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Land Use Efficiency of Castor (Ricinus communis L.) based Cropping Systems in Okigwe, Southeastern Nigeria

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ABSTRACT

A field study was carried out at Umuowa Ibu1 via the National Horticultural Research Mbato, Okigwe, Imo State, Nigeria, to evaluate the effect of cropping systems on the growth and yield of castor in southeastern Nigeria. The experiment was laid out in a randomized complete block design. The treatments consisted of nine castor-based cropping systems. Data collected were subjected to analysis of variance, and significant means were compared using LSD at a 5% probability level. Results showed that castor seed yield was influenced by the cropping systems. Significant castor yield was recorded in the sole castor treatment with 1289.34 and 1286.77 kg/ha in both cropping seasons, followed by 1288.43 and 1280.44 kg/ha recorded in the castor + cowpea intercrop. The yield obtained from sole castor was not significantly different when compared to the yield obtained from castor + cowpea and from the castor + groundnut intercrop treatment. The lowest castor seed yield, 1002.23 and 1007.23 kg/ha, was recorded in the castor + groundnut + garden egg intercrop. The yield of component crops decreased as the number of crops in the systems progressed from two to three. The castor + cowpea + pepper cropping system had the highest land equivalent ratio (LER), 5.62 and 5.63 in both cropping seasons. The lowest LER, 2.23 and 2.24, was recorded in the castor + groundnut treatment. The castor-based cropping system with cowpea and pepper was recommended for higher land use efficiency.

1. Introduction

Castor (*Ricinus communis* L.) is an important non-edible oilseed crop. It belongs to the same family, Euphorbiaceae, as cassava (*Manihot esculenta*) and Para rubber (*Hevea brasiliensis*). Castor oil is expensive and is mainly used in the manufacture of a wide range of industrial products such as nylon fibers, jet engine lubricants, hydraulic fluids, cosmetics, and pharmaceuticals (Mohammed Mohsin *et al.*, 2018). Its oil can be used in the treatment of many ailments, such as curing constipation, relieving pain, reducing inflammation, and treating stomach problems. It is a raw material in the cosmetic industry and is said to restore a youthful glow and maintain smooth and supple skin. It is also used in the manufacturing of dyes, detergents, soaps, polishes, greases, rubber, hydraulic brake fluids, polymers, wetting agents, surfactants, and surface coatings (Vaghela *et al.*, 2019). According to Vaghela *et al.* (2019), castor oil differs from other vegetable oils due to its non-freezing nature up to a temperature of -18°C. It is therefore considered to be the best lubricating agent, particularly for high-speed engines and airplanes. Castor is a non-edible oilseed crop (45 to 50% oil) with high industrial importance due to the presence of unique fatty acids, such as ricinoleic acid. In southeastern Nigeria, boiled and fermented castor seed is used in preparing a local seasoning popularly known as ogiri, which is commonly used in preparing bitter leaf and egusi soup, as well as African salad (Abacha) (Ikeh *et al.*, 2016). The demand for castor produce is high in both local and international markets.

Castor can be intercropped with many arable crops such as cassava, melon, cowpea, groundnut, sorghum, maize, and cotton. The basic concept of intercropping systems involves growing two or more crops together with the assumption that multiple crops can exploit the environment better than one, ultimately producing higher yields. The reason is that the component crops differ in resource use, and when grown together, they complement each other and make better overall use of resources. This practice offers several advantages, such as land economy, insurance against aberrant weather, higher yields, higher economic returns, soil fertility maintenance, and diversification of farm produce. Intercropping provides a substantial yield advantage over sole cropping due to temporal and spatial complementarity, minimizing interspecific and intraspecific competition (Mohammed Mohsin *et al.*, 2018). According to Vaghela *et al.* (2019), a significant feature of intercropping is that it is biologically more dynamic than sole cropping and is therefore less likely to succumb to the vagaries of weather. Thus, intercropping is intrinsically more secure and dependable in providing returns than sole cropping. According to Gangadhar (2022), the intercropping system is found to be more profitable and sustainable compared to sole cropping of castor, offering higher remuneration to farmers. Castor plants are more sensitive to moisture stress in the early stages of growth (Liv *et al.*, 2012), but they are tolerant to environmental stresses, particularly drought stress, at later stages of growth, which is one of the strengths of castor as a crop. Being an oil crop primarily for industrial purposes, there is a possibility of competition for land with food crops, pushing castor production into marginal soils and intercropping with other food crops. The intercropping approach in crop production arises due to better utilization of resources (both below and above ground) in space, time, or both. The significance in terms of enhanced yields per unit area and time accumulates due to differences in crop growth and canopy. Intercropping aims to enhance land productivity and better resource use stability across environments. It is feasible and cost-effective for crop production.

