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Compatibility of *Jatropha Curcas* with Maize (*Zea Mays* L.) Cv. Obatampa in a Hedgerow Intercropping System Grown on Ferric Acrisols

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Abstract: Skeptics are talking about the impact of the biofuel crop on food production. It is important that the compatibility of *Jatropha curcas* in agroforestry systems is investigated to provide answers to some of these problems being advanced. The Randomized Complete Block Design (RCBD) with three hedgerow spacings of 2 m x 1 m, 3 m x 1m, 4 m x 1 m of *Jatropha curcas* and a control (No hedgerow) was used to lay out the experiment. This was replicated 3 times. The study showed that in the second year, plant height and plant diameter at first node differed significantly between the treatments. Maximum stover weight was 11.9 tons/ha and 7.5 tons/ha in the first and second year respectively for 4 m x 1 m spacing. Generally yields were lower in the second year in all the treatments compared to the first year. Maximum grain yield of maize was 4.47 tons/ha and 2.99 tons/ha in the first and second year respectively at the control treatment. Chemical properties of the soil did not record any significant decline after two years of cultivation. pH, organic Carbon, total nitrogen, organic matter, exchangeable cations, total exchangeable bases, exchangeable acid and base saturation did not show significant difference between the treatments. The highest Land Equivalent Ratio (LER) of 1.6 and 1.2 was recorded at 4 m x 1 m for both years, making it the most suitable plant spacing for *Jatropha curcas* with maize.

Keywords: *Jatropha Curcas*, Growth, Yield, Land Equivalent Ratio, Nutrient Status

1. Introduction

The exploitation of bio-energy sources of fuel has recently been given much prominence by the scientific community and commercial entrepreneurs as a way to solve the energy crisis. Bio-diesel is the most valuable form of renewable energy that can be used directly in any existing unmodified diesel engine [1]. It is an alternative fuel that can be used in diesel engines and provides power similar to conventional diesel fuel. Biofuel can help reduce the country's dependence on foreign oil imports. Recent environmental and economic concerns (Kyoto protocol) have prompted a resurgence in the use of biodiesel throughout the world. In 1991, the European Community, (EC) proposed a 90% tax reduction for the use of biofuels, including biodiesel [1]. Biofuels create new markets for agricultural products and stimulate rural development because they are generated from crops. They hold enormous potential for farmers. The long term challenge is the ability to supply feedstock to keep up with growing demand. The supply of feed stock from maize, soya beans will be limited by competition from other uses and land constraints. The key to the future of biofuels therefore is finding inexpensive feed stocks that can be grown by farmers. *Jatropha curcas* proves to be one of the many plants that hold great promise as a biofuel crop. *Jatropha curcas* is more recently being cultivated as a bio-diesel plant. Soybean and rapseed have a relatively low oil yield compared with *Jatropha curcas*. A yield of 375 kg/ha (280 gallons/acre) is reported for soybean in the United States. In Europe, yield for rape seeds is said to be 1000 kg/ha (740 gallons per acre) whilst in India, *Jatropha curcas* is reported to have yield of 3000 kg/ha (2226 gallons/acre).

The world's population has grown from almost 5 billion 1980 to over 6 billion in 2000 [2], and finite availability of fertile land makes meeting energy needs for this growing population difficult. Ghana had a population of about 12.4 million in 1984. This figure increased to 18.8 million in 2000 with a growth rate of 2.6%.

The increase in population has caused a corresponding rise in food and fuel consumption, straining the earth's natural resources [3]. In developing countries, the pressure on natural resources is more acute because nearly 70% are subsistence-based and live in rural communities [4]. Heavily reliant on natural resources for food and energy, people by their basic instinct to survive derive their diet from their surroundings [5, 6].

Maize (Zea mays L.) belongs to the family Poaceae (Gramineae) and the tribe maydeae. Based on area and production, maize is one of the most important cereal crops in Ghana. It is rich in calories and forms part of the staple diet of every Ghanaian. It is Ghana's number one staple crop followed by rice. The yield in Ghana is low compared to other maize producing countries and there is an average short fall in domestic maize of 12%. There is concern that the use of land for the cultivation of bio-fuels could further jeopardize Ghana's self- sufficiency in maize production. Increasing grain yield per unit area and increasing the corn cultivable area are recognized as better solutions to solving the gap between consumption and production. The total land area of Ghana is about 23.8 million hectares of which 35% is cultivated. Ghana's agriculture is predominantly small holder, traditional and rainfed.

