR1	Total Kenaf fiber	0,142857143
CR2	Kenaf fiber condition (wholeness and color)	0,114285714
CR3	dryness level of Kenaf fiber	0,142857143
CR4	Shipment process to Collective merchant	0,085714286
CR5	Total employer for retting process	0,114285714
CR6	Kenaf fiber selling price	0,171428571
CR7	Inorganic respiration disorders	0,114285714
CR8	Using of urea fertilizer	0,114285714

ISSN: 2223-9944, e ISSN: 2223-9553

8. Technical response

The determination of the technical response is based on a literature study and discussion with the leader of the farmer group. It is selected 20 technical responses in accordance with the growing conditions of the kenaf plants until kenaf fiber was obtained.

9. Relationship Matrix

The relationship determination between VoC and the technical response uses 3 types of values, 9 if the relationship is strong, 3 if it has a moderate relationship, 1 if low relationship, and 0 if it has no relationship. Based on the assessment result by the leader of the farmer groups, there were 28 strong relationships between VoC and technical response, 11 moderate relationships, and 15 weak relationships.

Table 10. Relationship Matrix

	TR1	TR2	TR3	TR4	TR5	TR6	TR7	TR8	TR9	TR10	TR11	TR12	TR13	TR14	TR15	TR16	TR17	TR18	TR19	TR20
CR1	9	9	9	9	1	1	1	3	3	3	3	1		3	1	3			1	9
CR2		9	9	9	9	9	9	9	9	9	9	3		9	1	1			1	1
CR3								1		9	9	3	3		1	1				
CR4												9	9		1	1				
CR5														9	9	9				
CR6														3			9			
CR7																		9	9	9
CR8								3										3		9

10. Technical matrix

Technical matrix space calculates the contribution of each technical response, the technical response priority could be determined through the contribution values. The complete calculation such in table below.

Tabel 11. Technical Matrix Result

Attribute code	Technical Response (TRi)	% Contribution	Priority
TR1	Increasing yield production	3,43	15
TR2	Weed control (by herbicides or weed weeds)	6,17	5
TR3	Installation of rat traps on plantsing land	6,17	6
TR4	Hasvesting Kenaf stem on time	6,17	7
TR5	Supplying submerged water from Bengawan Solo river	3,13	18
TR6	Crown cutting during retting process	3,13	19
TR7	Submerged kenaf stem with the same dimension	3,13	20
TR8	Retting through microbial culture	5,18	8
TR9	As the Retting process, the maximum diameter of the kenaf stem bond is 20 cm	3,89	13
TR10	Drying kenaf fiber in heat sun	7,32	3
TR11	Providing indoor ventilation	7,32	4
TR12	Using closed pickup truk	4,5	10

TR13	The shipment based on item capacity	3,2	17
TR14	Fiber processing before soaking with a simple tool	8	2
TR15	Employing mothers around laren land	4,04	12
TR16	Employing worker out of laren	4,8	9
TR17	raise the price by Rp. 100/ Kg	4,12	11
TR18	Using of personal protective equipment (masker/faceshield)	3,66	14
TR19	Using of natural pesticide	3,43	16
TR20	Using of organic fertilizers	9,22	1

From the technical matrix calculations above, a priority technical response will be chosen. It will be used as the basis for improvement in the process of growing kenaf plants into kenaf fibers in the Bonorowo Laren, Lamongan. By the Pareto principle, the percentage of contributions that have a value of 80% will be the main priority for improvement. Based on the results of the Pareto diagram in Figure 2, the improvements that should be made by the farmer groups are the use of organic fertilizers, conducting robotization before soaking (reboner), drying kenaf fibers in the heat sun, providing indoor ventilation, controlling weeds (use herbicide or weed weeding), trapping rats in the planting area, harvesting kenaf stems on time, retting using microbial cultures, using closed trucks, increasing the selling price of dried kenaf fiber by Rp. 100/kg, employing mothers around laren land during the retting process, during the retting process the maximum diameter of kenaf stem ties is 20 cm, and the use of personal protective equipment (mask / faceshield) when spraying pesticides and fertilizing.

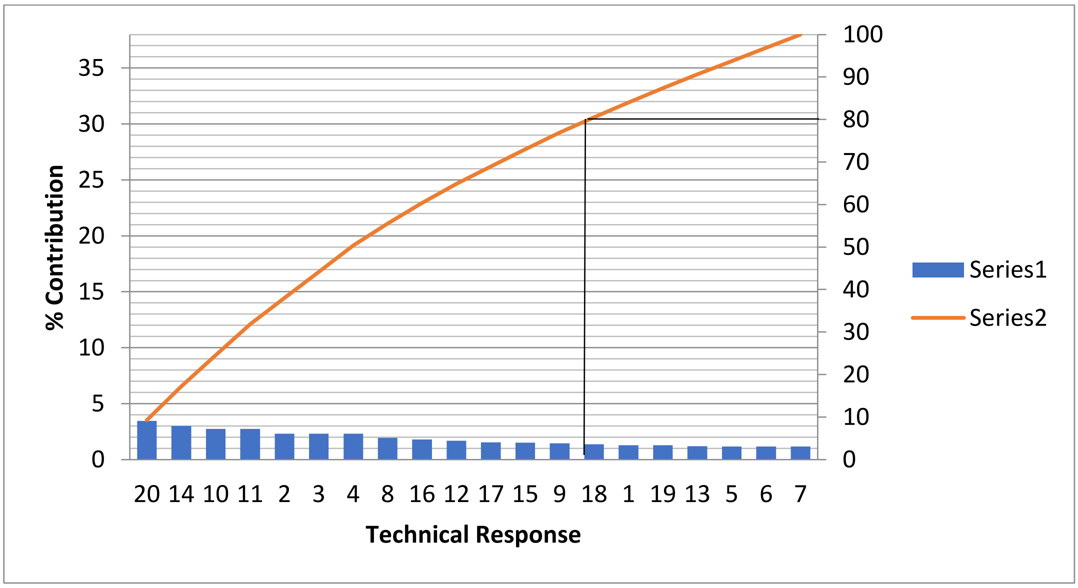

Figure 2. Pareto Diagaram on Technical Matrix Result

CONCLUSION

Based on the overall explanation above, there are 8 VoC attributes in HoQ, consisting of 2 environmetal attributes aspects and 6 quality attributes aspects. Two environmental attributes aspects came from the highest LCA results, while 6 quality attributes aspects came from literature and discussions with farmer groups. There are 20 technical responses that are used as the basis for improving the process of growing kenaf plantss to become kenaf fibers. The HoQ results in the technical matrix space show that the technical response should be followed up is the use of organic fertilizers, Fiber processing before soaking with a simple tool, drying kenaf fibers in the heat sun, providing indoor vemtilation, controlling weeds (using herbicides or weeding), installation of rat traps in the plantsing area, harvesting kenaf stalks on time, retting using microbial cultures, using closed trucks / colt tanks, increasing the price of dry kenaf fiber by Rp. 100, - per kg, Laren mothers around laren land for retting process, during the retting process the maximum diameter of kenaf stem ties is 20 cm, and the use of personal protective equipment when spraying pesticides and fertilizing.

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ISSN: 2223-9944, e ISSN: 2223-9553