ATLANTIS PRESS

Advances in Intelligent Systems Research (AISR), volume 149
International Conference on Science and Technology (ICOSAT 2017)

Morphological and Growth Characters of Andromonoecious *Jatropha curcas*

Dasumiati[a*], Miftahudin[b], Triadiati[c], Hartana, A[d]

[a]Department of Biology
Syarif Hidayatullah State Islamic University Jakarta
Tangerang Selatan, Indonesia
[b,c,d]Department of Biology, Faculty of Mathematics and Natural Sciences
Bogor Agricultural University, Dramaga, Indonesia
*Email: dasumiati@uinjkt.ac.id

Abstract

Jatropha (*Jatropha curcas* L.) is a potential plant for producing seed oil as a source for biodiesel. Generally, the plant is monoecious, but in some cases andromonoecious Jatropha was also found. Andromonoecious Jatropha produced hermaphrodite and male flowers in the same inflorescence. The objective of this research was to analyze some specific characters of andromonoecious Jatropha and compared the characters to monoecious Jatropha. The observation was conducted on Dompu accession that has sex type of andromonoecious and monoeciouss. The specific character that could distinguish andromonoecious and monoecious Jatropha were the number of branch, branch angle, the distance between nodes, the number of inflorescences per plant, fruit set, and seed weight per plant. Andromonoecious Jatropha had higher number of branch, inflorescences per plant, fruit set, and seed weight than monoecious Jatropha. Andromonoecious Jatropha's growth was similar to monoecious Jatropha, except for the formation of branches and flower. Andromonoecious Jatropha formed branches faster than monoecious, but formed flowers later than monoecious Jatropha.

Keywords: Branching, Hermaphrodite, Male, Sex determination

1. Introduction

Jatropha curcas (*Euphorbiaceae*) originated from Mexico and Central America is widely cultivated in the countries of Latin America, Asia and Africa [1], and the countries of the tropics and other subtropics [2], including Indonesia. Jatropha cultivation is occurred because of the potential as producer of biodiesel [3]. Developments in Jatropha cultivation is not followed by obvious grouping, exactly in grouping below the species. Information about this plant is quite limited. It causes the society in using terms that have been commonly used in other plants such as varieties, clones, and others [4]. Besides having the morphological diversity, Jatropha is also very diverse in terms of regions origin, resulting the confusion about the term of plant material obtained from different regions or generated in various ways. Therefore it is very important to characterize the diversity of Jatropha [5].

One of the diversity which is attractive in Jatropha is the diversity of flower sex type that is produced in one plant, male flower, female, and hermaphrodite. The diversity of flower sex types cause sex types variations between individual plants. General sex type owned by Jatropha is monocieous plant that produces female and male flowers on the same inflorescence [6]. The position of the female flower was replaced by the hermaphrodite flower so that male flower and hermaphrodite are produced on the same inflorescence. Plant that produce hermaphrodite and male flower on the same individual is called andromonoecious [7]. Andromonoecious Jatropha is rare to be found [8]. Monoecious and andromonoecius sex type is found in Jatropha of Dompu accession, so this Jatropha is used for research material.

The diversity of the sex type is genetic wealth that can be used for superior varieties development in Jatropha. Therefore, character analysis in Jatropha based on sex type is very important to help the development of next Jatropha research, such as creating a superior variety in the breeding activities [9]. Besides that, it also needs to analyze growth to know production opportunities of andromonoecious Jatropha. Characterization of monoecious Jatropha has been done from morphology until molecular stage. This characterization is still limited for characterization between accessions from various regions in its potential as biodiesel producer. Some of research which had reported characterization in morphology level of Jatropha monoecious is characterization for selection of plus candidate phenotype [1], minimum description for characterization and Jatropha evaluation in the utilization and improvement of plant [10]. In addition, morphology diversity of 60 individual of Jatropha chosen in experiment garden reported characterization of Jatropha leaf and its relationship with photosynthesis [11], [12].