The demand for legumes, oil seeds, and vegetables in Nigeria has led to the inclusion of these arable and field crops into intercropping systems, which have the capacity to generate more returns per unit area as well as improve the physico-chemical, biological, and overall properties of soil in a sustainable manner. Castor grows sluggishly during its early phase, encouraging weed germination and growth that interfere with available resources. Given this growth pattern, castor can be intercropped with fast-growing crops with short maturation periods or low-growing crops in appropriate planting geometries to increase yields from both the main and component crops and maximize economic returns per unit area.

Intercropping these crops also provides farmers with food crops such as cereals, legumes, or vegetables for dietary or income needs while waiting for castor, a cash crop, to mature. The advantage of intercropping castor with other crops can be increased by optimizing crop geometry for better availability of solar energy and other resources (Ikeh *et al*., 2012). Legume crops may be a better choice due to their beneficial effect of fixing atmospheric nitrogen, making extra nitrogen available for the castor to utilize more efficiently beyond 90 days after sowing (Mohammed Mohsin *et al*., 2018). Crop geometry is an important factor for achieving higher production by better utilization of moisture, space, and nutrients from the soil, and by harvesting the maximum possible solar radiation for better photosynthate formation (Thavaprakaash *et al*., 2005; Ikeh *et al*., 2016). Adopting appropriate crop combinations in intercropping systems can enhance the productivity of crops. Ikeh *et al*. (2012) emphasized the need to select the appropriate crop types or varieties that would be compatible in each cropping system.

Cowpea (*Vigna unguiculata* (L.) Walp): The second most important food grain legume crop in tropical Africa. Nigeria and other West African countries grow cowpeas for market and subsistence. It has high nutritive value, especially protein. Cowpea is important for human consumption and provides feed, forage, hay, and silage for livestock. It also serves as green manure and a cover crop for maintaining soil productivity. When grown with other crops like cereals or tuber crops, it compensates for the nitrogen loss removed by the main crop.

Groundnut (*Arachis hypogaea*): Also called peanut, it is grown as an oil and grain legume crop and is a major cash crop in Nigeria, used directly as food, for oil, and for the high-protein meal produced after oil extraction. Groundnut is a highly nutritious food; whole groundnut and groundnut meal are rich in protein, minerals, and vitamins (Akata and Ikeh, 2021).

Pepper (*Capsicum spp.*): An annual herb or shrub belonging to the Solanaceae family. Pepper is an important spice globally and one of the most important spices grown in Nigeria and other parts of the world. It is used in seasoning sauces, soups, and other dishes. As a medicinal plant, pepper is used in the prevention and treatment of colds and fevers (Udoh and Ndon, 2016). Very hot varieties of pepper (chilies) have a high content of the alkaloid capsaicin, which imparts pungency (Ikeh *et al*., 2012). Most farmers in Nigeria grow pepper in homestead farms as a backyard crop. Pepper can be intercropped with other crops such as root and tuber crops, cereals, and legumes.

Garden Egg (*Solanum melongena*): Belongs to the family Solanaceae, which includes other economically important crops such as tomatoes, pepper, and Irish potato. Garden egg is one of the leading fruits and leafy vegetables in the farming systems of southeastern Nigeria, grown in all seasons for both its leaves and immature fruits (Ikeh and Akpan, 2018). Garden egg production is a major source of income for rural women and their households in all agricultural zones of the country. The garden egg plays a central role in tradition. It is offered as a dessert fruit in traditional ceremonies such as marriages, child naming, thanksgiving services, and other socio-cultural gatherings. In southeastern Nigeria, where cola nuts are usually celebrated, the garden egg is becoming an alternative due to the high caffeine content and health implications of cola nuts. Garden egg or cola nut is the first edible food offered to a visitor or stranger (Ikeh and Akpan, 2018).

