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Research Paper

Relationships among *Jatropha curcas* seed yield and vegetative plant components under different management and cropping systems in Indonesia

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ABSTRACT

An understanding of how *Jatropha curcas* seed yield relates to vegetative plant components under different management regimes is lacking. Such information is necessary to predict yields and design management strategies. This study investigated yield and vegetative plant component interactions, and the effects of management practices in monoculture, intercropping, and hedge cropping systems in Indonesia. Monoculture and intercropping experiments in Gunungkidul Regency used jatropha IP-1M material; hedge experiments in Sumbawa Regency used the Sumbawa provenance. In two-year-old monoculture, pruning significantly decreased yield from 109 kg ha^{-1} to 28 kg ha^{-1} due to a 40% decrease in canopy volume and LAI. In four-year-old jatropha intercropping, root barriers reduced yields 80% by limiting jatropha root access to soil moisture and nutrients in the maize plantings. Intercropping without root barrier and with leaf mulch produced the largest yields of 25 kg ha^{-1}. In hedge plantings, plant height influenced yield. Single rows of one-year-old monoculture produced 0.97 g m^{-1} at 10 cm spacing, 1.69 g m^{-1} at 30 cm, and 0.14 g m^{-1} for 20 cm of mixed jatropha–gliricidia. Pruning significantly decreased LAI with 20 cm spacing indicating a higher proportion of above-ground biomass allocated for wood growth. Results indicate that seed yield across the three cropping systems can be determined by plant height and numbers of productive twig/branch, although number of inflorescences cluster per productive twig may be more important. Future research should focus on the transition of branches to reproductive phases, and on increasing numbers of productive twigs/branches and inflorescence clusters.

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1. Introduction

Jatropha (*Jatropha curcas* L.) has been promoted as a biofuel crop with the potential to bring about socio-economic benefits and wasteland reclamation in tropical semi-arid regions. It is reported to grow in marginal areas without competing with food production, and with the possibility of providing carbon credits [1]. Although measured yields of 0.2 t ha^{-1} to 1 t ha^{-1} [2–4] are common and disappointing, recorded yields of 2 t ha^{-1} to 3 t ha^{-1} are encouraging [1,5].

Jatropha seed yield is determined by plant growth and biomass partitioning, and is a function of genotype (G), environment (E), and management (M). Research to improve yield has focused on genetic diversity [6,7] using conventional breeding [8], interspecific hybridisation [9,10], mutation breeding [11], and genetic engineering [8]. Improved planting material is then field tested in multi-locations to assess performance. In parallel with breeding research, improved management practices are developed. Pruning, plant spacing, fertiliser application, irrigation, and pest/disease management all play important roles in improving yield [3,4,12–14].

Pruning can improve yield by maintaining branch architecture through optimised spatial arrangement of branches and leaves, tree size, canopy structure and shape [14]. Jatropha inflorescences develop at the ends of the (new) branches and pruning induces branching, leading to a belief that more branches equals more fruit [3,15–18], larger yields and improved harvest index [17].

In an earlier study of four-year-old jatropha at Gunungkidul in Indonesia, we determined above-ground and fruit biomass allocation relative to plant architecture using Functional Branch Analysis (FBA) [19]. Using the FBA model, we classified the plant into three categories, wood, branch, and twig according to diameter size. Wood has diameter ≥7 cm, branch a diameter ranging from 2 cm to 6.99 cm, and twig category a diameter ≤1.99 cm. We found that jatropha fruit develop on twigs that in the majority of cases have diameters ranging from 0.9 cm to 1.4 cm [19]. We named these twigs, fruit-bearing or productive twigs as opposed to non-productive twigs. In addition, we developed allometric equations for estimating total above-ground, branch, twig and leaf, and fruit biomass based on stem diameter.

Knowledge gaps exist regarding the effects of management such as pruning on seed yield, especially in relation to vegetative plant components such as tree height, stem diameter and biomass, canopy size, leaf area, number of productive twigs, and branch length.

Jatropha can be grown in monoculture, intercropping and as hedges [1,20,21]. The choice of cropping system is often determined by environment and socio-economic factors. Jatropha monocultures in general require greater capital inputs as they are often larger in extent and more intensively managed than either intercropping or hedge systems.

Intercropping jatropha with annual crops is a system that farmers use to maximise their economic return, while providing a degree of insurance against the loss or poor performance of one crop. The benefits of using the inter-row space, especially while the plants are still small, can be seen as an attractive proposition while waiting for first harvests [20]. When permanent intercropping is practiced, jatropha plants are often more widely spaced [22]. Growing trees or shrubs in combination with annual crops is a common agroforestry practice and has the advantage of improving soil fertility, recycling subsoil nutrients, reducing nutrient leaching, controlling soil erosion, and providing windbreaks [23]. Disadvantages can however be experienced with competition for light, water, and nutrients depending on species selection. Pruning can be effective in minimising above-ground competition and the waste material used as mulch [24]. Root pruning and root barriers can also be used to minimise below-ground competition [23].

Jatropha hedges are often planted by farmers as single rows for demarcation of property boundaries or as crop protection fencing [2,20,21,25]. Little regard is however paid to seed harvest or yield potential as hedges are often planted at relatively close spacing [20]. In Indonesia trees planted at distances of 10 cm or less are common. In Banten and Sumbawa, jatropha or mixed plantings of jatropha and gliricidia (*Gliricidia sepium*) hedges have been observed. Gliricidia leaves are used as fodder while the wood is used for poles or firewood.

The majority of information relating to jatropha seed yield and different cropping system practices is based on monoculture studies [2–4,21,26–29]. Data for intercropping [22] and hedge [2,20,21] systems are limited and do not investigate yield from a plant component perspective.

Our previous findings were based on unpruned monocultures of jatropha [19] and have not been tested in different management or cropping systems. For these reasons, the aim of this study was to determine jatropha seed yield, and to identify the vegetative plant components that influence seed yield under different management and cropping systems.

The research objectives were: (1) to determine seed yield in monoculture, intercropping, and hedge systems; (2) to understand which vegetative plant components significantly contribute to yield under different management practices; (3) to determine whether or not there is a vegetative plant component pattern across the different management practices that can be used to estimate seed yield.

2. Materials and methods

2.1. Study sites and conditions

The study was conducted in two locations in Indonesia. Monoculture and intercropping studies were located at the Mulo Village in the Wonosari District, Gunungkidul Regency of Special Province Yogyakarta (8° 0′ N, 110° 34′ E, 185 m ASL). Hedge studies were conducted at the Leseng Village in Moyo Hulu District, Sumbawa Regency, Nusa Tenggara Barat, (8° 35′ N, 117° 27′ E, 76 m ASL).

Gunungkidul has an equatorial rainforest climate with mean annual rainfall of 1800 mm, occurring predominantly from November to April with dry periods from June to August or September. Mean annual temperature and relative humidity are 26 °C and 70% respectively. The soils are Mollisols with texture varying from clay, silty clay to silty clay loam, with poor drainage. The soils are shallow, 10 cm–50 cm with