Characterization based on the sex determination that distinguish between sex type of monoecious with andromonoecious Jatropha had not been reported both in morphology and molecular. This research aims to characterize of andromonoecious Jatropha so it will be obtained specific characters and distinguished between andromonoecious with monoecious Jatropha, and analyzing growth.

2. Research Method

2.1 Plant material

This research is divided into two phase, namely morphology characterization and analysis of andromonoecious Jatropha growth. Plant material for morphology characterization is the plant from steam cuttings result of andromonoecious and monoecious Dompu accession which has had aged of 8 month, blossom and bear fruit (each of the 60 plants) planted on the latosol soil in Dramaga, Bogor. Plant materials used for growth analysis are andromonoecious and monoecious Jatropha resulted from self-pollination results (each of the 15 seeds or plants). The seeds are planted on the latosol soil at Bambu Apus, Pamulang, South Tangerang.

2.2 Characterization of morphology

Morphology characterization was done in andromonoecious and monoecious Jatropha. On the morphology characterization, observed characters include trunk, flower, fruit, and seeds character. Observed trunk character was height of plant, number of branches, corner of branches, and branches arrangement (primary and secondary), diameter of canopy, number of node located in the trunk over 15 cm after 5 cm from apical that showed the distance between the node. Character of trunk was observed after the first harvest. The character of flower observed was the diameter of flower (bud and blossom), the length and width of the petal (sepal), length of stalk, and the number of hermaphrodite flower, female and male per inflorescence, and ratio of hermaphrodite or female toward male flower. In addition, the number of inflorescence was observed per month for one year or two period of blooming. The character of the fruit observed was the number of fruit per inflorescence or cluster, the number of fruits per plant, morphology, length and diameter of the fruit. The character of the seeds observed was the number of seeds per fruit, length and diameter of the seeds, pips per inflorescence, weight of 100 seeds and the weight of total seeds per plant that was measured during three months of blooming.

2.3 Growth analysis

Growth analysis started from germination until fruit formation and the first harvest on andromonoecious Jatropha. The observed characters was the age that appears plumula, the establishment of the first leaf, the establishment of the first branch, the number of branches, high plants, the age of the formation of the first flowers, the age of formation of the first fruits and the age of the first fruit harvest.

2.4 Data analysis

Data analysis was review of T test (*T test*) on equal 5 % by comparing andromonoecious Jatropha with monoecious for morphology characterization. Furthermore, tendency of the characters owned by the sex type of andromonoecious was analyzed.

3. Results And Discussion

3.1 Vegetative organ

Andromonoecious Jatropha was shrubs which have heightof 106.9-212.5 cm with an average of 159 cm. If trunk was cut, the trunk would produce gland secretion from transparent until white. Trunks had node and internodes which was clear with number of node of 8-17 on the location of 15 cm in trunk. At the trunk with a certain distance some nodes were very near. From the primary trunk formed branch (primary branch) and secondary branch formed tertiary branches. Branching system of Jatropha was sympodial. Branches were formed from the beginning of trunk (Figure 1A) and then after about 20 cm formed another branches, and so on. Primary or secondary branches were formed or arranged on the near node so that some branches looked like ivory decorations in both beginning and top of trunk (Figure 1C). Number of primary branches is 4-10 branches with angle of 72.7^{o}, and number of secondary branches were 4-28 branches with angle 79.1^{o} (Table 1). The diameter of canopy ranged about 111-223 cm. The type of andromonoecious Jatropha leaf was single scattered throughout the trunks, leaf resembles liver or oval, top and bottom surface colored green, formed 3-5 curves and corners, on every curve was ribbed until the edge formed digit skeleton with 5-7 main leaf skeleton. Leaf long ranged 7.3-9.3 cm with an average of 8.5 cm, wide 8.4-10.5 cm with an average of 9.7 cm. Leaf stems colored green, long of 6-8.3 cm with an average of 7.1 cm.