The Land Equivalent Ratio (LER) is mostly used in research on intercropping to determine land-use efficiency (Onwueme and Sinha, 1991). Since component crops in an intercropping system vary in headings, phenology, growth habit, and morphology, qualitative and quantitative effects of intercropping on productivity are likely to vary with crops (Anan and Vidhaya, 2003). The objectives of this study were to compare the growth, yield, and land-use efficiency of cowpea, garden egg, groundnut, and pepper in different castor-based cropping systems.

2. Methods

2.1 Site Location

A field experiment was conducted during 2020 and 2021 at the Farm Settlement of Umuowa Ibu1 via the National Horticultural Research Institute (NIHORT) Okigwe sub-station, Okigwe, Imo State, Nigeria. Okigwe is located between latitudes 5°49'45"N and longitudes 7°21'2"E. Okigwe has a mean annual rainfall range of 80 to 375 mm, a mean relative humidity of 79%, and a mean temperature range of 22.7 to 34°C. The area, which lies within the humid tropical rainforest zone of Nigeria, has two distinct seasons: the wet and dry seasons. The wet season starts between March and April and lasts until October, with a brief break in August traditionally referred to as the "August Break." The dry season begins in November and extends to February and late March.

2.2 Soil Sample Collection and Analysis

Composite soil samples were taken from the surface soil at two depth of 0-15cm and 15-30cm. The soil samples were air dried and processed for mechanical and chemical analysis.

2.3 Experimental Design and Treatments

The experiment was laid out in a randomized complete block design (RCBD) and replicated three times. The experimental treatments consisted of nine cropping systems: sole castor, castor + groundnut, castor + cowpea, castor + garden egg, castor + pepper, castor + cowpea + pepper, castor + groundnut + pepper, castor + cowpea + garden egg, and castor + groundnut + garden egg.

2.4 Agronomic Practices

The site was under fallow for 3-years after being planted sweet potato and maize. Land preparation was manually done with machetes, spade and Indian hoe. The site, after clearing was left to dry and the trashes of were raked and packed at the borders. Ridges of 5m length were constructed at a distance of 1m x 1m. Planting was done on third week of August in both cropping seasons. All intercrops are sown at 30 cm x 10 cm row spacing.

3. Results and Dicussion

3.1 Results

Plant height as influenced by cropping systems is presented in Table 1. In both cropping seasons, result of plant height at harvest showed no statistically significant difference, irrespective of cropping system. Plant height recorded in sole castor was 169.15 and 168.40 cm in 2020 and 2021 cropping seasons, respectively while 165.11 and 164.51 cm height at harvest was recorded under castor + groundnut+ garden egg cropping system.

Number of castor branches per plant as influenced by cropping systems showed no significantly different in both 2020 and 2021 cropping seasons. Sole cropped castor had highest number of primary branches per plant; 5.97 and 5.93 in both cropping seasons, although the mean number of branches recorded in sole cropped castor was not significant difference when compared to 5.49 and 5.44 recorded in cropping system of castor + groundnut +garden egg.

Number of internodes per plant as influenced by cropping systems differed not significantly different ($p>0.05$) in both cropping seasons (Table 1). Sole castor had 20.01 and 19.50 internodes at harvest in 2020 and 2021. Number of internodes per plant recorded in in castor + groundnut intercrop was 19.69 and 18.75, respectively. The treatment of castor + groundnut +garden egg intercrop had 18.45 and 18.64 internodes in 2020 and 2021 cropping seasons.

Table 1. Growth Parameters of Castor as Influenced by Cropping System

Cropping systems	2020			2021		
	Plant Height at Harvest (cm)	Number of Primary Branches per plant	Number of Internodes per	Plant Height at Harvest (cm)	Number of Primary Branches per plant	Number of Internodes per
Sole Castor	169.45	5.97	20.01	168.40	5.93	19.50
Castor + Groundnut	168.40	5.43	19.69	167.77	5.81	18.75
Castor+ Cowpea	165.11	5.39	19.93	163.59	5.91	18.88
Castor + Garden egg	167.49	5.48	18.76	167.23	5.83	17.80
Castor + Pepper	167.89	5.62	18.71	168.50	5.88	18.91
Castor + cowpea + pepper	166.60	5.89	18.63	163.30	5.87	19.01
Castor + Groundnut + Pepper	163.33	5.53	19.20	165.15	5.80	18.60
Castor +Cowpea +Garden egg	165.89	5.51	18.33	165.22	5.75	19.40
Castor + Groundnut +Garden egg	165.11	5.49	18.45	164.51	5.44	18.64
LSD(p<0.05)	NS	NS	NS	NS	NS	NS