Agricultural production is undertaken by about 2 million, predominantly small holder subsistence farmers who account for about 80% of food in the country. The mean farm size is less than 1.2 hectares with a few exceeding two hectares [7]. In the midst of limited land for the cultivation of both maize and *Jatropha curcas*, it is surmised that the integration of these in an alley cropping could help provide an appropriate output from these plants.

Agroforestry is credited with improving the utilization of space by improving recycling of nutrients and organic matter. This translates into improved soil chemical, physical and biological characteristics with a reduction in the use of chemical fertilizers and improved infiltration of water. There is higher aggregate biomass production from an agroforestry mixture than from monoculture. Microclimate extremes are reduced as is soil erosion. Agroforestry thus provides a more favourable environment for sustained cropping, the creation of habitat diversity and provides a more continuous flow of more products over time [8]. A promising agroforestry technology for the humid and sub-humid tropics, which has been developed during the past decades, is alley cropping.

Alley cropping also known as hedgerow intercropping has been the subject of intensive research at the International Institute for Tropical Agriculture (IITA) in Nigeria [9, 10]. The concept of alley cropping was formalized at IITA where the term was defined as the growing of crops, usually food crops, in alleys formed by trees or woody shrubs that are established mainly to hasten soil fertility restoration and enhance productivity [11]. Currently it entails growing food crops between hedgerows of planted shrubs and trees, preferable leguminous species. It is a management-intensive system that can lead to increased crop yields and productivity of the land. This study was therefore designed to determine the appropriate hedgerow spacing in order to maximize grain yield of maize cv. obatampa in a *Jatropha curcas* hedgerow intercropping system.

2. Objectives for the Study

The specific objectives of the study were therefore to:

1 Determine the growth and yield of maize cv. Obatampa in alleys of *Jatropha curcas* grown on ferric acrisol.

2 Assess the effect of *Jatropha curcas* on soil chemical properties.

3 To evaluate the economics of using *Jatropha curcas* in an alley cropping system.

3. Materials and Method

3.1. Description of the Study Area

The experiment was laid out at Ayakumaso which is about 3 km from Sunyani. It lies between latitude 7°55′N and7°35′N and longitude 2°00′W and 2°30′W (SMA, 1998). The area has a tropical climate, with high temperatures averaging 23.9ºC. Its mean monthly temperature varies between 23°C and 33°C with the lowest in August and highest in March and April respectively. It has a double maxima rainfall pattern. Rainfall ranges, from an average of 1000 mm to 1500 mm. The major rainy season occurs from April to end of July whilst September to October is the minor wet season. It has relative humidity of about 70%. The vegetation type is the dry semi-deciduous forest. The soil texture at the study site is silt loam and classified as ferric acrisols.

3.2. Design of Experiment

The experiment was laid using the Randomized Complete Block Design. Three hedgerow spacing treatments of 2m x 1m, 3m x 1m, 4m x 1m of *Jatropha curcas* and a control (No hedgerow) were used. These were replicated three times. Plot sizes for each treatment were 12 m x 5 m. The 2 m x 1 m, 3 m x 1 m, and 4 m x 1 m spacing had 6, 4, and 3 hedgerows respectively. The alleys of *Jatropha curcas* were established on the 1st of May, 2008. The test crop used in the alleys was Maize (*Zea mays*, var Obatampa) and sown at a spacing of 100 cm x 40 cm giving a population of 25,000 plants ha-1. The planting date for the maize was 21st July, 2008 and repeated on the 25th July, 2009.

3.3. Soil Analysis

300 g of soil samples were collected at a depth of 0 – 30 cm prior to the establishment of the experiment and taken to the Soil Research Institute (SRI) for analysis. The samples were thoroughly mixed before the analysis. At the end of the experiment, composite soil samples were again taken from

each treatment. The soil samples were air-dried and analyzed for soil pH, Organic C, Total N, Organic matter, Ca, Mg, K, Na, T.E.B., Exchangeable acid and Base saturation.

3.4. Measurement of Test Crop

Vegetative traits such as plant height, plant diameter, number of leaves and stover weight were determined by randomly selecting 10 maize plants from each plot. The stover weight was determined after drying at 72 hours at 65^{o}C. Plant height was measured with the measuring tape and diameter was measured using the vernier caliper. At harvest, 10 maize plants from each plot were taken to determine yield and yield components.

3.5. Data Analysis

All data recorded were analyzed using the GEN-STAT package. The Analysis of Variance (ANOVA) was generated to determine if there were any significant differences between the treatments. The Fishers Least Significant Difference (LSD) was then used to separate the means between the treatments at 5% probability level.

