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Yield Performance of *Jatropha curcas* L. After Pruning During Five Years Production Cycles in North Lombok Dry Land, Indonesia

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Pruning is an agronomical practices resulting in inducing of more branches, and then increasing inflorescences number leading to higher seed yield. The objective of the research was to determine the effect of pruning time on the yield performance of *Jatropha curcas* L. A series of experiments was conducted from November 2008 to November 2013 at dry land of North Lombok, West Nusa Tenggara, Indonesia using West Lombok genotype. The experimental design was Randomized Block Design with three replications. There were four treatments i.e. a) without pruning, b) pruning of sapling at planting time, c) total pruning at the first year, d) total pruning at the second year es, e) total pruning at the third year, and f), total pruning at the forth year. The result showed that plant development and maintenance canopy was an important agronomic practice to obtain high seed production. The best time for pruning during 5-years production cycle were total pruning at the second year with seed yields during 5 years production cycle (from the first to the fifth year) were 718.4 kg Ha^{-1}; 1,135.4 kg Ha^{-1}; 1,972.9 kg Ha^{-1}; 5,436.3 kg Ha^{-1}, and 8,271.6 kg Ha^{-1} respectively. The total yield was higher (16,314.6 kg Ha^{-1}), compared to un-pruned tree (14,800.1 kg Ha^{-1}). The increase was about 10.2 %.

Keywords: branch, canopy architecture, oil content, seed yield

INTRODUCTION

In recent years, due to concerns on fossil fuel depleting and price increasing, *Jatropha curcas* L. has attracted attention to partially replace fossil fuel as biodiesel. In Indonesia, this plant is considered as an oil-producing plant to fulfill fuel need and poverty alleviation and income generation initiatives in rural area. It can be produced in most parts of the country, especially in the dry south eastern part of Nusa Tenggara (Koh and Ghazi, 2011). It is commonly grown as a live hedge around agricultural fields and home-garden as it is not fed by animals.

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Table 1: The climate condition at the research area from 2008 to 2013

Climate components	2008	2009	2010	2011	2012	2013
Rainfall (mm)	699	652	1,149	660	907	723
Rainy months	5	4	7	4	5	4
Rainy days	57	48	75	50	71	61
Minimum air temperature (^{O}C)	25.8	25.4	24.4	25.9	25.2	26.1
Maximum air temperature (^{O}C)	32.5	32.7	32.9	33.1	33.8	34.7
Relative humidity (%)	89	89,4	90.2	89.7	84.2	78.7

In the meantime, acquiring and documenting such in-depth knowledge of growth and yield potential of perennial crops, like *Jatropha curcas* are huge task. Without much scientific agronomical study, especially in long period of cultivation, there are many assumptions that the seed yield of *Jatropha curcas* varies from 2-5 ton ha^{-1} to 7-12 ton ha^{-1} (Sigh *et al*. 2014). There is not yet an information of the plant yield potential for long period of cultivation. On the other hands, research activity was limited only on the laboratory scale, production process technology, biodiesel property, oil standardization, and genetic engineering. The necessity to obtain adequate information on the growth and yield potential during long period of cultivation is imperative for any agronomy and breeding programs to succeed. As Sunil *et al*. (2008) argued that identification of promising *Jatropha* germ-plasm would entail a concerted study over a period of time, usually 5-10 years.

Flowering on *Jatropha* occurs terminally. The number of branches formed affects the productivity (Ratree, 2004; Ramu *et al*., 2005), and branching can be stimulated by pruning (Gour, 2006) or select genotypes that have many branching characters (Islam *et al*., 2011). Pruning is commonly used in Asia to boost yields and ease harvesting of Jatropha (Behera *et al*., 2010; Rajaona *et al*., 2011). It is also a method to form a plant to improve the efficiency of solar energy harvesting and to control the growth and development of some fruit trees and estate crops. In Jatropha, branching is expected to support number of fruits that can grow and develop in each branch terminal formed so the seed production increases. Moreover, pruning and canopy management on the plant cultivation are important crop architectural intervention to enhance more branches production and to stimulate abundant healthy inflorescence then to enhance good fruit setting and seed yield (Behera *et al*. 2010). This article presents the results of study undertaken to assess the performance on the seed yield of Jatropha after pruning at several different plant ages during five years of production cycle.

