Evaluation and selection of Jatropha genotypes for biofuel

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Abstract. Jatropha curcas L., a monoecious perennial shrub, has received attention nationwide during the past two decades. In 2006, the Indonesian government has decided to option for Jatropha and palm oils for in country biofuel production. To support the program, development of high yielding jatropha varieties is necessary. This paper reviews the latest Jatropha improvement program in Indonesia. From 2005 to 2006, germplasm collection was mobilized to various provinces in Jawa, Sumatera, Sulawesi and Nusa Tenggara islands and successfully collected a sizeable amount of jatropha germplasm which serves as a base population for selection. By applying a simple recurrent breeding selection based on fruit count per year, a significant improvement has been achieved. Seed yield productivity increased more than six-fold, from 0.36-ton dry seed per ha in the initial population (IP-0) to 2.4-ton seed yield per hectare in the third cycle of selection (IP-3). To improve further the seed yield per hectare, jatropha hybrid varieties was developed involving superior provenances. Hybrid variety named Jatropha Energy Terbarukan (JET) variety-2, was released in 2017 with seed yield potential of 2.6 ton per hectare. The potential use of this high yielding genotypes for biofuel is discussed.

Keywords: Jatropha curcas, improve population, hybrid, provenance, biofuel

1. Introduction

Fossil-Fuels, the present major contributors to energy, are considered not only environmentally harmful but also going to be depleted shortly because of their finite quantity. Prediction showed that deposit of fossil-based fuels would vanish soon [19]. These facts have forced Indonesia to look seriously for ecologically sustainable alternative energy resource in order to reduce the amount of imported oil and a heavy burden of subsidy. In this search several plants based bio-energy such as palm oil, coconut oil, peanut oil, corn oil, bio-ethanol from cassava and sugar-cane, jatropha seed-oil etc. have emerged as a viable alternative [19]. However, of these only jatropha oil is regarded as non-edible oil and hence, it will not compete with other end uses in the future [16-18, 20, 29]. Further, its drought resistance, ability to grow in marginal lands without much inputs and the need for only moderate rainfall makes it the most potential alternative renewable energy resources in the future [4, 10,14].

To support jatropha program for alternative and renewable energy sources, development of high yielding jatropha genotypes is imperative. This paper will review the progress of jatropha improvement program in Indonesia.
2. Germplasm Collection and Evaluation

Plant genetic resources are raw material for breeding program [31]. It is widely acknowledged that success of any breeding program is depended upon the extent of variability present within the germplasm collection [30]. To provide material for breeding program, three missions were sent out to numerous provinces in Jawa, Sumatera, Sulawesi and Nusa Tenggara Islands. The missions collected a sizeable amount of jatropha germplasm in 2005 to 2006 (Fig. 1). A morphological and quantitative characters variations were observed amongst the collected jatropha accessions (Tabel 1 and Fig. 2 to Fig. 6).These variation are possibly arisen due to long adaptation process of this plant since it first introduced to Indonesia by The Portuguese sailor in 17 centuries [8].

![Graph of cuttings collected](image)

**Figure 1. Number cutting collected across nine provinces [Source : 10]**

| Table 1. Germplasm variability in yield characters and oil content |
|---------------------------------------------------------------|
| Characters          | Mean ± SE | Min  | Max  | Range | CV  |
|---------------------|-----------|------|------|-------|-----|
| # fruit/plant/year  | 341.89 ± 8.74 | 1.80 | 971.20 | 969.40 | 52.57 |
| Dry seed weight/plant (kg) | 0.238± 0.0064 | 0.0003 | 0.709 | 0.706 | 55.35 |
| 100 seed weight (g)  | 60.101± 0.330 | 36.667 | 84.034 | 47.367 | 11.29 |
| Oil content(%)      | 34.270± 0.188 | 19.383 | 44.373 | 47.367 | 11.27 |

Note: CV= Coefficient of variation (%) [Source :10]

3. Evaluation and selection for direct use

Considering that jatropha curcas is an outcrossing species [1, 3, 6-7, 13], the jatropha breeding program at ISFCRI was therefore done based on population improvement [8,9,23]. According to Sprague [24] this method will only be effective if there are sufficient variability present in the natural population, especially in term of additive gene effect.