Number of spikes per plant as influenced by castor-based cropping system is shown in Table 2. The effect of cropping systems on number of spikes per plant varied significantly different ($p>0.05$) in both cropping seasons. The highest number of spikes per plant; 10.95 and 10.80 in both cropping seasons was recorded in sole castor. While 10.75 and 10.78 spikes per plant was recorded in the treatment of castor intercropped with cowpea. In both cropping seasons, the least number of spikes per plant; 6.48 and 6.55 was recorded in treatment of castor intercrop with groundnut and garden egg. Result showed no significant difference when number of spikes per plant recorded in the treatment of sole castor were compared to the treatments except the treatments of castor+ groundnut + garden egg.

Table 2. Yield and Yield Components of Castor as Influenced by Cropping Systems

Cropping systems	2020				2021			
	Number of Spike per Plant	Number of Capsules per Spike	Weight of 100 Seeds (g)	Seed Yield (kg/ha)	Number of Spike per Plant	Number of Capsules per Spike	Weight of 100 Seeds (g)	Seed Yield (kg/ha)
Sole Castor	10.95	58.22	31.40	1289.34	10.80	58.66	32.02	1286.77
Castor + Groundnut	10.20	52.33	31.25	1277.78	10.21	53.44	31.41	1271.55
Castor+ Cowpea	10.75	58.13	31.38	1288.43	10.78	57.24	32.15	1280.44
Castor + Garden egg	8.45	49.34	30.31	1059.63	9.93	50.11	31.98	1093.55
Castor + Pepper	10.02	50.33	31.08	1077.25	9.98	52.55	31.31	1078.33
Castor + cowpea + pepper	9.23	53.43	31.77	1063.45	10.03	53.33	31.13	1079.88
Castor + Groundnut + Pepper	8.70	46.91	30.10	1061.91	8.66	48.81	30.91	1060.98
Castor +Cowpea +Garden egg	7.81	45.01	30.81	1040.53	6782	46.45	31.01	1033.53
Castor + Groundnut +Garden egg	6.48	44.53	30.75	1002.23	6.55	46.31	31.24	1007.23
LSD(p<0.05)	2.17	3.06	NS	8.77	2.07	2.12	NS	10.33

Number of capsules of spike per plant as influenced by cropping systems is presented in Table 2. Result showed significantly different when the mean values were compared. Sole castor produced significant higher number of capsules per spike; 58.22 and 58.66 in 2020 and 2021, cropping seasons, respectively. This was followed by 58.13 and 57.24 number of capsules per spike recorded in treatment of castor intercrop with cowpea. The least number of capsules per spike; 44.53 and 46.31 in both cropping seasons, was recorded in the treatment of castor +groundnut + garden egg.

Weight of 100g seeds as influenced by cropping system is shown in Table 2. The result showed no significant differences among the treatments. Weight of 100 seeds per ranges from 30.10 g to 31.40 g in 2020. In 2021 cropping season, the range was 30.91g to 32.02 g.

Castor seed yield as influenced by cropping systems is shown in Table 2. Results differed significantly different ($p<0.05$) among the cropping systems. Significant seed yield was recorded in the treatment of sole castor with 1289.34 and 1286.77 kg/ha in 2020 and 2021 cropping seasons, respectively. This was followed by 1288.43 and 1280.44 kg/ha recorded in castor + cowpea intercrop. The least seed yield; 1002.23 and 1007.23 kg/ha in 2020 and 2021 cropping seasons, respectively was recorded in cropping system of castor + groundnut + garden egg. The yield obtain from sole castor was not significant difference when compared to yield obtained from castor+ cowpea and also in the treatment of castor + groundnut intercrop.