Figure 1. Andromonoecious Jatropha profile (A) with branches (C) and distance profile of monoecious Jatropha (B) with branches (D)

Table 1. Comparison of organ characters at andromonoecious with monoecious Jatropha

Characters	Andromonoecious	Monoecious
Height of plants (cm)	159.0±33.7	169.2±25.2
The number of the node on 15 cm trunks	14±2*	7 ±1
The number of primary branches	6±1*	2 ±1
The number of secondary branches	14±6*	4±2
The primary branch angle (^{0})	72.7±6.7*	46.7±4.0
The secondary branch angle (^{0})	79.1±6.4*	49.1±6.1
The length of the leaves stalk (cm)	7.1±0.6*	10.0±1.4
The length of the leaf (cm)	8.5±0.5*	9.3±0.7
The width of the leaf (cm)	9.7±0.6*	11.2±0.8

Note: Data that followed the sign * shows the real different in trial T (on equal to 95%)

Based on vegetative characters, so it could be seen the tendency of the characters owned by andromonoecious Jatropha. The tendency of the vegetative characters was used to detect sex type of Jatropha earlier. The characters that was looked different between andromonoecious with monoecious Jatropha was the number of primary branches, the number of secondary branches, primary branches angle, secondary branch angle, and the number of node on 15 cm trunk. It showed that andromonoecious Jatropha tend to have the number and angle of the primary or secondary branches and the number of the node on 15 cm trunk were higher than monoecious Jatropha (Figure 2). Length characters of the trunk and the size of the leaf tend to be smaller on the andromonoecious Jatropha than monoecious Jatropha (Figure 2).

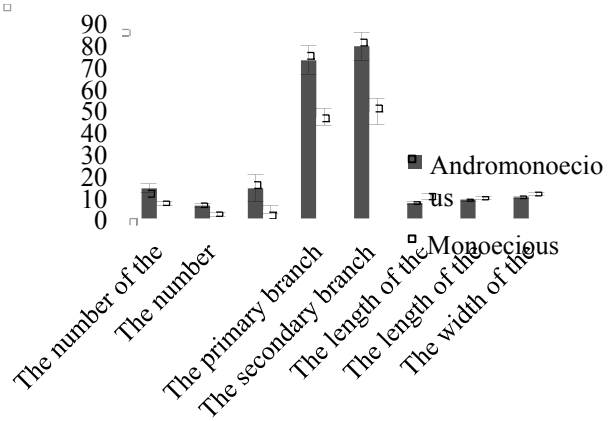

Figure 2. Trend of Vegetative characters on andromonoecious and monoecious Jatropha

3.2 Genetative Organ

Andromonoecious Jatropha flower was unlimited compound flower (*infloresentia racemosa*) malai shaped (*panicle*). Flowers grew at the end of trunk or branch, and at underarm leaves. The average number of inflorescence per plant during the observation was 47 inflorescences. Inflorescence had two main branches, one branch had many ramifications (secondary and tertiary branches) compared to other branch. Inflorescences produce male and hermaphrodite flowers. The average number of male flowers and hermaphrodite per inflorescence was 116 male flowers and 9 hermaphrodite flowers (Table 2). The hermaphrodite flower located on each ofthe end of the inflorescence branches and surrounded by male flowers (Figure 3A). Comparison of hermaphrodite flower toward male flower was 1:8-1:17 (The ratio of 0.06-0.13) (Table 2).

Generally, Development of hermaphrodite flowers formed the fruit with average fruit set of 96.6%, so that the total number of fruit per inflorescence was almost same with the number of hermaphrodite flower per inflorescence (Table 2, Figure 3B). Fruit was box shaped which was known as capsule, had green color when young and changed to yellow or blackish when ripe time. Fruit that comes from hermaphrodite flower can be seen from unique characteristic. That unique characteristic was at the end of fruit near of fruit stalk which still attach stamen until harvest (Figure 3C), even still could be observed after fruit grew dark or dry. The Fruit had diameter of 3-3.6 cm and length of 3.2-3.9 cm. Fruit consisted of 3-4 fruit room. Each of fruit room was filled by one seed. The seed had the form of oval with length of 1.9-2.6 cm and diameter in the widest part was 0.7-1.3 cm, the seed became white when juvenile and turned into blackish brown when ripe (Figure 3D). Based on the proximate test, andromonoecious Jatropha seed contained 25.2% fat concentration with the water concentration of 8.8%. The fat concentration was measured 6 weeks after the harvest.

