

Research Article

The potential of intercropping food crops and energy crop to improve productivity of a degraded agriculture land in arid tropics

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Abstract: Degraded agricultural lands in the arid tropics have low soil organic carbon (SOC) and hence low productivity. Poor farmers that their livelihoods depend highly on these types of lands are suffering. Cropping strategies that are able to improve the soil productivity are needed. In the present study, some intercropping models of food crops with bio-energy crop of castor (*Ricinus communis* L.) were tested to assess their potential to improve the degraded land productivity. The intercropping models were: (1) castor - hybrid maize, (2) castor – short season maize, (3) castor – mungbean, and (4) castor –short season maize – mungbean. The results show that yields of the component crops in monoculture were relatively the same as in intercropping, resulted in a high Land Equivalent Ratio (LER). The highest LER (3.07) was calculated from intercropping castor plants with short season maize crops followed by mungbean with intercropping productivity of IDR 15,097,600.00 ha⁻¹. Intercropping has a great potential to improve degraded agriculture land productivity and castor is a promising plant to improve biodiversity and area coverage on the land.

Keywords: soil organic carbon, biodiversity, castor, maize, mungbean, land equivalent ratio

Introduction

Food crops production on degraded agricultural lands in arid tropics continues to decrease along with the decrease of the land quality. This condition is worsened by the effect of climate change that creates unfavourable condition for the food crops to grow. On the other hand, environmental services expected from the degraded agricultural lands are mounting because of the high food demands and the high rate of agricultural lands use change (Harvey and Pilgrim, 2011). Poor farmers that their livelihoods depend on these degraded lands have to live with a very little income that may affect the whole country economics. Strategic soil and cropping management that improves soil organic carbon (SOC) and reduces soil erosion is required to improve land productivity and to ensure a better life for the farmers. One of the ways to improve land productivity and to improve farmers' income on the less productive land is by improving SOC, diversifying the crops and by improving the land cover (Lal, 2011). Growing annual food crops

continuously on a piece of land, especially on a degraded land, can reduce the SOC because of the intensive soil tillage (Lal, 2006). To avoid the continuing land degradation and to improve the SOC, incorporation of a short rotation woody species into the cropping system is suggested (Blanco-Canqui, 2009). Castor (*Ricinus communis* L.), a bio-energy crop, is one of the suggested woody crop species to be grown on degraded lands because of its ability to provide quick ground cover and to contribute sufficient carbon into the soil (Wang et al., 2010). Castor plants grow fast at a high CO₂ atmospheric concentration (Vanaja et al., 2008) that makes these plants able to accumulate sufficient carbon into their biomass and roots. Other report also suggested that in addition to produce oil, castor plants could also be used to revegetate a contaminated land because of the ability of these plants to absorb heavy metal from a contaminated soil (Olivares et al., 2013). The seed shell of the castor was also reported as a good material for remediating basic dye contaminated wastewater (Oladoja et al., 2008).

Castor has a low economic yield and therefore, it is not suggested to grow this bio-energy crop in monoculture (Chand and Sujatha, 2000). Replacing food crops with bio-energy crops on agricultural lands is also a not good option to produce bio-energy and to improve SOC (Delucchi, 2011). To improve crops biodiversity on a degraded agricultural land and to improve the land productivity as well as to produce sufficient bio-energy feedstock, intercropping of food crops with castor is an option. Earlier findings reported that intercropping castor with pulses, such as chickpea, green gram and Indian bean resulted in less yields of all the component crops as compared to the monoculture (Dhimmar, 2009). Later, Jaya (2011) reported that there was no yield reduction of all component crops when castor was intercropped with mungbean, ground nut and soybean on dry land as compared to yield of those crops grown in monoculture. The present study was aimed to evaluate productivity of degraded agriculture land under crop diversification by means of intercropping food crops (maize and mungbean) with bio-energy crop of castor.

Materials and Methods

Site Descriptions

An experiment was conducted on a piece of abandoned degraded agriculture land in the arid tropics of Gumantar Village, in the Northern part of the island of Lombok (8°14'29"S and 116°17'01E). Climate type in the experimental area according to Oldeman classification is D type. The site was abandoned for about three years because of its poor soil properties and hence low land productivity. Prior to the experiment reported in this study, the land had been used for growing castor for two consecutive years by a bio-energy company. The C organic of the soil was only 1.24% with 0.19% of total N, 12.55 ppm of available P, 2.93 meq/100 g exchangeable K, pH of 7.0 and field capacity of 29% (%/v). The soil type is an Entisol with loam texture. The experiment was started in February and was ended in November 2013. The source of irrigation water in the experimental site was a deep wells pump.

