

Carbon sequestration potential in soil and biomass of *Jatropha curcas*

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Abstract

A study was carried out to determine the potential of *Jatropha curcas*, a biofuel crop to sequester carbon by measuring how litterfall, biomass production and canopy photosynthesis rate can offset soil respiration. Litterfall production and its decomposability was monitored monthly for 10 months, biomass production was determined through destructive harvesting while canopy photosynthesis rate and soil respiration was measured using a portable photosynthesis meter system and an automated soil CO₂ flux system, respectively. Biomass of a 32-month old *Jatropha curcas* sequestered 13.0 Mg C/ha, while 2-year old *Jatropha curcas* had a canopy photosynthesis rate of 29.59 μmol/m/s. The combination of these two parameters offsets emission from soil respiration that ranged between 0.84 to 1.04 μmol/m/s. Litterfall despite being highly decomposable did not contribute to soil total carbon.

Key Words

Carbon sequestration, *Jatropha curcas*, biomass production, litterfall production, canopy photosynthesis rate, soil respiration.

Introduction

Production of biofuel from crops has raised many issues mainly on the ethics of using food as the raw ingredient for biofuel production and the extent of environmental friendly biofuel in terms of greenhouse gases reduction. Consumption of energy to produce biofuel releases nearly as much carbon dioxide (CO₂) to the atmosphere as burning conventional fuel from petroleum and coal (Bourne 2007). The main advantage of biofuel in terms of suppressing the current rate of CO₂ released to the atmosphere lies in the natural mechanism of plants in assimilating CO₂ during photosynthesis as its structural material (i.e. biomass). Assimilated CO₂ in plant biomass will in turn be transformed into stable organic matter (i.e. humus) after litterfall and sloughed root decomposition in the soil returning converted CO₂ in the form of carbon (C) to soil. However, cultivation practices of biofuel crops involving soil preparation are causing rapid decomposition of soil organic matter releasing CO₂ back into the atmosphere (Robert 2001). The present study aims to determine the balance between CO₂ released to the atmosphere through soil respiration and CO₂ assimilated through photosynthesis of *Jatropha curcas*, a perennial biofuel crop. The study also aims to quantify biomass in terms of dry matter production and annual litterfall by *Jatropha curcas* and its contribution to increased soil C.

Methods

Study site

The study was conducted at University Agriculture Park, Plot D, UPM, Serdang, Selangor, Malaysia. Soil at the study site is a Plinthic Paleudult of the Batu Lapan series. An area of one hectare at the study site was planted with *Jatropha curcas* of different ages at a planting distance of 2x3m from three months old seedlings.

Litterfall collection and chemical analysis

Litterfall was collected from nine randomly chosen *Jatropha* trees where litter traps made of nylon fishing nets were placed under the canopy of each tree. The size of each net was approximately 4m². Litterfall was removed from the litter trap and collected monthly beginning from July 2008 until April 2009. The collected litterfall was oven-dried at 60°C and ground to 1mm using a cutting mill. Total C content of the litterfall was analyzed using a carbon analyzer (LECO CR-412). Total nitrogen content was determined using the Kjeldahl method. A ratio of carbon to nitrogen (C:N) on a weight basis was then derived based on the results.

Biomass dry weight determination and carbon content analysis

Three *Jatropha curcas* trees were selected from three different ages; 10, 17 and 32 months for destructive

sampling. The trees were sawn down at the base of the stem closest to the ground. The fresh weight of the above ground part of the trees was directly determined. The leaves were later removed and separately weighed. The belowground (root) portion of the trees was excavated using a backhoe and soil particles attached to the roots were removed and the roots were then immediately weighed. All parts of the tree were subsampled and oven dried to a constant weight for moisture determination. The samples were later ground to 2mm to be analyzed for total C content using a carbon analyzer. Dry matter of the whole tree was derived by correcting the fresh weight of each tree for its moisture content. The mass of C present in each tree was then calculated.

Leaf photosynthesis and leaf area index measurement

Leaf photosynthesis rate was measured every fortnight in September and October 2009 using a portable photosynthesis meter system (LI-6400XT, Li-Cor Biosciences). Photosynthesis was measured three hours after sunrise on three trees of two different ages (one and two years old). Fully matured leaves from each tree were selected for photosynthesis measurement. For each tree that was measured for its photosynthesis rate, its leaf area index (LAI) was measured using a leaf canopy analyzer (LAI-2000, Li-Cor Biosciences).