MATERIALS AND METHODS

Plant material and their preparation

Plant material was a superior selected genotype of West Nusa Tenggara, Indonesia, namely West Lombok. Seeds were collected from representative trees showing good growth and development. Capsules with yellowing color (ripe stage) were harvested, and the seeds were air dried for two days before sowing in a nursery.

Experimental design and site condition

Seedling preparation and field experiment were performed at Amor-Amor Village, District of Kayangan, North Lombok regency, West Nusa Tenggara, Indonesia located at 8^{O}16'15.02''S 116^{O}17'34.02''T at 75-100 m above sea level, from November 2008 to November 2013. Two and half-month-old seedling raised in black polybags were planted in the field experiment to evaluate yield performance in a Randomized Block Design with three replications. The plot size was 8 x 12 m and number of plants per plot was 24 with 2 x 2 m plant spacing. All the twenty-four plants in each plot constituted as the measurement unit. Six treatments of plant pruning time were: a) without pruning, b) pruning of sapling at planting time, c) total pruning (the trunk at about 40 cm height) at the first year, d) total pruning at the second year, e) total pruning at third year, and f) total pruning forth year. Pruning was done during plant dormancy period (several weeks before rainy season).

The study area was a dry land with characteristics of sandy loam Entisols and composed of sand (69%), silt (25%), and clay (5%), with 1.8% organic carbon, 0.2% total N, the pH 5.9-6.3, and cation exchange capacity of the soil was 7.2-10.4 cmol.kg^{-1}. During 5 years experiment, rainfall was distributed only in 4-5 months per year, except in 2010, it was 7 months. Maximum air temperature was slightly increase, but the relative humidity was reduced (Table 1).

Therefore, the plant was cultivated in infertile sandy soil and the soil was a common plant production area in semi-arid tropics and could represent plant cultivated soil in terms of low fertility and sandy texture.

Agronomic practices

Fertilizer was applied at planting time of 5,000 kg of manure ha^{-1} (2 kg $tree^{-1}$) and 25 kg of Urea ha^{-1} (10 g $tree^{-1}$), 150 kg of SP-36 ha^{-1} (60 g $tree^{-1}$), and 30 kg of KCl ha^{-1} (12 g $tree^{-1}$). The second Urea application (25 kg Urea ha^{-1} (10 g $tree^{-1}$)) was applied one month after planting. At the second and third year, the plants were given 25 kg of Urea ha^{-1} (10 g $tree^{-1}$), 150 kg of SP-36 ha^{-1} (60 g $tree^{-1}$), and 30 kg of KCl ha^{-1} (12 g $tree^{-1}$). Then, at the forth and the fifth year, the plants were fertilized again using 50 kg of Urea ha^{-1}, 175 kg of SP-36 ha^{-1}, and 45 kg of KCl ha^{-1}. In the second to the fifth year, Urea, SP-36, and KCl were applied at the beginning of the rainy season (November). Weeding was done in radius one meter from the stem base. Irrigation was applied weekly up to one month after planting, and after that, no irrigation was applied.

Observation and data analysis

Number of capsules per inflorescence and per plant, weight of seeds per plant and per plot, and seed oil content were measured and recorded. Extraction of seed oil was carried out following the Soxchlet Extraction Method modified by Sudarmadji *et al*. (1997) in which, the seed kernels were separated and powdered. The seed kernels (3 g) were ground mechanically and defatted in a soxchlet apparatus using hexane for 6 h. Solvent was removed by vacuum evaporation, and then exposed to heat in a drying oven at 50°C for 39 h. The amount of oil recovered was calculated as percentage of total oil. Each extraction was run in triplicate and the final value was the average of samples of each treatments. Data were subjected to analysis of variance and the mean along with standard error were computed for each of quantitative traits using Minitab-14 statistical program.

