SAMPLE RESEARCH PROPOSAL

Project title

Potential use of *Mucuna bracteata* as a biomass resource without reducing the legume's effectiveness as a cover crop under oil palm

Researchers

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Project Summary

Can *Mucuna bracteata*, in addition to being a ground cover for oil palm, be harvested as a source for renewable biomass for Malaysia? *M. bracteata* has the potential to become a biomass resource because it is a fast growing plant and produces high biomass yield. However, little is known about its biomass quality or whether the plant can be harvested regularly like pasture for biomass. Consequently, this study aims to determine the suitability of *M. bracteata* as a biomass resource by 1) determining its growth rate and how often and how much can be harvested for biomass without inhibiting its regrowth and its effectiveness as a soil cover, and 2) determining the biomass quality of *M. bracteata*. An oil palm plantation with 1-2 year old palms will be selected. The treatments (with three replications for each treatment) are the four harvesting frequency of M. bracteata: harvest once every 2, 4, and 6 months, and no harvest for the fourth treatment (control). Field layout will be a Randomized Complete Block Design (RCBD). Soil parameters to be measured once every two months are pH, total C and N, available P, CEC and exchangeable cations, aggregate stability, and soil water content. The vegetative green matter and litter of M. bracteata will be harvested separately to obtain biomass dry weight and moisture content. Additional biomass quality properties to be measured are: calorific value, volatile matter and fixed carbon contents, ash content, nutrient status (C, P, K, Ca and Mg) and N, as well as H, O, S, and alkali metal content would be measured. Lastly, crude protein, cellulose, hemicellulose, and lignin will also be measured. Also to be measured are M. bracteata's N fixation, leaf area index, and light interception. It is hoped that the information produced from this research would help to determine whether M. bracteata can be harvested for biomass for commercial value, and in turn, support Malaysia's efforts to diversify the source of biomass and to increase the use of renewable biomass for energy and bio-based products and chemicals.

Introduction (Problem and justification of study)

Malaysian Biomass Initiatives (MBI) is a programme of the Prime Minister's Global Science and Innovation Advisory Council, and MBI was established to increase the use of renewable biomass as a source of feedstock for the production of chemicals, fuels, or materials (or the so-called bio-based products). MBI's goals are that by increasing the use of renewable biomass, Malaysia would reduce her greenhouse gas emissions and lessen the impact of rising fossil-fuel prices. Increased use of renewable biomass would also encourage the growth and adoption of green technologies in Malaysia.

Malaysia currently produces more than 70 million tonnes of biomass annually, 94% of which is derived from only a single source: oil palm (such as in the forms of empty fruit bunches, palm oil mill effluent, mesocarp fibre, and palm kernel shell and cake). Malaysia desires to reduce this over-dependency on a oil palm as a biomass resource and to increase the quantity of biomass available in the country for use.

Consequently, can the under-utilized leguminous crop, *Mucuna bracteata*, from oil palm plantations become a biomass resource in Malaysia? *M. bracteata* is under-utilized because this leguminous plant is currently grown only as a cover crop (with no commercial yield) in oil palm plantations. *M. bracteata* is one of the most widely planted legumes since its introduction in oil palm plantations in Malaysia in 1991 (Mathews, 1998). *M. bracteata* is popular because this legume is fast growing, drought resistant, and shade tolerant, and it quickly produces a thick and uniform cover for soil fertility protection (Chiu et al., 2001). *M. bracteata* is grown under the oil palm to reduce soil erosion, conserve soil water and nutrients, and reduce weeds, as well as to add nutrients (in particular by fixing atmospheric N) and organic matter to the soil.

Biomass is any plant material derived from the photosynthetic process. Biomass is available on a renewable basis either through natural processes or it can be made available as a by-product of human activities such as organic wastes. Numerous crops have been and are currently being tested for potential use as a biomass resource. These crops include woody crops, grasses or herbaceous plants (all perennial crops), starch and sugar crops, and oilseeds (McKendry, 2002). A biomass source can be converted into three main types of product: 1) electrical or heat energy, 2) transport fuel, and 3) chemical feedstock.

According to McKendry (2002), several criteria determine the suitability of a crop as a biomass resource, two of which are the crop growth rate (the faster the growth, the better) and the quantity of biomass produced (the higher the quantity, the better).