Table 2. Comparison of the characters in the generative organ on andromonoecious with monoecious Jatropha

Characters	Andromonoecious	Monoecious
The number of inflorescence per plant	47±19*	35±14
The number of hermaphrodite flowers per inflorescence	9±5*	-
The number of femaleflowers per inflorescence	-	6±3*
The number of male flower per inflorescence	116±47	103±49
The ratio of hermaphrodite flower towards male flowers	0.08±0.04	0.06±0.03
Fruit set (%)	96.6±8.5*	73.6±27.8
The number of fruit per inflorescence	8±3*	4±3
The diameter of fruit (cm)	3.5±0.1	3.4±0.1
The length of fruit (cm)	3.7±0.1	3.6±0.1
The number of seeds per fruit	3±1	2±1
The number of seeds per inflorescence	22±8.1	10±6.2
The width of the seed (cm)	1.2±0.1	1.2±.1
The length of the seed (cm)	2.4±0.1	2.4±0.1
The weight of seeds per inflorescence (g)	26.7±9*	11.9±6.8
Weight of 100 seeds (g)	115.9±5.9	113.8±5.6
The total weight of seeds (g)	272.3±120.3*	178.7±83.2

Note: Data that was followed the sign * showed the real different in T test (on equal of 95%).

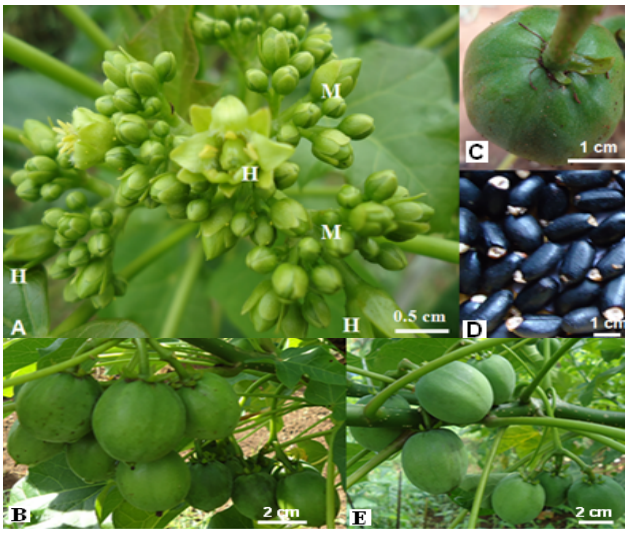

Figure 3. Inflorescence (A), a series of fruit (B), fruit (C), andromonoecious Jatropha seeds (D) and series of fruit monoecious Jatropha (E). (M=series of male flower, H= hermaphrodite flowers)

3.3 Growth of Jatropha

Germination of andromonoecious Jatropha seed was similar with monoecious Jatropha seed. Germination was begun with imbibitions process that caused the seeds grew up and was followed by crack of seed skin, radicula or root of embryo went out from the seeds caruncleholes, this process could occur 2-5 days after planting (DAP). The roots of embryo grew according to geotropism and developed into a primary roots that form a *radix primaria*. This primary root would grow and form the branches or lateral roots, so it would finally establish a system of *radix primaria*. The type of andromonoecious Jatropha germination was germination above ground (epigeal), cotyledon lifted up and appeared on the land surface that would develop into a cotyledon leaf.