Treatments

There were four castor-based intercropping types tested to find out the most productive intercropping type and the highest Land Equivalent Ratio (LER). The intercropping types were: (1) Intercropped castor (cv. Beaq Amor)

with a maize hybrid (Bisi 16), (2) Intercropped castor with a short-season maize (this line is being developed at University of Mataram), (3) Intercropped castor with mungbean (Vima-1) and (4) Intercropped castor with short-season maize then followed by mungbean. All the treatments had three replications and were arranged in a Randomized Complete Block Design. For each of the component crop, monoculture plot was made to be able to calculate LER. The spacing for castor plants was 4 m between rows and 3 m within row (East-West oriented rows) and there were 9 plants in each a 12 by 10 m plot. Maize crops were planted between the rows of castor plants at 70 cm x 20 cm of spacing. The spacing used for mungbean was 40 cm x 10 cm. Distant between maize and mungbean rows from castor rows was 75 cm.

Crop Management

The castor plants were fertilized three times, first was at 10 days after sowing (DAS), second was at 35 DAS and the third was at 110 DAS. The first and second fertilizer applied was 120 g N-P-K (15-15-15) for each plant and the third fertilizer application was 100 g. The maize crops were fertilized with 300 kg ha⁻¹ of N-P-K and 200 kg ha⁻¹ Urea at 10 DAS followed by an application of Urea at the same rate at 35 DAS. Mungbean crops were fertilized once at 10 DAS with 200 kg ha⁻¹ of N-P-K. Watering by flooding to the experimental plots was done regularly when the soil condition reached 25% of the field capacity. The main pest in castor, castor semi-looper (*Achaea janata*), was suppressed by using a pesticide containing Deltamethrin.

Measurements

Parameters measured were grouped into two; microclimate under the castor plants canopy and yield of the component crops. The microclimate components measured were transmitted light, soil moisture, ambient air temperature and relative humidity. The transmitted light was measured using an AccuPAR (*PAR Light Ceptometer, Decagon Devices*) and the measurements were done directly above and under the plants canopy during a clear day at midday. Soil moisture at 20 cm depth with 25 cm and 50 cm distance from main stem of the castor plants was measured using a *FieldScout TDR 300 Soil Moisture Tester*. Ambient air temperature and relative humidity were measured using a digital Thermo hygrometer. The crop yields reported in this study

were in the form of seeds. In addition to seed yield, the numbers of racemes per plant and seed weight per raceme for castor were also measured. Projection of land productivity of each intercropping type was made based on the seeds price at the time of harvest.

Data Analysis

The collected data from the four intercropping treatments were analyzed using Analysis of Variance at 95% level. Calculation for Land Equivalent Ratio (LER) was done following an equation proposed by Mead and Willey (1980) as follows: $LER = \sum \left(\frac{Y_p}{Y_m} \right)$, where Y_p is crop yield from a component crop in intercropping and Y_m is crop yield from monoculture.

Results and Discussion

All the component crops in this experiment received sufficient water from rainfall up to May 2013. Irrigation water for the crops afterward was met by pumping the ground water from the available deep-wells. Most of the component crops grew well except for the first planted mungbean in the castor+mungbean intercropping (C+MB) and in monoculture. In the second

sowing for castor+short season maize+mungbean (C+EM+MB) treatment, the mungbean grew well. The even growth of the crops, especially for castor, resulted in no difference in transmitted light by the plants' canopy at 35 DAS (Table 1). The same trend was also found at 49 DAS light measurements. Relatively the same transmitted light under the castor canopy resulted in the same microclimate conditions, such as air temperature, soil moisture content and relative humidity under the canopy (Table 1).