RESULT AND DISCUSSION

Shoot branching is a process by which buds located in the axil of a leaf develop and form branches (Ongario and Leyser, 2008), then flower (inflorescence) for *Jatropha*. Annual increment in number of productive inflorescence per trees, number of capsule per inflorescence, number of capsule per trees, seed dry weight per trees and per hectare and also seed oil content were affected by pruning.

In general, pruning at different plants age was effective significantly to the plant seed yield. Pruning at dormancy period or during the dry season was stimulated branching and flowering in the next rainy season, then affecting crop yields. In detail, pruning significantly affected on the number of productive inflorescence (flower bunch) per trees, the number of capsules (fruits) per trees, but not significantly affected on the number of capsules per inflorescence (Figure 1). In this study, the productive inflorescence produced at least five capsules. The pruning also significantly affected on the weight of dry seed per trees and per hectare (Figure 2). However, there were no significant differences of seed kernel oil content between pruned and un-pruned plants (Table 2) during the 5-year of production cycle.

Figure 1 showed that the number of productive inflorescence and capsule per trees (plants) continuesly increased along with plant age, and it was significant difference between the pruned and no un-pruned plants. The figure also showed that the number of capsules per inflorescence was no different between the pruned and un-pruned plants since the first year. In general, the number of capsules produced per inflorescence was ranged from 10.8 to 13.8. The number of capsules produced per inflorescence depended on the ratio between the plant male and female flowers. The flower ratio of West Nusa Tenggara genotypes ranged from 8.6-12.7 at the second year (Santoso *et al*., 2011b), and decreased along with the plant ages (Silitonga, 2011; Raju and Ezradenam, 2002). The same trend also happened to the number of capsules per inflorescence.

Figure 2 showed the yearly yield potential with respect to seed dry weight per trees and per hectare, and Table 2 showed total seed dry weight per trees and per hectare during five years production cycle. In Figure 2, the plant with no pruning showed higher seed yield both per tree and per hectare (718.4-748.9 kg ha^{-1}) compared to the pruned plants (483.8 kg ha^{-1}) at the first year of production cycle. At the second year, plant pruned at the first year was showed higher seed yield (1,297.9 kg ha^{-1}) than plant with no pruning. Seed yield of plant that pruned at planting time was showed the highest (2,549.4 kg ha^{-1}) at the third year of production year. However, the highest seed yield (5,064.4 kg ha^{-1}) at the forth year was showed by the plant pruned at the second year, and then the highest seed yield (7,423.6 kg ha^{-1}) at the fifth year was found at plant pruned at second year followed by plant pruned at third year (6,909.6 kg ha^{-1}). The highest seed production during five-year production cycle was obtained on the plant pruned at the second year, i.e. 8,057.4 g $tree^{-1}$, and 16,314.6 kg ha^{-1} (Table 2). From this study, we found phenomena that the plant would produce maximum seed yield after 2-3 year of pruning, and drastically reduced after pruning, and then increased back at next year after.

Un-prune plant of West Lombok (LB) genotype produced 748.9 kg ha^{-1} of seed dry weight in the first year and up to