Development epicotyls sup ward form trunk, node and leaf. Under part of cotyledon (hypocotyls) sweep, so that cotyledon was lifted up and away from ground surface. Cotyledons opened, and then diminish and changes color from white to green formed cotyledon leaf. Cotyledon leaf was first photosynthetic organ owned by new sprouts plant until first leaf producing. First leaf formed around the age of 9 DAPS. Cotyledon leaf could survive until the ages of 15-21 DAP, although the first leaf and the next leaf were produced. Andromonoecious Jatropha forms the primary branch about at the age of 50 DAP (Table 3). Branches were formed on the node which was adjacent with the number of 3-5 branches (Figure 4A). At the time of one year old, the number of branches was about 4-16 (primary branch), and about 1-18 (secondary branch) on andromonoecious with the angle of the branches was about 40-80^{o} (Figure 4B).

Figure 4. Branches of andromonoecious Jatropha age of 1.5 months (A) and 1 years (B), branches of monoecious Jatropha age of 1.5 months (C) and 1 years (D)

Andromonoecious Jatropha produced first flower at the average age of 227 DAP. The number of male flowers and hermaphrodite per inflorescence which was produced in early blossom was average of 121 male flowers and 8 hermaphrodite flowers with ratio of hermaphrodite flower toward male flowers of 0.07 (Table 3). All of the flower hermaphrodite developed into fruit and could be harvested at first age of 295 DAP. The number of seeds produced per inflorescence on the first harvest was an average of 21 seeds.

Table 3. Characters in development of andromonoeciousand monoecious Jatropha

Characters	Andromonoecious	Monoecious
Age of appearance of plumula to the ground surface (DAP)	5±0	5±0
Age of the first leaf forming (DAP)	9±0	9±0
Age of the first branch formed (DAP)	50±2*	66±4
Height of plants (cm)	119.3±6.3*	137.3±11.3
The diameter of the trunk (cm)	5.4±6.5	5.3±4.2
The number of the node on 15 cm trunk	13±2	12±1
The number of primary branches	10±2*	5±1
The primary branch angle (^{0})	55.6±8.1*	45.3±6.9
The first blossom age (DAP)	227±9.4*	218±8.7
The number of male flower per inflorescence	121±13	106±26
The number of hermaphrodite flowers per inflorescence	8±2*	-
The number of female flowers per inflorescence	-	6±2*
The ratio of hermaphrodite flowers or female toward male flower	0.07±0.02*	0.05±0.01
The number of fruit per inflorescence	8±2*	5±2
The first harvest age (DAP)	295±8*	278±8
The number of seeds/inflorescence	23±5*	14±5

Note: Data that followed the sign * showed the real different in T test (on equal of 95%)

4. Discussion

Andromonoecious Jatropha generally had similar characters with general Jatropha (monoecious). Wood trunk was cylindrical shape with clear node and internode, sympodial branches system, growing up to 5 m height, and producing sap. Jatropha was supported by *radix primaria* system that were able to hold water and resistant to

drought [5]. On the growth, andromonoecious Jatropha could produce branches faster or earlier with greater numberthan monoecious Jatropha ($P<0.05$) (Table 3). Andromonoecious Jatropha had first branch in greater number than monoecious Jatropha at the age of 50 DAP. Monoecious Jatropha had not been set up branches in 50 DAP (Figure 4C), and branches began to be formed at the age of 66 DAP (Table 3). Branch that formed as many as one branch on the node was far from the surface of the ground. At the age of one year, the number of primary branches were only 1-3 branches and 1-5 secondary branches with the angle of the branches ranged between 40-55^{o} (Figure 4D). Since the branches formed at the first time with the great number of sex types could be predicted because the great number of branches was lean to be owned by andromonoecious Jatropha (Figure 2). Jatropha that had produced branch with great number and tight since juvenile was predicted to have andromonoecious sex type, while Jatropha that had not produce branches was predicted to has monoecious sex type. Branches produced by andromonoecious Jatropha were located at the bottom or near the trunkend. Branches of Jatropha was divided into 3 patterns, namely the *basal, intermediate, top*, and the *entire*. Andromonoecious Jatropha had *basal* branch pattern, while monoecious Jatropha had *top* branch pattern [10].