3.6. Limitations of the Study

Limitations encountered during the study were:

1) Data was collected for two years and therefore can only predict what is likely to happen in the third and subsequent years.
2) The research did not take into consideration planting distances greater than 4 m between rows because the objective of the research is to make optimum use of land.

4. Results

4.1. Effect of Jatropha Curcas Spacing on Growth Parameters of Maize

The effect of *Jatropha curcas* spacing on the growth of maize is shown in Table 1. Plant height, diameter, number of leaves, number of nodes per plant were not affected by *Jatropha curcas* spacing in the first year. However, in the second year, significant differences ($P < 0.05$) in height and diameter of maize were realized (Table 1). Spacing of 2 m x 1 m differed with the control, 3 m x 1m and 4 m x 1m treatments. An increase in plant height of 17.19%, 22.39% and 23.38% were obtained for 3 m x 1 m, 4 m x 1 m and control respectively with respect to 2 m x 1 m in the second year. The control (No hedgerow) had the highest plant height (2.72 m and 2.48 m), diameter (20. 35 mm and 19.09 mm), number of leaves (11 and 10) and number of nodes (12.33 and 12.33) for the years 2008 and 2009 respectively (Table 1). Diameter growth in the second year was highest in 4 m x 1 m but it did not differ significantly from the control and 3 m x 1 m treatment. It increased by 19.7%, 16.9% and 18.5% for control, 3 m x 1 m and 4 m x 1 m respectively with respect to 2 m x 1 m. Stover weight was however significantly different ($P < 0.05$) in the first and second year. In the first year, significant difference was realized between 2 m x 1 m and the other treatments. No significant effect was attained between the control (No hedgerow), 3 m x 1 m and 4 m x 1 m treatments. Similar results were obtained in the second year where the control and 4 m x 1 m treatments did not differ significantly (Table 3). However, these differed significantly from 2 m x 1 m and 3 m x 1 m treatments (Table 3).

Table 1. *Effect of J. curcas spacing on growth parameters of Maize.*

Treatments (Hedgerow spacing)	Height (m)		Diameter at 1st node (mm)		Number of leaves		Number of nodes per plant	
	2008	2009	2008	2009	2008	2009	2008	2009
Control	2.72	2.48	20.35	19.09	11.00	10.00	12.33	12.33
2m x 1m	2.43	2.01	21.03	16.36	10.12	9.67	11.53	11.33
3m x 1m	2.51	2.36	21.22	19.12	11.00	10.33	11.63	11.39
4m x 1m	2.55	2.46	21.55	19.38	11.33	10.00	12.33	12.03
S.E.	0.87	0.16	0.39	1.07	0.36	0.21	0.28	0.54
LSD (0.05)	NS	0.32	NS	2.70	NS	NS	NS	NS

*NS means Not Significant

4.2. Effect of Jatropha Curcas Spacing on Yield and Yield Components of Maize

Table 2. *Effect of J. curcas spacing on yield and yield components of maize.*

Treatments	100 seed weight		Number rows/cob		Number seed/row	
	2008	2009	2008	2009	2008	2009
Control	43.00	25.17	14.67	14.22	35.00	30.56
2m x 1m	41.80	21.15	14.00	14.17	30.08	26.33
3m x 1m	41.88	23.73	13.67	14.58	31.62	27.67
4m x 1m	42.77	24.67	15.00	15.00	33.67	28.00
S.E.	3.42	0.97	0.63	0.25	1.40	3.60
LSD (0.05)	NS	2.36	NS	NS	NS	NS

*NS means Not Significant

The results showed significant differences in the yield of maize at different spacing of *Jatropha curcas*. Maize yields ranged between 2.05 tons ha-1 and 4.47 tons ha-1 in the first year and 1.56 and 2.99 tons ha-1 in the second year. The differences in yield were significant in both years; however, the differences ($P < 0.05$) for 3 m x 1m and 4 m x 1 m treatments in both years were not significant (Table 3). There were no significant differences in 100 seed weight, number of rows/cob, number of seeds/row, weight of ear and weight of seed/cob with respect to *Jatropha curcas* spacing in the first year (Table 2 and 3). In the second year, however, significant differences ($P < 0.05$) were observed for 100 seed weight, weight of ear, weight of seed/cob. 100 seed weight was highest (25.17 g) at No hedgerow (control) but did not differ significantly from the spacing at 3 m x 1 m (23.73 g) and 4 m x 1 m (24.67 g) (Table 2). Significant differences were found between 100 seed weight at 2 m x 1m spacing and all other spacing. Weight of ear and weight of seed/cob showed the same trend for the second year. The maximum weight of ear of 228.1 g was recorded for the control while the lowest was 198.7 g for 2 m x 1 m. Weight of seed/cob was also highest (125.8 g) at No hedgerow (control) and lowest (99.30 g) at 2m x 1 m in the second year. In both cases, the highest results obtained from the control plot did not differ significantly (P < 0.05) from 3 m x 1 m and 4 m x 1 m treatment (Table 3). Generally, yield and yield components of maize were lower in the second year.