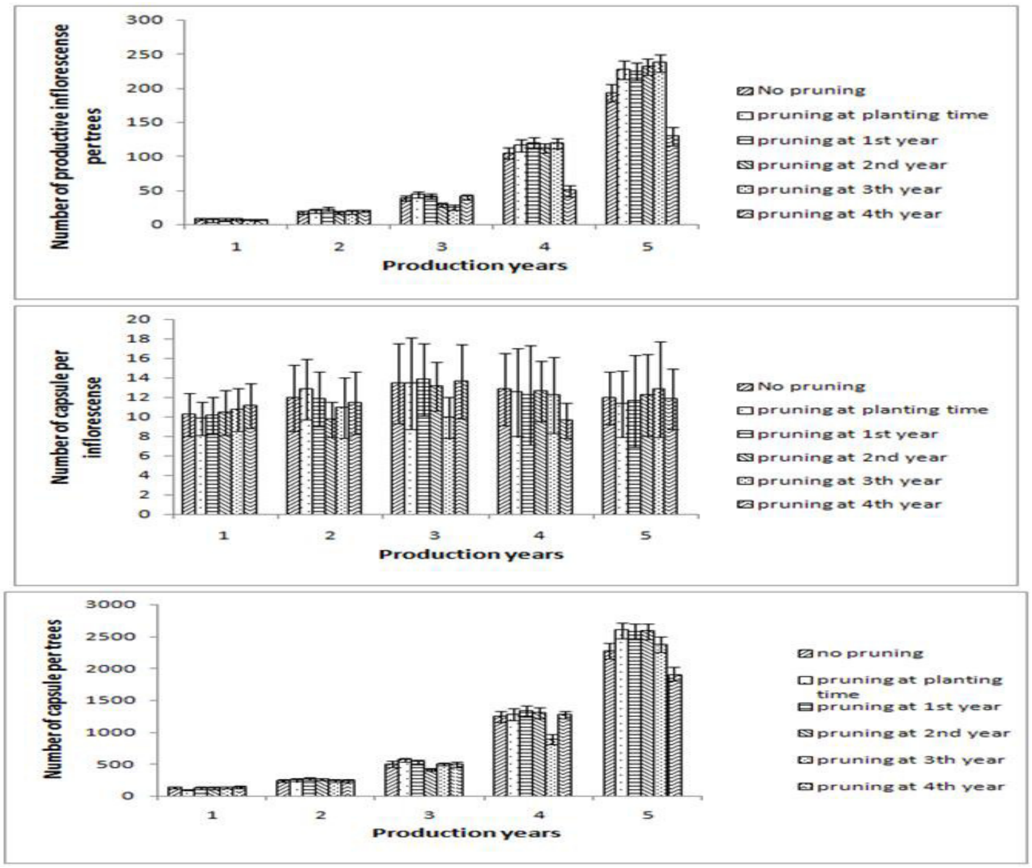

Figure 1: The number of productive inflorescence per trees (above) and per inflorescence (centre), and the number of plant capsules per trees (below) after pruning