The number and branch angel produced by andromonoecious Jatropha was greater than monoecious Jatropha ($P<0.05$). Andromonoecious Jatropha form many branches without the need of cutting and girdling treatment. The number of branches produced was more than monoecious Jatropha with girdling treatment that only produced 2 branches each of girdling [13]. The number of Jatropha primary was divided branches into 3 groups, namely <3, 3-6, and >6 branches [14]. Andromonoecious Jatropha included into the third group which has the number of primary branches of >6 branches, while monoecious Jatropha included to first or second group. Jatropha IP-3P only obtained 3 primary branches [15]. The amount of branches caused andromonoecious Jatropha to have canopy and great profile. The number of branches on andromonoecious Jatropha which was followed by the distance between the near node with the number of node on 15 cm trunk was greater than which was compared monoecious Jatropha ($P<0.05$). Plants height, leaves size (the stack length, the leaf length and leaf width) on andromonoecious were smaller than monoecious. The node, underarms leaf, and end of trunks or branches were flower growth point on Jatropha. With great number of the branches, so Jatropha had many flower grown points and had chances to produce many flowers.

Andromonoecious Jatropha produce flower more slowly, but the number of flower which was produced more than monoecious Jatropha (Table 3). Each of the plant would have different blossom age, this was determined by the age of transition on vegetative to generative phase that occurred in the shoot apical meristem (SAM). Because andromonoecious Jatropha produced the number of branches in greater number, soandromonoecious Jatropha had SAM more than monoecious. In plants that had many SAM, it would experience longer flower initiation than plant that had few of SAM [16].

Mostly the generative characters observed was different between andromonoecious and monoecious Jatropha ($P<0.05$), except the number of male flowers, the ratio of the hermaphrodite or female toward male flower, seeds size and weight 100 seeds ($P>0.05$). The number of inflorescence per plant and hermaphrodite flowers per inflorescence at andromonoecious Jatropa was more than monoecious Jatropa (Table 2). Andromonoecious Jatropha flower which was the complex flower in the form of malai have dichasial branch type with the number of branches more than monoecious Jatropha flower. Each branch on andromonoecious Jatropha inflorescence was closed by one hermaphrodite flower and was surrounded by male flower, while on monoecious was closed by the female flowers [17]. The production of hermaphrodite flower on Jatropha was influenced by genetic factors [11]. The great number of inflorescence branches caused the number of hermaphrodite flower that was produced more than the female flowers on monoecious Jatropha inflorescence. Because the number of male flower per inflorescence between this two Jatropha inflorescence was almost same, so ratio of the number of hermaphrodite flower to male flower per inflorescence in andromonoecious was bigger (1:13) than ratio of female flower to male flower on monoecious (1:17). The flower ratio both of these plants was moderate type in accordance with the classification presented by [10], namely 1:1-10, 1:11-20, and 1:>20. In other accession of monoecious Jatropha, the ratio of female flower to male flower was 1:13 [18], [19], 1:29 [20] and 1:22-27.

The percentage of hermaphrodite or female flower become fruit (fruit punches seth) which was calculated at the time of harvest which was the end of fruit set. The number of hermaphrodite flowers on andromonoecious Jatropha was supported by high fruit set, so that the number of fruits was produced (8 pieces) also more than monoecious Jatropha (5 pieces) (Figure 3D-E). This was influenced by the pollination process. The hermaphrodite flowers that had anther and the stigma at near position were suspected tend to do their own pollination without the pollinator support. Dasumiati et al. (2015) said that the hermaphrodite flowers on andromoecious Jatropha did self-pollination because pollination happen at a time before completely bloom. But the female flower in monoecious Jatropha urgently required pollinator for pollination. Pollinator on Jatropha was insect such as bee (*Apisdorsata*, *A. florea*), butterfly, housefly, dragonfly, beetle, ant and ladybug [19].