Soil CO₂ flux

Soil CO₂ flux was measured weekly in September and October 2009 using an automated soil CO₂ flux system (LI-8100, Li-Cor Biosciences) under the canopy of three randomly chosen trees.

Soil total carbon content

Soil was sampled on the three different locations at the study site; uncultivated section of the site (N), under the littertrap (UL) and under tree canopy without a littertrap placed under it (WL) at two different depths (0-20 and 20-40cm). All the sampled soils were air-dried, ground and sieved to 1mm and analyzed for total carbon content using a carbon analyzer (LECO CR-412).

Statistical analysis

Analysis of variance was conducted to test the effect of age on biomass dry matter production and its carbon content and for sampling depth and location on soil total carbon. All means were compared using Tukey's test.

Results and discussion

Litterfall

Litterfall production showed no consistent trend with time as the mass of litterfall fluctuated during the study period (Figure 1) ranging from 62.59 to 183.52kg/ha month⁻¹. Despite the inconsistency of litterfall mass, litterfall C:N ratio remained fairly constant throughout the study period ranging from 17:1 to 21:1. The C:N range of the litterfall indicates that litterfall of *Jatropha curcas* was highly decomposable as plant materials with C:N less than 20:1 decompose rapidly (Heal et al., 1997). The contribution of C to soil through litterfall decomposition in the present study was determined based on differences in soil total C sampled at different sites (N, UL and WL), which will be discussed later.

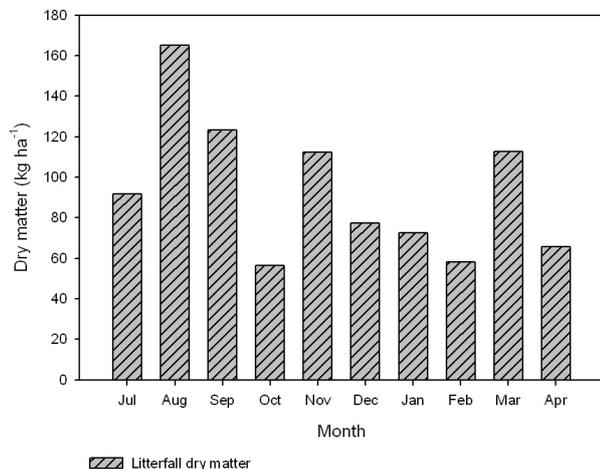


Figure 1. Dry mass of litterfall for each month

Biomass production

A rapid increase of dry weight was observed in the aboveground part of the tree (excluding leaves) compared to leaves and root where a more gradual increase in dry weight was observed (Figure 2). Higher biomass production of *Jatropha curcas* from the aboveground portion of the tree compared to the belowground portion could be explained by the ability of the tree to adapt to drought without having to extend its root system to obtain water (Heller, 1996; Ericsson et al., 1996). There was an increase of C in biomass during a 12-month period with an increase of mean whole tree (aboveground and belowground) C of 11.53Mg C/ha (Table 1). The results from both Figure 2 and Table 1 indicate that *Jatropha curcas* stores substantial amounts of C but this is predominantly stored in the aboveground portion of the tree compared to other parts.

Table 1. Mean dry weight (\pm standard error) of different parts of *Jatropha curcas*. Means with different alphabets are significantly different using Tukey's test at $p < 0.05$.

Age (month)	Plant part						Total C in biomass (Mg/ha)
	Aboveground		Belowground		Leaves		
	C content (%)	C in biomass (Mg/ha)	C content (%)	C in biomass (Mg/ha)	C content (%)	C in biomass (Mg/ha)	
32	46.90 \pm 0.27a	9.91 \pm 0.70a	46.88a*	3.09 \pm 0.042a	46.57 \pm 0.56a	1.62 \pm 0.33a	13.00 \pm 1.06a [#]
17	46.75 \pm 0.36a	5.14 \pm 0.42b	46.76b*	1.81 \pm 0.09b	46.01 \pm 0.42a	0.78 \pm 0.06ab	6.95 \pm 0.51b [#]
10	46.23 \pm 0.27a	0.95 \pm 0.07c	44.59c*	0.52 \pm 0.02c	45.64 \pm 0.20a	0.37 \pm 0.19b	1.47 \pm 0.19c [#]