Soil moisture content at 25 cm from castor stem base was slightly higher than that at 50 cm from castor stem base at 49 DAS (Table 1). Roots from maize and mungbean plants that were planted at 75 cm distance from the castor stem base took more water at 50 cm zone than that from 25 cm zone. Soil moisture measurements were conducted at one day after irrigation and at the time of measurements, the soil moisture content was at 75.5% to 79.3% of the field capacity. The crops (especially castor and mungbean) started to show wilting in their top leaves when the soil moisture content reached 11%/v or at 38% from the field capacity. At that condition, irrigation water then was applied to the whole experimental site.

Table 1. Microclimate conditions under the canopy of castor plants

	Treatments			
	C+M ^{*)}	C+EM	C+MB	C+EM+MB
Light interception (%) at 35 DAS	27.7	25.3	26.3	28.2
Light interception (%) at 49 DAS	50.7	46.4	50.3	50.9
Soil moisture (%) 25 cm from stem base	22.3	23.0	23.0	22.3
Soil moisture (%) 50 cm from stem base	22.3	21.9	22.0	22.1
Air temperature (°C)	34.8	34.8	34.7	34.8
Relative humidity (%)	51.6	50.9	50.8	51.2

*) C+M= castor+maize, C+EM= castor+early maize, C+MB= castor+mungbean, C+EM+MB= castor and early maize followed by mungbean.

The first harvest for castor from the main raceme was at 115 DAS and then followed by the next harvests from primary and secondary racemes up to 210 DAS. Castor yield from the main and primary racemes recorded in this experiment was considered as low (Table 2) even though the early vegetative growth of the castor plants was excellent. Earlier, Jaya (2011) reported that for the same castor variety (Beaq Amor) yielded 30% higher on a clay dry land soil in East Lombok. However, the values of soil properties reported in East Lombok, such as soil C-organic, total N,

available P and exchangeable K were almost double than that reported in this study. Number of secondary racemes was also categorized as low with an average of 2.3 racemes (Table 2). The loam texture with a low soil organic matter of the degraded land was considered as the main factor to cause the low castor yield. In this kind of growing environment, especially at low N, castor plant tends to allocate more of their carbohydrate into the roots instead of shoots (Reddy and Matcha, 2010).

Table 2. Yield components of castor grown under different intercropping

	Treatments			
	C+M ^{*)}	C+EM	C+MB	C+EM+MB
Number of primary racemes	2.4	2.8	2.7	2.7
Number of secondary racemes	5.7	6.4	6.1	6.3
Main raceme seeds weight (g)	83.4	85.1	83.4	81.6
Primary racemes seeds weight (g)	147.8	160.8	155.1	159.0
Secondary racemes seeds weight (g)	164.7	173.7	169.6	169.4
Total seed weight per plant (g)	395.9	419.6	408.1	410.0

^{*)} C+M= castor+maize, C+EM= castor+early maize, C+MB= castor+mungbean, C+EM+MB= castor and early maize followed by mungbean.

All yield components of the castor were not affected by the intercropping system (Table 2). These show that all the component crops (maize, early maize and mungbean) did not compete with castor when the distance of their planting row was at least 75 cm from the castor stem base. These results contradict earlier findings by Dhimmar (2009) that pulses such as chickpea, green gram and Indian bean reduced castor yield, especially when the pulses were grown in paired row planting. However, there was no further explanation on the distance between rows of the pulses and the stem base of the castor. When castor plants were grown in pair under intercropping with pulses (groundnut, soybean and mungbean) on dry land, with distance of the pulses row from castor stem base was 50 cm, the growth and yield of the castor plants were not affected (Jaya, 2011). These results show that the crops species and the row distance of the under storey crops determine growth and yield of the component crops in intercropping.

Yield of all the component crops is presented in Table 3. The data show that there was no significant different of crops yield resulted from

monoculture and intercropping in all component crops. This means that intercropping improves total yield from a piece of land as well as improves the land productivity. In term of total yield produced per unit land, intercropping castor with hybrid maize (C+M) was the highest but not significantly different with castor-early maize followed by mungbean (C+EM+MB). The least total yield production was recorded from intercropping castor with mungbean (C+MB) but the selling price of mungbean was high, resulted in high intercrop productivity. The price assumption used in this study to express the intercropping productivity was the price of the component crops yield at harvest (castor bean IDR 3,000 kg⁻¹, maize IDR 2,000 kg⁻¹ and mungbean IDR 13,000 kg⁻¹).