Table 3. *Effect of J. curcas spacing on yield and yield components of maize.*

Treatment	Weight of ear (g)		Weight of seed/cob (g)		Stover weight (tons/ha)		Grain Yield (tons/ha)	
	2008	2009	2008	2009	2008	2009	2008	2009
Control	267.2	228.1	202.8	125.8	11.99	8.95	4.47	2.99
2m x 1m	239.3	198.7	133.5	99.30	8.72	4.38	2.05	1.58
3m x 1m	242.3	217.1	164.3	112.5	11.77	4.88	2.82	2.00
4m x 1m	245.2	218.5	178.9	119.5	11.86	7.49	3.80	2.10
S.E.	34.5	2.83	25.9	3.76	0.37	1.14	0.51	0.11
LSD(0.05)	NS	9.80	NS	13.03	1.28	3.95	1.77	0.38

*NS means Not Significant

4.3. Effect of Jatropha Curcas Spacing and Cultivation of Maize on Soil Chemical Properties

Data on soil chemical properties were analysed for year 2008 and 2009 after harvesting. The soil chemical properties were not significantly (P < 0.05) affected by *Jatropha curcas* spacing and maize cultivation. Also, soil samples taken before the experiment, the control treatment (No hedge), 2m x 1 m, 3 m x 1 m and 4 m x 1 m treatments did not differ significantly (Table 5 and Table 6). However, the results showed that before the experiment was carried out, the site had high proportion of total nitrogen, organic matter and exchangeable potassium when compared to the ranking in Table 4. ECEC was however moderate. After two years of cultivating *Jatropha curcas* with maize a similar trend in ranking was observed.

Table 4. *Soil nutrients (mineral content) and its ranking.*

Nutrient	Rank/Grade
Phosphorus P (ppm), (Blay -1)	
< 10.0	Low
10.0 – 20.0	Moderate
> 20.0	High
Potassium, K (ppm); Exchangeable K (cmol) (+)/Kg	
< 50;< 0.2	Low
50 – 100 ;0.2 – 0.4	Moderate
> 100;> 0.4	High
Calcium, Ca (ppm) / Mg = 0.25 Ca	
< 5.0	Low
5.0 – 10.0	Moderate
> 10.0	High
ECEC (cmol) (+)/ Kg	
< 10.0	Low
10.0 – 20.0	Moderate
> 20.0	High
Organic matter (%)	
< 1.5	Low
1.6 – 3.0	Moderate
> 3.0	High
Nitrogen (%)	
< 0.1	Low
0.1 – 0.2	Moderate
> 0.2	High

Table 5. *Chemical properties of the soil after harvesting in 2009.*

Treatment	PH	Org. C.	Total N (%)	Org. Matter	Exchangeable cations me/100g			
					Ca	Mg	K	Na
Before the experiment	5.43	2.75	0.24	4.74	10.80	3.61	0.75	0.13
Control	5.87	2.69	0.25	4.65	12.20	3.61	0.62	0.12
2m x 1m	5.68	2.99	0.26	5.15	8.73	8.39	0.83	0.17
3m x 1m	5.95	3.24	0.28	5.58	12.06	7.53	0.90	0.15
4m x 1m	5.75	2.76	0.24	4.76	9.66	4.19	0.79	0.15
C.V. (%)	4.98	9.00	9.14	8.99	29.94	14.78	8.05	10.35
S.E.	0.29	0.26	0.023	0.45	3.19	0.825	0.064	0.015
LSD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS

*NS means Not Significant

Table 6. *Chemical properties of the soil after harvesting in 2009.*

Treatments	T.E.B.	Exch. Acid (Al + H)	E.C.E.C. me/100g	Base saturation (%)	Available – Bray's	
					P ppm	K ppm
Before the experiment	15.29	0.28	15.59	98.71	5.67	177.32
Control	16.55	0.15	16.53	98.68	4.59	167.40
2m x 1m	18.12	0.24	18.36	98.93	8.29	184.13
3m x 1m	20.64	0.13	20.80	99.37	8.60	217.61
4m x 1m	14.79	0.18	14.77	98.81	5.94	160.70
C.V. (%)	15.73	44.45	15.33	0.59	3.97	42.44
S.E.	2.71	0.08	2.67	0.58	0.64	4.45
LSD (0.05)	NS	NS	NS	NS	NS	NS

4.4. Land Equivalent Ratio of Cultivating Jatropha Curcas with Maize

One way to assess the benefits of growing two or more crops together or intercropping is to measure productivity using the Land Equivalent Ratio (LER). It was proposed to help judge the relative performance of a component of a crop combination compared to sole stands of that species. LER is the sum of the relative yields of the components species. That is:

$$LER = Ci/Cs + Ti/Ts$$

Where Ci = Crop yield under intercropping
Cs = crop yield under sole crop
Ti = Tree yield under intercrop
Ts = Tree yield under sole system

Using the LER as a measure of both beneficial and negative interaction between the crops, all the treatments were beneficial over that of the control (Table 7). The highest LER of 1.62 and 1.20 was attained at 4 m x 1 m for the year 2008 and 2009 respectively. Lowest LER of 1 was obtained at the control treatment for both years (Table 7).

Table 7. *Land equivalent ratio of the various treatments for year 2008 and 2009.*

Treatment	Crop	Partial LER	Total LER 2008	Crop	Partial LER	Total LER 2009
Control	Maize	4.47/4.47 = 1	1	Maize	2.99/2.99 = 1	1
2m x 1m	Maize	2.05/4.47 = 0.45	1.45	Maize	1.58/2.99 = 0.53	1.14
	Jatropha	0.5/0.5= 1		Jatropha	1.22/2.00 = 0.61	
3m x 1m	Maize	2.85/4.47 = 0.6	1.54	Maize	2.00/2.99 = 0.67	1.18
	Jatropha	0.47/0.5 = 1		Jatropha	1.03/2.00 = 0.51	
4m x 1m	Maize	3.80/4.47 = 0.8	1.62	Maize	2.10/2.99 = 0.70	1.20
	Jatropha	0.41/0.5 = 0.9		Jatropha	1.00/2.00 = 0.50	

*LER greater than 1 shows intercropping is advantageous, LER < 1 show disadvantage, LER = 1 show no effect.

5. Discussion

5.1. Effect of Jatropha Curcas Hedgerow Spacing on Growth of Zea Mays L.

Plant heights, number of leaves, number of nodes per plant were not significantly affected by *Jatropha curcas* spacing in the first year. In the second year, however differences were observed in plant height and diameter. Maximum plant height (2.48 m) in the control plants was highest and lowest in at the 2 m x 1m (2.01 m). Diameter of maize stalks was highest at the 4 m x 1 m spacing (19.38 mm) and lowest at 2 m x 1 m (16.36 mm). The results suggest that the dense population of *Jatropha curcas* at the 2 m x 1 m spacing may have accounted for reduced plant height and diameter of maize. The reduced height and diameter may be due to limiting supply of water and nutrients from the soil and other environmental resources at dense population of *Jatropha curcas*. Since the maize component is smaller, its root will be confined to soil horizons that are also available to the roots of

Jatropha curcas, but *Jatropha curcas* can exploit soil volume beyond the reach of maize. Therefore, the effects of nutrients and water competition will be more severe for maize culminating in reduced height and diameter. These findings are in conformity with results of [12] and [13] who observed reduced plant height at high plant population. A contrary finding to this study has also been reported. It is reported that plant height and internodes length increased with increasing plant population because of competition for light [14]. [15] also recorded highest plant height in dense population.

5.2. Effect of Jatropha Curcas Hedgerow Spacing on Yield and Yield Component of Zea Mays

Generally no significant differences were observed in the first year. Differences in yield and yield components of maize started emerging in the second year even though yield was generally lower than in the first year. The lower yields observed in the second year at the closer spacing of 2 m x 1 m could be attributed to competition for nutrients, space and water. Yield reductions involving one or all component in intercropping have been attributed to interspecific competition for nutrients, moisture and/or space [14, 16]. [17] and [18] concluded that the main reasons for the comparatively poor crop performance under alley cropping treatments were root competition and shading. It is possible that in the second year *Jatropha curcas* competed with maize for nutrients and water thus causing a reduction in yield and yield parameters at closer spacing