Groundnut seed yield as influenced by cropping systems is presented in Table 3. The result showed significant differences among the yields. Significant seed yield was recorded in the treatment of groundnut + castor intercrop; 1743.33 and 1681.01 kg/ha in 2020 and 2021 cropping seasons. This was followed by1631.13 and 1675.24 kg/ha recorded in cropping system of Castor + Groundnut + Pepper intercrop. The least groundnut seed yield; 1564.92 and 1695.40 kg/ha, respectively was recorded in cropping system of Castor + Groundnut + Garden egg.

Table 3. Yields of Components Crops as Influenced by Castor Based Cropping System

Cropping systems	2020				2021			
	Groundnut Seed Yield (kg/ha)	Cowpea Seed Yield (kg/ha)	Garden egg Fruit Yield (kg/ha)	Pepper Fruit Yield (kg/ha)	Groundnut Seed Yield (kg/ha)	Cowpea Seed Yield (kg/ha)	Garden egg Fruit Yield (kg/ha)	Pepper Fruit Yield (kg/ha)
Sole Castor	-	-	-	-	-	-	-	-
Castor + Groundnut	1743.33	-	-	-	1681.01	-	-	-
Castor+ Cowpea	-	5712.37	-	-	-	5665.60	-	-
Castor + Garden egg	-	-	1810.09	-	-	-	1793.55	-
Castor +Pepper	-	-	-	1911.13	-	-	-	1894.34
Castor + cowpea + pepper	-	5514.32	-	1734.56	-	5549.45	-	1712.98
Castor + Groundnut + Pepper	1631.13	-	-	1577.33	1675.24	-	-	1569.22
Castor +Cowpea +Garden egg	-	5263.41	1783.23	-	-	5198.11	1783.40	-
Castor + Groundnut + Garden egg	1564.92	-	1773.40	-	1651.43	-	1695.40	-
LSD($p<0.05$)	7.55	5.45	11.18	9.73				

Cowpea seed yield as influenced by cropping system is shown in Table 3. The result maintain similar pattern as in groundnut yield. Significant cowpea seed yield; 5712.37 and 5665.60 kg/ha in 2020 and 2021 was recorded in cropping system of Castor + Cowpea. This was followed by 5514.32 and 5549.45 kg/ha, respectively harvested from Castor + cowpea + pepper intercrop. The least cowpea seed yield; 5263.41 and 5198.11 kg/ha was recorded in cropping system of Castor +Cowpea +Garden egg.

Garden egg yield as influenced by cropping system is shown in Table 3. Castor + Garden egg intercrop had significant fruit yield; 1810.09 and 1793.55 kg/ha in 2020 and 2023 cropping seasons. The cropping system of Castor +Cowpea +Garden egg produced fruit yield of 1783.23 and 1783.40 kg/ha in both cropping seasons. The least garden egg fruit yield: 73.40 and 1695.40 kg/ha was recorded in Castor + Groundnut + Garden egg cropping system.

Pepper yield as influenced by castor-based cropping systems is shown in Table 3. Treatment of castor + pepper cropping system produced significant fresh pepper yield; 1911.13 and 1894.34 kg/ha in both cropping seasons. Pepper under cropping system of Castor + cowpea + Pepper had fruit yield of 1734.56 and 1712.98 kg/ha in 2020 and 2021 cropping seasons, respectively. The least pepper yield; 1577.33 and 1569.22 kg/ha (Table 3).

Land equivalent ratio of castor-based cropping system is shown in Table 4. All the LER were above 1. The highest LER: 5.62 and 5.64 was recorded in castor+ cowpea + pepper intercrop while Castor +Cowpea +Garden egg had LER of 5.45 and 5.43 in 2020 and 2021 cropping seasons, respectively. The least LER in both cropping seasons, 2.25 on average was recorded in castor + groundnut intercrop. Results revealed that intercrops that higher average land-use efficiency than sole crop.

3.2 Discussions

Plant height as influenced by cropping system showed no significant difference ($p<0.05$) in both cropping seasons. The no significant variation observed in plant height could be attributed to high comparative competition advantages castor has over the components crops. Castor grow in rank and vigorous, formed story canopy compared cowpea, groundnut, pepper and garden egg in the same cropping system. The may be non-existence or may be little competition for sunlight, space, nutrient and water between castor and the other component crops within the same cropping system. The results are confirmed with the results reported by Kumar *et al.* (2013) who reported no significant difference in plant height under castor-mungbean intercropping systems. Also Vaghela *et al*. (2019) who reported no significant difference in plant height of castor under castor bases cropping systems.