Data in Table 3 shows that the highest intercropping productivity resulted from intercropping castor with early maize and then followed by mungbean (C+EM+MB) while the least productive intercropping was castor with early maize (C+EM).

Table 3. Effect of intercropping system on crop yield and productivity

Treatments	Yield (kg/ha)				Total yield (kg/ha)	Intercrop productivity (IDR/ha)
	Castor	Maize	Early Maize	Mungbean		
Monoculture	308.2	3,756.8	2,782.2	662.2	-	-
C+M ^{*)}	296.9	3,740.2	-	-	4,037.1 c	8,371,100 b
C+EM	314.6	-	2,748.9	-	3,063.5 b	6,441,600 a
C+MB	306.0	-	-	548.1	854.1a	8,043,300 ab
C+EM+MB	307.4	-	2,798.9	708.0	3,814.3 c	15,097,600 c
<i>LSD</i>	-	-	-	-	256.01	1,495,22
Monocropping productivity (IDR/ha)	924,600	7,513,660	5,564,440	8,608,600		

^{*)} C+M= castor+maize, C+EM= castor+early maize, C+MB= castor+mungbean, C+EM+MB= castor and early maize followed by mungbean.

It should be noted that the hybrid maize was harvested at 110 DAS, the early maize was harvested at 76 DAS and the mungbean was at 52 DAS. This means that to get the highest land productivity, a longer time is required, at least 139 days for C+EM+MB system. When the rainwater is still available, growing mungbean after early maize under castor canopy can improve the land productivity as well as crop diversity. Another advantage for this system is that the early maize leaves are still green at harvest that can be utilized as feeds for animals.

Growing castor in monoculture to produce bio-fuels is not the best option in utilizing a degraded land in the humid tropics because of the low land productivity (Table 3). Data in Table 4 shows that a great improvement in land productivity was achieved whenever castor was intercropped with

food crops. The highest improvement was achieved when castor was intercropped with hybrid maize and followed by castor with mungbean and castor with early maize. However, when the food crops such as hybrid maize and early maize were grown in monoculture, adding castor plants in the form of intercropping resulted in less improvement as compared to adding food crops into a castor plantation. In the case of mungbean, castor reduced the land productivity by as much as 6.6%. Considering the benefit of growing castor that can act as a 'saving' for the farmers during dry season (Jaya et al., 2012), produces bio-energy, sequesters carbon and provides land cover (Wang et al., 2010; Olivares et al., 2013), intercropping castor with food crops on a degraded land is suggested.

Table 4. Percent (%) land productivity improvement (or loss) under different intercropping

Monoculture	Intercropping			
	C+M ^{*)}	C+EM	C+MB	C+EM+MB
Castor (C)	805.4	596.7	769.9	1,532.9
Maize (M)	11.4			
Early Maize (EM)		15.8		171.3
Mungbean (MB)			(6.6)	75.4

^{*)} C+M= castor+maize, C+EM= castor+early maize, C+MB= castor+mungbean, C+EM+MB= castor and early maize followed by mungbean.

Land Equivalent Ratio (LER) value for castor decreased slightly under intercropping as compared to monocropping (Table 5). The lowest LER value in intercropping was calculated in mungbean (0.83) and this fact is in line with the percent land productivity data in Table 4. The LER value for mungbean shows that a larger land area (of around 17%) is required by mungbean in intercropping with castor to produce the same yield as in monocropping. LER values in maize,

both for hybrid and early maize, are relatively the same for in intercropping and in monocropping (Table 5). These mean that both maize varieties produced the same yield either in monoculture or in intercropping with castor in the same size of land as shown in Table 3. LER values for all component crops increase with intercropping with a range from 1.83 to 3.07 (Table 5) that shows the advantage of intercropping over monocropping.

Table 5. Effect of intercropping system on Land Equivalent Ratio (LER)

Treatments	Land Equivalent Ratio (LER)				
	Castor	Maize	Early Maize	Mungbean	Intercrop
Monocrop	1.00	1.00	1.00	1.00	1.00 a
C+M	0.96	1.00	-	-	1.96 b
C+EM	1.02	-	0.99	-	2.01 b
C+MB	0.99	-	-	0.83	1.82 b
C+EM+MB	1.00	-	1.00	1.07	3.07 c
<i>LSD (0.05)</i>					<i>0.24</i>

^{*)} C+M= castor+maize, C+EM= castor+early maize, C+MB= castor+mungbean, C+EM+MB= castor+early maize followed by mungbean.