Environmental conditions affect the existence of pollinator. When the environmental condition was not favorable for the pollinator, then pollination did not occur on monoecious. One of pollinator on Jatropha was fly which visited flower after 9.00 AM, while the flower was already bloom since 6.30 PM [17]. This caused that the female flower was not pollinated or lately to be pollinated, so that affect the number of fruit and seeds produced.

Generally, each fruit on Jatropha had three fruit rooms, each fruit room produced a seed [5]. Three fruit rooms and three seeds could be produced by the hermaphrodite flowers, while the female flowers produced fruit with the three fruit rooms but only filled by 1-3 seeds and in common condition was 2 seeds. The seed candidate which was in the fruit room was not developed well or did not happen fertilization. This could be caused by late pollination and fertilization was not perfect on every ovary in ovarium room. The female flower had probability to get pollen in small amounts and too late, so that fertilization occurred lately and less perfect. The ovary which did not experience fertilization would fail to form the embryo or seeds. As a result of this process, so the number of seeds on andromonoecious Jatropha was more than monoecious. Andromonoecious Jatropha seed produced the high level of fat, although it had the similar size of seeds with the monoecious Jatropha seed. Based on the proximate test, andromonoecious seed contained 25.2% fat concentration with water concentration of 8.8%, while monoecious only containe15.8% fat concentration with the water concentration of 9.6%. Andromonoecious Jatropha that produced many seeds and supported by the weight of seeds and high fat concentration, so andromonoecious Jatropha was expected to produce the seeds that contain the oil concentration with high percentage of rendemen. Based on the branch character, disposal, fat concentration, and growth, so andromonoecious Jatropha was very good to be developed to ful fill the needs of the biodiesel production material. With climate change or weather was uncertain today, andromonoecious Jatropha still could produced well.

4.2. Conclusion

Andromonoecious Jatropha had specific character, namely forming many the number of branches (15 branches), great branch angel (78.1^{o}), the small distance between the node (13 node at a distance of 15 cm), the high number of hermaphrodite flower, great flower diameter (2.1 cm),high *fruit set* (85-100%), and the high weight seed which was compared to monoecious Jatropha. Andromonoecious Jatropha had growth that was almost same with the monoecious Jathropa, except on the formation of branches. Andromonoecious Jatropha formed branches faster than monoecious, but the time of monoecious Jatropha blossom was faster than andromonoecious Jatropha.

References

[1] Mishra, D. K. (2009). Selection of candidate plus phenotypes of *Jatropha curcas* L. using method of paired comparisons. *Biomass and Bioenergy,* 33, 542-545.

[2] Umamaheswari, D., Paramathma, M., & Manivannan, N. (2009). Association analysis between oil yield and its component characters in *Jatropha*. *Electronic Journal of Plant Breeding*, 1, 78-81.

[3] Sharma, D. K., Pandey, A. K., & Lata. (2009). Use of *Jatropha curcas* hull biomass for bioactive compost production. *Biomassa and Bioenergy*, 33, 159-162.

[4] Hasnam. (2007). Penggunaan istilah varietas, provenan, klon dan populasi jarak pagar. *Info Tek Jarak Pagar*, 2(8), 29.

[5] Heller, J. (1996). *Physic nut. Jatropha curcas L. Promoting The Conservation and Use of Underutilitized and Negleted Crop 1*. International Plant Genetic Resources Institute. Rome.

[6] Alam, N. C. N., Abdullah, T. L., & Nur, A. P. A. (2011). Flowering and fruit set under Malaysian climate of *Jatropha curcas*L.

[7] Dellaporta, S. L., & Urrea, A. C. (1993). Sex determination in flowering plants. *The Plant Cell*, 5, 1241-1251.

[8] Dasumiati, Miftahudin, Triadiati, Hartana, A., & Pranowo D. (2014). Increasing hermaphrodite flowers using plant growth regulators in andromonoecious *Jatropha curcas*. *Hayati. Journal of Bosciences,* 21(3), 111-120.