*Only one replicate was determined for C content

[#]Excluding leaves

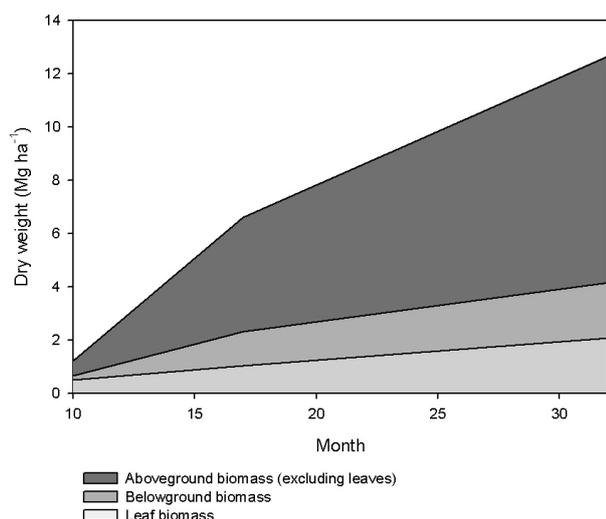


Figure 2. Biomass allocation to various parts of *Jatropha curcas*.

Canopy photosynthesis

Mean leaf photosynthesis (\pm standard error) for one year and two year old trees were 7.24 \pm 0.91 and 8.04 \pm 1.38 μ mol/m/s respectively. Based on the mean LAI for one year old trees of 0.54 and mean LAI for two years old trees of 0.92 and assuming the canopy covers a ground area of 4m², canopy photosynthesis rate for a one year old and two years old tree would be 15.64 μ mol/m/s and 29.59 μ mol/m/s respectively. The actual photosynthesis rate however would be less than the calculated rate as the calculated rate was based on the photosynthesis rate of fully matured leaves. However, the number of fully matured leaves on a *Jatropha curcas* tree at a given time is unknown.

Soil CO₂ flux

Soil CO₂ flux showed no significant differences between the different time of the month when the measurement was carried out ranging from 0.84 to 1.04 μ mol/m/s. Based on the consistency of our data, for the purpose of comparison with canopy photosynthesis, we assumed that the soil CO₂ flux and canopy photosynthesis rate will remain constant within this range throughout the year.

Soil total carbon

At depths of 0-20 and 20-40cm, there were no significant differences of soil total C at different position in

the field where soils were sampled. The results indicated that there was no addition to soil total C through the decomposition of litterfall. However, the labile portion of the total carbon has to be analyzed before ruling out the contribution of litterfall to any increase in soil C. No differences that were observed between the uncultivated section and the parts of the field that was cultivated could be explained by the study site that was regularly ploughed before the site was planted with *Jatropha curcas* therefore obtaining a reference sample of the site that was naturally undisturbed to determine its initial C content was not possible.

Table 2. Mean mass of soil carbon (\pm standard error) at different sampling points. Means with same letter are not significantly different using Tukey's test at $p < 0.05$.

Sampling depth (cm)	C mass in soil (Mg/ha)		
	Uncultivated section	With littertrap	Without littertrap
0-20	36.79 \pm 4.54a	37.99 \pm 1.03a	36.79 \pm 3.34a
20-40	28.41 \pm 0.66a	28.22 \pm 0.84a	30.73 \pm 5.03a

Conclusion

Although litterfall production of *Jatropha curcas* does not indicate any addition to soil total C, sequestration of C by *Jatropha curcas* is visible in its biomass production through photosynthesis. The results from the present study showed that assimilation of CO₂ through canopy photosynthesis rate of one year and two years old trees of 15.64 μ mol/m/s and 29.59 μ mol/m/s respectively exceeds the amount of CO₂ released by soil respiration at rates of between 0.84 to 1.04 μ mol/m/s. Nevertheless, the results obtained are still inconclusive of the actual C sequestration rate of *Jatropha curcas* as plant photosynthesis is inactive at night and plant and soil respiration during the night also has to be included to get the actual picture on the capability of *Jatropha curcas* to sequester C.

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