Number of castor branches per plant as influenced by cropping systems differed not significantly different ($p<0.05$) in both cropping seasons. The no significant difference recorded in number of branches per plant irrespective of any cropping systems could be that castor in each system had adequate soil and climatic conditions required for optimal growth and development. The little competition in terms of nutrients impacted by component crops in the systems were not enough to reduced its growth and development processes.

The no significant variation recorded internode of castor at different cropping systems revealed that castor could be more compatible with all the component crops. In the systems no crop had shading effect and/ or allelopathic effects on castor crop during the growth and development phases. This might be due to relatively less competition between castor and the component crops, the growth pattern of castor differs from cowpea and groundnut (low growing crops). Also, in the system, castor was taller than the other component crops. These advantages castor had over the component crops could also translate that castor had utilization of non-renewable resources like water, nutrients, space and solar radiation which resulted into higher portioning, sink source and dry matter accumulation in reproductive parts. This report agrees with Vaghela *et al.* (2019) and Srilatha *et al.* (2002).

Number of spikes per varied significantly differ among the cropping systems. Sole castor produced significant higher number of capsules per spike and number of capsules per spike. This was followed by cropping systems of castor + cowpea. The least was observed in cropping system of castor + groundnut + garden egg. The significant higher number of spikes per plant, number of capsules per plant and seed yield recorded in sole castor and castor + cowpea than that of other intercropping systems might be due to supply of nitrogen by fixing atmospheric N in soil to the associated castor, better moisture conservation by working as cover crop, suppression of weeds and higher sunshine availability. The findings agree with the results reported by Dhimmar (2009), Singh (2009) and Mudalagiriyappa *et al.* (2011).

They higher seed yield rec in sole castor cropping system could attributed to relatively less inter row competition in sole castor and better use of resources like water, nutrients, space and sunlight ultimately resulted into higher number of spikes per plant and number of capsules per spike which could the the factor that resulted to increase in seed yield. This finding is in consonance and conformity with the findings of Neginhal *et al.* (2011), Kumar *et al.* (2011) and Kumavat *et al.* (2016) and Vaghela *et al* (2019), who reported increase in yield when castor is cultivated sole. In both cropping seasons, result showed higher LER ratio when castor intercrop with cowpea. Higher cowpea yield in this system might be due higher yield potentiality and early maturation of cowpea before castor started forming canopy. Also, result showed no significant difference between castor seed yield in sole and castor + cowpea cropping system could be less competition for space and nutrient between castor and cowpea. The same trend was recorded in castor inter crop with groundnut.

4. Conclusion

With respect to land use efficiency, castor +cowpea + pepper intercropping and castor +cowpea had land equivalent ratio (LER) of above five (5) unit. This indicate that 56 to 82% more land would have been used in single cropping to produce the same quantities of castor, cowpea, pepper and garden egg as in the inter-cropping systems. The study therefore recommends intercropping of castor and other companion crops such as cowpea, pepper and garden egg in the study area. This would ensure adequate production of cash and food crops in the land area and enhances more returns from the same piece of land.

5. References

Anan, P. and Vidhaya, T. (2003). Growth, Yield and Land Use Efficiency of Corn and Legumes Grown under Intercropping Systems, Plant Production Science, 6:2, 139-146, DOI: 10.1626/pps.6.139

Dhimmar, S. K. (2009). Effect on growth and yield of rabi castor in pulses intercropping under varying planting geometry. *American-Eurasian Journal of Scientific Research*, 4 (3): 165-168.

Ikeh, A. O. Ndaeyo, N. U., Uduak, I. G., Iwo, G. A., Ugbe, L. A., Udoh, E. I., Effiong, G. S. (2012) Growth and Yield Responses of Pepper (*Capsicum frutescens* L.) to varied Poultry Manure Rates in Uyo, Southeastern Nigeria. *ARPN Journal of Agricultural and Biological Science* 7:9:735-742.