These results are in agreement with some castor based intercropping studies in India that had been reviewed by Chand and Sujatha (2000). The lowest LER value (1.82) was calculated from intercropping between castor and mungbean and the highest was intercropping between castor and early maize followed by mungbean (C+EM+MB). These results suggested that in order to improve the degraded land utilization and productivity, castor based intercropping with some food crops is recommended to produce bio-energy and foods.

Conclusion

Intercropping food crops, such as maize and mungbean with energy crop of castor on a degraded land in arid tropics improved the land productivity. The highest land productivity improvement was achieved by an intercropping system of castor with early maize then followed by mungbean after the harvest of the early maize. By this system, in addition to land productivity and crop diversity improvements, in the long run, land quality and livelihoods of the farmers in arid tropics are expected to improve as well. Further study on carbon sequestration by castor plants on degraded land is required.

Acknowledgements

The authors would like to thank University of Mataram for actively involved in conducting this study.

References

- Blanko-Canqui, H. 2009. Energy crops and their implications on soil environment. *Agronomy Journal* 102: 403-419.
- Chand, P. and Sujatha, M. 2000. Castor based intercropping systems – A Review. *Agricultural Reviews-Agricultural Research Communications Centre India* 21: 244-248.
- Delucchi, M. 2011. A conceptual framework for estimating the climate impacts of land-use change due to energy crops programs. *Biomass and Bio-energy* 35: 2337-2360.
- Dhimmar, S. K. 2009. Effect on growth and yield of rabi castor in pulses intercropping under varying planting geometry. *American-Eurasian Journal of Scientific Research* 4: 165-168.
- Harvey, M. and Pilgrim, S. 2011. The new competition for land: Food, energy and climate change. *Food Policy* 36: S40-S51.
- Jaya, I.K.D. 2011. Agronomic aspects of intercropping of energy crop of castor (*Ricinus communis* L.) and pulses. *Proceedings International Seminar on Natural Resources, Climate Change and Food Security in Developing Countries* Book 1.p 407-415.
- Jaya, I.K.D., Rosmilawati, Sudika, I.W. and Suriawan, L.J. 2012. Crop diversity on dryland as an adaptation strategy to climate change. *Proceedings The 2nd Society for Indonesian Biodiversity* p 93-97.
- Lal, R. 2006. Enhancing crop yields in developing countries through restoration of the soil organic carbon pool in agricultural lands. *Land Degradation and Development* 17: 197-209.
- Lal, R. 2011. Sequestering carbon in soils of agro-ecosystems. *Food Policy* 36: S33-S39.
- Mead, R. and Willey, R.W. 1980. The concept of a 'Land Equivalent Ratio' and advantages in yields from intercropping. *Experimental Agriculture* 16: 217-228.
- Oladoja, N.A., Aboluwoye, C.O., Oladimeji, Y.B., Ashogbon, A. O. and Otemuyiwa, I.O. 2008. Studies on castor shell as a sorbent in basic dye contaminated wastewater remediation. *Desalination* 227: 190-203.
- Olivares, A.R., Carrillo-González, R., González-Chávez, M.D.A. and Hernández, R.M. S. 2013. Potential of castor bean (*Ricinus communis* L.) for phytoremediation of mine tailings and oil production. *Journal of Environmental Management* 114: 316-323.
- Reddy, K.R. and Matcha, S.K. 2010. Quantifying nitrogen effects on castor bean (*Ricinus communis* L.) development, growth and photosynthesis. *Industrial Crops and Products* 31: 185-191.
- Vanaja, M., Jyothi, M., Ratnakumar, P., Vagheera, P., Reddy, P.R., Lakshmi, N.J., Yadaf, S.K., Maheswari, M. and Venkateswarlu, M. 2008. Growth and yield responses of castor bean (*Ricinus communis* L.) to two enhanced CO₂ levels. *Plant Soil and Environment* 54: 38-46.
- Wang, Q., Li, Y. and Alva, A. 2010. Growing castor crops to improve biomass accumulation and carbon sequestration: A phytotron study. *Journal of Environmental Protection* 1: 73-84.