The collected germplasm was then planted at density 2,500 plant per hectare (2m x2m spacing) in three gardens, representing three different agro-ecological zone (dry areas, low land; fairly-wet climate, mid-land and wet climate, mid land), and serve as base populations for crop improvement program. The improvement of jatropha population was accomplished by applying positive mass selection in every cycle of selection; superior plant genotypes was selected based on number of fruit
count per plant, distribution of inflorescence per plant, fruit size and pest and disease infestation status. Only individual plants with high fruit count are selected.

In the year 2006, the first cycle of recurrent selection was done based on fruit count 200 capsules per plant per year. As a result, three improved populations, namely IP-1 A, IP-1M and IP-1P have been identified and released [8]. The averaged yield of IP-1 was 0.97-1.06-ton seed per hectare, which is double than the original base population/IP-0 (0.37-0.43 ton/ha). On the following year (2007), the second cycle of recurrent selection was made on IP-1 populations based on 400 capsules per year and has resulted in three IP-2 populations (IP-2A,IP-2M and IP-2 P); the averaged yield of IP-2 was 1.9–2.2 tons per ha, which is again double than the averaged yield of IP-1 [8]. Later on, in the year 2008, selection was made based on 600 capsules per year in IP-2 populations. The resulting three selected IP-3 populations have shown only slight improvement (15%) over IP-2 populations. The averaged yield of IP-3 was 2.2 to 2.4 ton per ha, indicating depletion of additive effect has occurred [11].

Jatropha is a perennial plant with primary and secondary branches bearing fruits [3]. Yield is increasing in the second year up to fourth year and stable from fifth year onwards of cultivation. Prunning is expected to provide sufficient number and strong branches bearing fruits. However, it was found that yield increase from year 1 to year 5 does not follow the geometric progression [9]. This probably due to high genetic x environment interaction [22].

**Figure 2.** Leaf shape variation: A. circle dan B. oval [source: 27]

**Figure 3.** Variation in lobe number: A. 3 (three lobes); B. 5 (five lobes) and C. 7 (seven lobes) [source: 27]
**Figure 4.** Variation in shoot color: A. Green; B. Reddish green; C. Red with green vein; D. red [Source :27]

**Figure 5.** Variation in fruit bunch: A. Green dan B. Reddish green [Source: 27]
Figure 6. Variation in seed number per fruit: A. 1 (one); B. 2 (two); C. 3 (three); D. 4 (four) dan E. 5 (five) [Source : 27]

4. Yield evaluation of several promising germplasm

Beside progress made through the above population improvement, individual germplasm characterization has also identified several promising accessions/genotypes, having average productivity higher than the two control genotypes IP-1A and IP-1M (Fig. 7) [5, 15]. A two year seed yield evaluation of these promising accessions across two locations showed high GxE interaction (Table 2); JC12 recorded the best performance in KP. Asembagus, whereas JC-4 was the best performer at KP. Muktiharjo [15].
Figure 7. Three IP-3 populations (IP-3A/M/P) developed by recurrent selection [Source: 10]