Gangadhar K, Yadav, J.S and Yadav, A.K. (2022). Impact of intercropping system on castor growth and production under the semi-arid region of Haryana. *International Journal of Chemical Studies*, 10(5):93-9

Ikeh, A.O**.** and Akpan, E.A. (2018). Response of Dry Season Garden Egg (*Solanum melongena*) to Watering Regime and Organic Mulching Levels in Okigwe, Southeastern Nigeria. *Journal of Agricultural and Crop Research*, 6(2):38-46.

Ikeh, A.O. and Akpan, E.A. (2018). Response of Dry Season Garden Egg (Solanum melongena) to Watering Regime and Organic Mulching Levels in Okigwe, Southeastern Nigeria. *Journal of Agricultural and Crop Research*, 6 (2):38-46.

Ikeh, A.O., Udounang, P.I., Akpan, E.A and Peleyeju, K.O. (2016). Growth and Storage Root Yield of Cassava as Influenced by Time of Intercropping with Castor (*Ricinus communis* L.) in Okigwe, Southeastern Nigeria. *Journal of Forestry, Environment and Sustainable Development*, 2(1):153-160.

Kumar M, Shivran A.C, Chouhan, R., Meena, K.S, and Verma, K.C. (2013). Effect of row ratio and sulphur levels on yield attributes, seed yield and quality in castor-mungbean intercropping systems under dryland condition. *Environment and Ecology*, 31(2C):1061-1064

Kumavat AK, Ardesna RB, Kumar D, Chouhan M. (2016). Yield, quality, nutrient uptake, soil fertility and weed dry weight as influenced by castor (Ricinus communis L.) intercropped with mungbean (Vigna radiata L.) under different row ratios and spacing during Rabi season. The Bioscan, 11(1):607-610.

Mohammed Mohsin, J.S. Yadav, Harender and Naveen Rathi. (2018). Effect of Castor Based Intercropping Systems on Yields and Economics of Castor (Ricinus communis L.).*International Journal of Curr. Microbiol. Applied Science*, 7 (10): 3014-3020. Doi: https://doi.org/10.20546/ijcmas.2018.710.351

Mudalagiriyappa, Nanjappa HV, Ramachandrappa BK, Kumar HCS. (2011). Productivity and economics of castor (Ricinus communis L.) based intercropping systems in vertisols under rainfed conditions. Indian Journal of Dryland Agriculture Research and Development, 26(2):77-81

Neginhal, M.P, Ramachandrappa, B.K, Dhanapal, G.N, Nanjappa, H.V. (2011). Productive performance of intercrops in nipped castor (Ricinus communis L.) in Alfisols of dryland. *Mysore Journal of Agricultural Sciences*, 45(2):322-325

Singh, I. (2009). Study on intercropping of castor, Ricinus communis L. under irrigated condition. *Journal of Oilseeds Research*, 26(2):170-171.

Srilatha, A.N, Masthan S.C, Mohammed S. (2002). Production potential of castor intercropping with legumes under rainfed conditions. Journal of Oilseeds Research, 19(1):127-128.

Thavaprakaash, N., K. Velayudham and V.B. Muthukumar. 2005b. Effect of crop geometry, intercropping systems and integrated nutrient management practices on productivity of baby corn (Zea mays L.) based inter cropping system Research Journal of Agricultural and Biological Sciences, 1(4): 295-302

Liv S. S., Dick, L. A., Marco, B., Magno J. D., Cândido, G. C, William Crosby, T. D., Xiaohua H, P., Lakshmamma, C. L., Olga L. T., Machado, T. M., Máira Milani, T. D., Miller, J. B., Morris, S. A., Morse, A. A., Navas, D. J., Soares, V. S., Ming, L. W., Maurício, D. Z, and Helge, Z. (2012). A Review on the Challenges for Increased Production of Castor. *Agronomy Journal*, 104 (4) 853-880.

Udoh, D. J and Ndon, B. A. (2016). Crop Production Techniques for the Tropics. 2nd Edition Concept Publication Limited, Lagos, Nigeria. Pp.464.

Vaghela, S.J., Patel, J.C., Patel, D.G. Dabhi, K.B. and Dabhi, J.S (2019). Yield, equivalent yield and economics of castor as influenced by different castor (Ricinus communis L.) based cropping systems in North Gujarat agro-climatic condition. Journal of Pharmacognosy and Phytochemistry; 8(5): 1727-173.