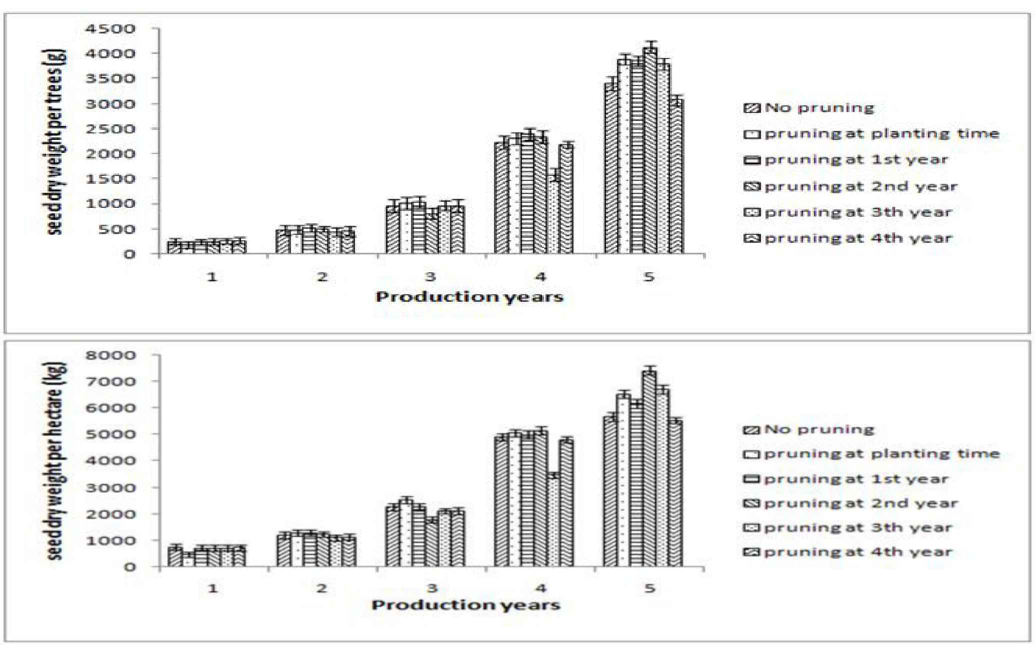

Figure 2: The plant seed yield of after pruning. The weight of dry seed per trees (above) and per hectare (below)

Table 2: Total seed dry weight per trees and per hectares during five years production cycle

Pruning times	Dry seed weight per trees (g)	Dry seed weight per hectare (kg)
No pruning	7,312.2	14,800.1
Pruning at planting time	7,892.4	15,917.5
Pruning at 1st year	8,017.0	15,471.2
Pruning at 2nd year	8,057.4	16,314.6
Pruning at 3th year	7,048.7	14,148.5
Pruning at 4th year	6,952.8	13,342.6

Table 3. The seed kernel oil content after pruning

Pruning times	Kernel oil content (%)				
	Year 1	Year 2	Year 3	Year 4	Year 5
No pruning	38.7	38.1	39.2	38.7	39.1
Pruning at planting time	36.9	37.2	38.5	38.1	38.3
Pruning at 1st year	37.4	38.2	38.3	38.2	38.1
Pruning at 2nd year	36.8	37.8	37.8	37.7	37.9
Pruning at 3th year	38.7	38.1	39.0	38.2	39.1
Pruning at 4th year	37.7	38.1	38.8	37.9	38.8
LSD 5%	-	-	-	-	-

Explanation: oil content was based on Folch *et al*. (1957) modified by Sudarmadji *et al*. (1997)

1,202.1 kg ha^{-1} of seed dry weight in the second year; then 2,261.4 kg ha^{-1}, 4,919.1 kg ha^{-1}, 5,669.6 kg ha^{-1} of seed dry weight in the third, forth, and fifth year, respectively. Figure 2 also showed that, the best time for pruning during 5-years production cycle were total pruning at the second year with seed yield at 1 to 5 years of 718.4 kg Ha^{-1}; 1,135.4 kg Ha^{-1}; 1,972.9 kg Ha^{-1}; 5,436.3 kg Ha^{-1}, and 8,271.6 kg Ha^{-1} respectively. Compared to JO.S2, a new variety reported by Yi *et al.* (2014), the yield was bite lower. The new variety yield was 987.8 g $plant^{-1}$ or 2.47 t ha^{-1} at the first year. Kumar and Sharma (2008) reported that, seed production ranged from 2 t. ha^{-1} to 12.5 t. ha^{-1} after five years of growth. Moreover, seed production ranged from about 0.3-10.9 t.ha^{-1} per year (Openshaw, 2000). Meanwhile from this study, the yield of pruned plant at the second, third and forth year decreased in the next year after pruning compared with un-prune plant. However, a threefold increase was occurred after two years of pruning. Seed yield of pruned plant was higher compared to seed yield of un-prune plant. So, in the present study, the dry seed yield of both un-prune and prune plants ranged between of those reports, but was lower than as reported by Achten *et al*. (2008) that, dry seed yield of 9.8-12.3 t.ha^{-1} was a reasonable yield estimation for an adequately managed plantation with favorable environmental conditions. This might be because the planting standing tree was not a superior variety. It was selected from wild genotype and grown at dry land with rainny irrigation.