M. bracteata has the potential to become a biomass resource because it has a rapid growth rate and it produces high biomass yields. For instance, *M. bracteata* can grow 3 to 4 m long within 4 weeks and can produce a 1-m thick soil cover, with 400 mm thickness of mulch litter below (Chiu, 2007). Even under 10-year old oil palms, *M. bracteata* can sustain a full ground cover with 500 mm thickness and with a litter mulch thickness of 150 mm (Chiu, 2007). *M. bracteata* furthermore produces three to four times more biomass and about three times more nutrients (N, P, K, Ca, and Mg) in its leaf litter and green vegetative matter than other leguminous cover crops such as *Calopogonium caeruleum* and *Pueraria phaseoloides* (Shaharudin et al., 2000; Shaharudin and Jamaluddin, 2007).

Another important biomass resource criterion is the biomass quality. The chemical and physical properties of a particular biomass determine the value of the biomass as well as the bio-conversion method to be used (McKendry, 2002). Unfortunately, much less is known about the biomass quality of *M. bracteata* because the use of this legume as a biomass resource in Malaysia has not been explored.

To determine the suitability of *M. bracteata* as a biomass resource, the following properties must be determined:

1. Moisture content (intrinsic and extrinsic)
2. Calorific value
3. Proportions of fixed carbon and volatiles
4. Ash or residue content
5. Alkali metal content
6. Cellulose:lignin ratio

Consequently, this study aims to establish not only the biomass quantity but also the biomass quality of *M. bracteata*.

The potential use of *M. bracteata* is large. With a targeted annual oil palm replanting rate of 140,000 ha (PEMANDU, 2013), there would be at least 1 million ha of *M. bracteata* for harvesting at any one time and could supplement the erratic and insufficient oil palm biomass which currently constitutes about 94% of the national supply. Considering *M. bracteata*'s rapid growth and high biomass yield, it is desirable if this legume, in addition to its role as a cover crop to protect the soil, can act as a source of biomass that could be harvested regularly.

This study aims to answer the following questions. Can *M. bracteata*'s above ground biomass be harvested like pasture, and if so, how frequent or to what level can it be cut without inhibiting or delaying its regrowth? To what degree would harvesting *M. bracteata* affect its effectiveness as a cover crop to conserve soil water and nutrients? What are the physical and chemical biomass characteristics (*i.e.*, biomass quality) of *M. bracteata*?

The information produced from this research would help to determine whether *M. bracteata* have the necessary quantity and quality of a biomass resource and whether this legume can be harvested for biomass for commercial value, and in turn, support Malaysia's efforts to diversify the sources of biomass and to increase the use of renewable biomass in the production of biofuel and high-value bio-based chemicals and products.

Objectives of study

The general objectives of this study are to determine whether *Mucuna bracteata* can serve as a biomass resource and still remain an effective cover crop for soil and plant fertility protection under oil palm.

The specific objectives of this study are:

1. To determine the biomass quantity and quality of *M. bracteata*;
2. To determine *M.bracteata*'s growth rate and how often and how much it can be harvested for biomass without inhibiting its regrowth or survival; and

3. To determine to what degree harvesting *M. bracteata* would influence its effectiveness as a cover crop to: a) conserve soil water and nutrients and b) increase the nutrients content in oil palm leaves which would indicate oil palm fertility.

Related research

Mucuna species are well known for their rapid growth rates to cover the soil surface quickly, produce large amounts of aboveground biomass, and accumulate nutrients with subsequent beneficial effects on crop growth and yield. Nevertheless, there is a dearth of Malaysian studies on *Mucuna bracteata*. Studies carried out in oil palm plantations in Malaysia show clearly that M. bracteata is a fast growing crop. Chiu et al. (2001) measured that this legume can produce a 1-m thick soil cover, with 400 mm thickness of mulch litter. The vines of M. bracteata can grow 3 to 4 m long within 4 weeks (Chiu, 2007). Chiu (2007) further reported that even under 10-year-old oil palms, M. bracteata can sustain a full ground cover with 500 mm thickness and with a litter mulch thickness of 150 mm. Shaharudin et al. (2000) reported that M. bracteata produced three to four times more biomass than other leguminous cover crops, Calopogonium caeruleum and Pueraria phaseoloides (i.e., 17.2 vs. 5.7 ton of dry matter per ha). M. bracteata also contains about three times more nutrients (N, P, K, Ca, and Mg) in its leaf litter and green vegetative matter than that the aforementioned legumes (Shaharudin and Jamaluddin, 2007).