Table 2. Seed yield and 100 seed weight of the accessions across two locations

| Genotype (accessions) | KP. Asembagus          | KP. Muktiharjo         |
|-----------------------|------------------------|------------------------|
|                       | Seed yield 1st harvest | Seed yield 2nd harvest | Seed weight 1st harvest | Seed weight 2nd harvest | 100 seed weight |
|                       | (2006)                 | (2007)                 | (2007)                 | (2007)                 |
| JC1                   | 171.41 cd              | 844.6 b                | 70.0 a                 | 84.11 bc               | 65.54 a         |
| JC2                   | 202.03 bcd             | 1126.2 b               | 63.0 ab                | 95.57 bc               | 67.98 a         |
| JC3                   | 245.99 abc             | 1038.0 b               | 61.3 ab                | 32.29 c                | 69.14 a         |
| JC4                   | 260.68 ab              | 968.0 b                | 60.3 ab                | 310.16 a               | 67.10 a         |
| JC5                   | 213.13 bcd             | 1140.9 b               | 61.3 ab                | 127.34 abc             | 69.55 a         |
| JC6                   | 169.06 cd              | 742.1 bc               | 61.7 ab                | 192.19 abc             | 64.23 a         |
| JC7                   | 164.17 cd              | 1047.9 b               | 62.7 ab                | 106.77 bc              | 66.82 a         |
| JC8                   | 186.56 bcd             | 817.9 b                | 64.3 ab                | 188.02 abc             | 63.80 a         |
| JC9                   | 9.22 e                 | 297.8 c                | 58.3 b                 | 164.32 abc             | 69.65 a         |
| JC 10                 | 154.90 d               | 966.5 b                | 64.0 ab                | 104.69 bc              | 67.52 a         |
| JC 11                 | 271.20 ab              | 1055.5 b               | 67.3 ab                | 235.68 abc             | 65.54 a         |
| JC 12                 | 315.63 a               | 1912.9 a               | 58.0 b                 | 258.07 ab              | 66.47 a         |

[Source : 15]

5. Germplasm evaluation of oil content

Being a new cultivated oil crop, increased productivity is the main target for the current jatropha breeding program [10, 26]. By productivity means not only seed yield but also oil content, as oil yield is the product of seed yield and oil content. The present recommended planting material (IP1-A/M/P, IP-2A/M/P and IP-3A/M/P) possess oil content from 30 to 35% on dry basis. In order to find out the potential accessions having higher oil content (than the recommended genotypes) and can be used as donor parents in crossing program to develop high yielding varieties coupled with high oil content, an evaluation of oil content across germplasm was attempted; three hybrid clones derived from crossing program were found to have oil content above 37% (Fig. 8)[21].
6. Hybrid development

It has been known that in any breeding program there will be no improvement if there is no variation [25,2, 23]. The existing variation observed in the collected jatropha germplasm is going to be depleted soon; it is predicted that there will be no scope of improvement beyond IP-3 [8]. Considering this fact, hybridization program followed by selection is undertaken with the objective of developing Jatropha hybrid clones having productivity higher than IP3. In 2007, five cross combinations involving high yielding jatropha clones were undertaken. The resulting seeds were grown in the field with plant density 2,500 plant ha⁻¹ and spacing 2mx2 m. Dose of fertilization and maintenance were done according to the standard procedure. Selection was made on the individual hybrid based on the fruit count, that is, it should posed number of fruit 30% higher than the best IP-3 parents. Five selected hybrid clones along with three controls (IP-3A/IP-3M/IP-3P) were then propagated through vegetative and evaluated in three locations for three consecutive years. Based on dry seed yield (kg/ha/year) and oil content (%) hybrid clone JET 2 was found superior compared to IP-3A (the best control variety). It has potential seed yield 2600 kg seed/ha/year with oil content comparable to IP-3A (35.5%) [5].

7. Research implication

The commercial use of the elite jatropha genotypes developed in this research has been assessed in simulation studies, using three different technology levels, namely low, medium and high. Study showed that current productivity level have not attain the productive and profitable phase [4, 10, 13]; shade lowering crops such as medicinal and aromatic plants as intercrop will add to farmers income during those periods [10]. Intercropping with annual crop is expected to increase the farmers income. In addition, several leguminous crops i.e. ground nut, mung-bean etc. could be grown as intercrop, which will supply soil with nitrogen, that later would be available to the plantation.

The expansion of industrial-scale Jatropha plantation for producing raw materials of biofuels quickly leads to social-environmental-political problems such as food vs fuel conflicts, low economic benefit for the farmers, land acquisition, destruction of forests, and detrimental impact on soil and water quality [28]. In order to avoid these problems one of the ideal ways is to aim at local production for local consumption. In this way energy sufficiency for local government would be achieved.

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