(2 m x 1 m). [18] also noted that reduced crop yields, due to root competition between hedgerows and crops in the alleys, were detected at 11 months after hedgerow establishment, and that competition increased with age of the hedgerows as measured by steadily declining crop yields close to the hedgerows. This is corroborated by this study since, there were no significant differences in the first year but subsequently occurred in the second year. The ITTA study by [19] showed that maize and cowpeas yields were generally lower under alley cropping than when grown as sole crops. This can be confirmed in this study where yields and yield components where generally higher in the control treatment (No hedgerow) than the hedgerow intercropping for both first and second years. It is significant to note that the control did not differ significantly from wider spacing of 3 m x 1 m and 4 m x 1 m. [20] observed that though 2 m hedgerow spacing gave higher biomass, the yield of maize was reduced in this hedgerow spacing compared to the 4 m hedgerow spacing. Also [21] showed that competition for light was a more critical factor than root competition for intercropped maize between teak trees. Low yields from maize rows adjacent to *Leucaena leucocephala* hedgerow was attributed to shade [10].

5.3. Effect of Jatropha Curcas Spacing and Cultivation Of Maize on Soil Chemical Properties

The chemical properties of the soil did not decline significantly over the two-year period of establishment of *Jatropha curcas* hedgerows and the cultivation of maize. This implies that *Jatropha curcas* can be integrated into our land use system without a significant deterioration of soil chemical properties in the short term. Soil under alley cropping was higher in organic matter and nutrient content than soil without trees [22]. An experiment to compared the effect of *Cassia siamea*, *Gliricidia sepium* and *Flemingia macrophylla* in alley cropping trial found that soil organic matter and nutrient status were maintained at higher levels with *Cassia siamea* (which surprisingly, is not a N2-fixing species) [23]. This study showed a higher organic matter content for the *Jatropha curcas* hedgerow treatments over the non alleyed treatments even though these were not significantly different. This increase although not significant could be due to the short duration of the study and the addition of leaf litter into the soil from the hedgerows. Over a period of six years, the relative rates of decline in the status of nitrogen, pH and exchangeable bases of the soil were much less under alley cropping than under non-alley cropped [19]. This was attributed to the nutrient cycling capability of *Leucaena leucocephala* hedgerow, as there was evidence of a slight increase in soil pH and exchangeable bases during the third and fourth years after the establishment of the hedgerows. Could the slight increase in exchangeable bases in the *Jatropha curcas* hedgerows be attributed to nutrient cycling capability of *Jatropha curcas*? In this study, it was observed that there was an extension of *Jatropha curcas* roots laterally. This may provide an avenue for the intercept nutrients and recycling to the topsoil.

5.4. Land Equivalent Ratio of Cultivating Jatropha Curcas with Maize

The highest Land Equivalent Ratio (LER) attained at the hedgerow width of 4 m shows the beneficial effect of intercropping *Jatropha curcas* and maize at this treatment. The results for the year 2008 (LER of 1.62) means that an area planted as monoculture (Maize) would require 16.2% more land to produce the same yield as the same area planted to *Jatropha curcas* and maize combination. According to [24] intercropping was highly advantageous for pepper and Cardamon. Pepper intercropped with grevillea produced 3.9 times more than in monoculture and Cardamon intercropped with Grevillea and Pepper yielded 2.3 times more than in monoculture [24]. The high LER showed a very clear benefit from intercropping *Jatropha curcas* and maize at 4 m x 1 m hedgerow spacing. It reported that, on average, mixtures are 12% more productive than pure stands, based on 202 direct observations, or 13% more productive, based on 604 estimates using yield-density relationships [25]. It can be stated that a *Jatropha curcas* and maize mixtures would be beneficial than planting maize as a monocrop.

6. Conclusion

Hedgerow intercropping of *Jatropha curcas* with maize could prove useful if a spacing of 4 m x 1 m is adopted. It should be noted that closer spacing of *Jatropha curcas* could create competition with the associated crop resulting in reduced yields. Even though alley width of 4 m spacing did not give the highest yield compared to the control, its highest land equivalent ratio implies it could be the most appropriate spacing. Soil chemical properties were not affected within the two year of cultivating *Jatropha curcas* with maize. It implies that its use in alley cropping would not result in any deterioration in soil chemical status within a short term. In the midst of declining land area for the cultivation of *Jatropha curcas* as a biofuel crop, its use in alley cropping at the appropriate hedgerow spacing could be exploited to produce the crop.

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