Methodology

An oil palm plantation with young palms (1-2 years old) will be chosen. *Mucuna bracteata* will be planted under the oil palm trees, with a planting density of 476 plants per ha and a planting distance of 3 m between planting points. Method of field planting and crop maintenance of *M. bracteata* will be according to Goh and Chiu (2007).

There would be four treatments with three replications for each treatment. The field experiment layout will be arranged as a Randomized Complete Block Design (RCBD). The treatments are the various harvesting frequencies, where *M. bracteata* will be harvested once every 2, 4, and 6 months. The fourth treatment is the control without any harvesting activities (zero harvest).

Selected soil properties will be measured just before planting and repeated once every two months for 24 months. The soil parameters (0-150 and 150-300 mm depth; sampled randomly) to be analyzed are pH (soil/water ratio 1:2.5; Mc Lean, 1982), total C (the combustion method using the 412-Leco Carbon Auto-Analyzer; Skjemstad and Baldock, 2008), total N (Kjeldahl method; Bremner and Mulvaney, 1982), available P (Mo blue method according to the Bray and Kurtz no. 2 extracting solution; Olsen and Sommers, 1982), CEC and exchangeable cations (K, Ca, and Mg) (leaching method by using neutral 1 M ammonium acetate solution; Thomas, 1982), and soil aggregate stability (wet-sieving method; Kemper and Rosenau, 1986). Also to be measured is the soil water content at every 150 mm soil depth down to

1 m (using TRIME-PICO soil moisture sensor). The N fixation of *M. bracteata* would also be measured (N-15 dilution technique; Zaharah et al., 1986).

The vegetative green matter and litter of *M. bracteata* will be harvested separately to obtain biomass dry weight and moisture content. Additional biomass quality properties to be measured are: calorific value (energy content when burned), volatile matter (VM) and fixed carbon (FC) contents, ash content, nutrient status (C, P, K, Ca and Mg using the dry ashing method) and N by the Kjeldahl method, as well as H, O, S, and alkali metal content would be measured. Lastly, crude protein, cellulose, hemicellulose, and lignin will also be made on the samples (all methods by AOAC International, 1995).

Light interception and LAI (leaf area index) of *M. bracteata*'s will be measured prior to harvesting (using PAR Ceptometer, model AccuPAR LP-80, Decagon Devices Inc., USA).

An automatic weather station (Watchdog weather station) would be placed at the site to measure the meteorological properties at every 30-minute intervals.

ANOVA and mean separation tests will be used, among others, to determine the optimal harvesting frequency of *M. bracteata* which would provide high biomass and at the same time allow *M. bracteata* to give sufficient protection to the soil and oil palm fertility.

Project Costing

Expense category	**Year 1 (RM)**	**Year 2 (RM)**	**Year 3 (RM)**	**Total (RM)**
Temporary and contract personnel - PhD students (2)	40,000	40,000	40,000	**120,000**
		Usual to Add 5-10% per year		
Travel and transportation - Travel to and accommodation at field sites - Travel to conferences, seminars	7,000	7,000	7,000	**21,000**
Rentals	-	-	-	**-**
Research materials and supplies - Lab wares, chemicals - Books and perishables (computer accessories)	10,000	10,000	10,000	**30,000**
Minor modifications and repairs	3,000	3,000	-	**6,000**
Special services - Fees for seminars, conferences - Analyses	2,000	2,000	2,000	**6,000**
Special equipment and accessories		-	-	**22,000**
- Aquapro moisture sensor, data logger, and access tubing (1 set)	7,000			
-IR camera and UAV overfly	15,000			
Total (RM)	**84,000**	**62,000**	**59,000**	**205,000**

Project Schedule

Period of project: 30 months

Activities	Month 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Field preparation and planting	X	X	X	X																										
Field preparation complete				•																										
Harvest *M. bracteata*						X		X		X		X		X		X		X		X		X		X						
Field data sampling				X	X	X		X		X		X		X		X		X		X		X		X						
Lab analyses				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
Complete the first 6-month data collection and lab analyses												•																		
Complete the second 6-month data collection and lab analyses																		•												
Complete the third 6-month data collection and lab analyses																								•						
Complete the last 6-month data collection and lab analyses																														•
Report writing and presentation																		X	X	X	X	X	X	X	X	X	X	X	X	X

Key: Milestone, •

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