This study also showed that, during five years production cycle, the yearly yield improvement of un-prune plant ranged from 1 to 2.5 times than the previous year, and did not follow the geometrical progression based on dichotomy pattern by Yi *et al.* (2014) and Wang and Ding (2012) stating that, botanically, each top-branch continuously formed new branches dichotomously from 4 to 5 times, so the seed yield could reach 4 to 5 times compared to the previous year. Santoso *et al*. (2014) found that the yearly yield improvement of five Jatropha genotypes of West Nusa Tenggara did not follow the geometrical pattern. Along with an increasing in the plant age (4-5 years), the more dense canopy formed, with small and short branches, was not supported by enough leaves, the number of capsules produced per inflorescence would become lower when the plants was 2-3 years old. Due to this fact, totally pruning should be carried out after 4 years old, in order to stimulate branches with bigger and healthy leaves. Gour (2006) supported this finding and stated that total cutting should be carried out during the dry dormant season to increase branching and the number of tip-borne inflorescences, as well as to form a wide low-growing tree. Even though, there was drastic seed yield reduction after pruning of pruned plant compared to un-pruned plant (Gosh *et al.*, 2011).

The yield reduction of the prunned plant in the next year after prunning also related to the growth of new vegetative organs. New buds and leaves formed need sugar to develop well, especially in the first year. This resulted in high competition between plant reproductive (generative) development and new vegetative growth to renew the loss of photosynthetic potential. In addition, we found that seed yield was higher under pruning of trees due to shorter trunk and longer primary branches in total after pruning. On the other hand, un-prune plant had a dense or tangled mass of branches which was usually small and short after 4-5 years. The inner shoots were deprived of light, and then develop as a un-productive branch.

Table 3 showed that during the five years production cycle with standard jatropha cultural practices, seed oil content (kernel base) was not significantly different between the prune and un-prune plants. This study was not in line with Leon *et al.* (2003) stating that yield component such as seed oil content could be modified by environments or cultural practices. However, Santoso *et al.* (2011a) reported that there was no significantly different of oil seed content of the *Jatropha curcas* grown from different planting material, e.g. seed and stem cut in the same genotype.

In general, that there was declining in the dry seed yield of un-prune plant along with increasing in the plant age. Although the total pruning led to a decrease in dry seed yield in a year after pruning, but it was led to an increase dry seed yield after two years compared to un-prune plant. For that reason, pruning is needed to produce a succession of young shoots and branches or mature branches so that the cropping element is kept young and also productive with higher number of capsules per inflorescence. Gill and Bal (2006) stated that, the aim of the renewal pruning is to keep the bush young with an adequate supply of one-year-old wood to ensure a good flowering, and then fruiting. Therefore, as the crop ages, one third to a quarter of the oldest stem and branches should be removed to encourage stronger new growth. This finding was also in agreement to that trees are pruned at the trunk of 30-45 cm height to optimize the tree architecture by maximizing the number of lateral branches for a given planting density and optimal biomass production (Behera *et al.*, 2010).

CONCLUSIONS

Based on the growth and yield performance quantified in this study, we believe that pruning has a potential agronomical practice to achieve a higher yield through improving crop condition management. Pruning during long period of plant growth and development has also benefit to check a potentially higher yielding genotype for breeding program. Total pruning at different age of the tree showed significant differences in dry seed yield. During five years production cycle, pruning at the age of two years increased the total dry seed yield 10.2 percent (16,314.6 kg ha^{-1}) of un-pruned plant (14,800.1 kg ha^{-1}). Total pruning every year seems not to be necessary, but the plants only need to be pruning totally in the fifth year because they are too tall with non productive inflorescence and low number of fruit per inflorescence. Moreover, harvest can be difficult with lower seed yield and high cost.

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