[9] Surahman, M., Santosa, E., & Nisya, F. N. (2009). Karakterisasi dan analisis gerombol plasma nutfah jarak pagar Indonesia dan beberapa negara lain menggunakan marka morfologi dan molekuler. *Jurnal Agronomi Indonesia*, 37(3), 256-264.

[10] Sunil, N., Kumar, V., Sujatha, M., Rao, G. R., & Varaprasad, K. S. (2013). Minimal descriptors for characterization and evaluation of *Jatropha curcas* L. germplasm for utilization in crop improvement. *Biomass and Bioenergy*, 48, 239-249.

[11] Hartati, S. (2009). Jarak pagar hermaprodit, interaksi factor genetic dan lingkungan. *Info Tek Perkebunan*, 1(1), 2.

[12] Raden, I., Purwoko, B. S., Hariyadi, Ghulamahdi, M., & Santoso, E. (2008). Karakteristik daun jarak pagar (*Jatropha curcas* L.) dan hubungannya dengan fotosintesis. *Buletin Agronomi,* 36(2), 168-175.

[13] Darmanti, S. (2008). Pembentukan cabang lateral jarak pagar (*Jatropha curcas*) setelah perlakuan girdling. *Bioma*, 10(1), 7-11

[14] Sunil, N., Varaprasad, K. S., Siraraj, N., Suresh, T., Kumar, Abraham, B., & Prasad, R. B. N. (2008). Assessing *Jatropha curcas* L. Germplasm *in-situ* : A case study. *Biomass and Bioenergy*, 32, 198-202.

[15] Syakir, M. (2010). Prospek dan kendala pengembangan jarak pagar (*Jatropha curcas* L.) sebagai bahan bakar nabati di Indonesia. *Perspektif*, 9(2), 55-65.

[16] Amasino, R. (2009). Floral induction and monocarpic *versus* polycarpic life histories. *Genome Biology*, 10, 228.

[17] Wang, X. R., & Ding, G. J. (2012). Reproductive biology characteristic of *Jatropha curcas* (*Euphorbiaceae*). *Revista Biologia Tropical*, 60(4), 1525-1533.

[18] Wijaya, A., Susantidiana, Harun, M. U., & Hawalid, H. (2009). Flower characteristics and the yield of Jatropha (*Jatropha curcas* L.) accessions. *HAYATI Journal of Biosciences*, 16, 123-126.

[19] Kaur, K., Dhillon, G. P. S., & Gill, R. I. S. (2011). Floral biology and breeding system of *Jatropha curcas* in North-Western India. *Journal of Tropical Forest Science*, 23(1), 4-9.

[20] Raju, A. J. S., & Ezradanam, V. (2002). Pollination ecology and fruiting behaviour in a monoecious species, *Jatropha curcas* L. (*Euphorbiaceae*). *Current Science*, 83, 1395-1398.

[9] Surahman, M., Santosa, E., & Nisya, F. N. (2009). Karakterisasi dan analisis gerombol plasma nutfah jarak pagar Indonesia dan beberapa negara lain menggunakan marka morfologi dan molekuler. *Jurnal Agronomi Indonesia*, 37(3), 256-264.

[10] Sunil, N., Kumar, V., Sujatha, M., Rao, G. R., & Varaprasad, K. S. (2013). Minimal descriptors for characterization and evaluation of *Jatropha curcas* L. germplasm for utilization in crop improvement. *Biomass and Bioenergy*, 48, 239-249.

[11] Hartati, S. (2009). Jarak pagar hermaprodit, interaksi factor genetic dan lingkungan. *Info Tek Perkebunan*, 1(1), 2.

[12] Raden, I., Purwoko, B. S., Hariyadi, Ghulamahdi, M., & Santoso, E. (2008). Karakteristik daun jarak pagar (*Jatropha curcas* L.) dan hubungannya dengan fotosintesis. *Buletin Agronomi,* 36(2), 168-175.