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Comparative Economic Analysis of Irrigated and Rain-Fed Farming of Amaranth (*Amaranthus cruentus* L.) – Jute Mallow (*Corchorus olitorus* L.) Intercropping in Savanna, Nigeria

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Abstract
Irrigation has the potential to boost agricultural productivity and raise farm income and food production but in sub-Saharan Africa, agriculture is almost entirely rain-fed. Irrigation covers 4 to 6% of the total cultivated area. The profitability of three different cropping systems at contrasting growth conditions was analysed in this present study. Two Field experiments were conducted at the Research Experimental Station of the Institute of Food Security, Environmental Resources and Agricultural Research, Federal University of Agriculture, Abeokuta (07^0 15'N 03^0 25'E) under irrigation during the dry season of 2020 (November – December) and rain-fed during the early wet season (May – July) of 2021. Amaranth (*Amaranthus cruentus* L.) and jute mallow (*Corchorus olitorus* L.) were grown alone or in intercrops with each other. Both irrigated and rain-fed intercrop production systems resulted in a greater land-equivalent ratio, LER (>1.00) than sole crops, but they are comparable to one another. The two intercrop production systems had land-equivalent coefficient, LEC values of 0.77 and 0.8, which were higher than the 0.25 expected. Irrigated intercrop production had the highest gross margin which was 50 and 52 % higher than both rain-fed intercrop and sole amaranth production respectively which were profitable. The intercrop vegetable production under irrigation had the highest benefit-cost ratio (1.55), the highest rate of return (0.55) and the least gross ratio (0.65). Irrigated intercrop production is the most profitable cropping system. It is therefore recommended that intercropping of amaranth-jute mallow under irrigated production system should be practised for increased profitability.

Keywords: Profitability; Cropping systems; Irrigation; Amaranth; Jute Mallow

Introduction

Intercropping, defined as growing two or more crops at the same time on a single field, is an ancient practice still widely used in developing countries of the world. The final output of the system depends largely on the interactions between the component crops, management practices, prevailing environmental conditions, time of planting, planting pattern, fertiliser application, compatibility of component crop species, and pests (Somefun *et al*., 2020). Its advantages include enhanced crop productivity, better utilisation of environmental resources, reduced pests, diseases and weeds incidence, increased yield and productivity, compatibility of component species, and improvement and maintenance of soil fertility (Somefun *et al*., 2020). Vegetables play a considerable feature in supplying the important minerals, vitamins and fibre not found in large quantities in starchy staple foods. Vegetables add flavours to meals. They are tasty, healthful and supply both proteins and carbohydrates. They are a very good source of income for women farmers and offer opportunities for the disabled to earn a living (Fadeyi *et al*., 2022). Its cultivation serves as a means of livelihood for households both in rural and urban communities where they are grown for commercial purposes to generate income as well as for nutritional and medicinal values (Oladapo and Afolami, 2021). Amaranth belongs to the family Amaranthaceae and has specific traits not only in its nutritive value but in its short lifecycle (Abu-Ziada, 2008). It is rich in vitamins, including β-carotene (precursor of vitamin A), vitamins B6 and C, riboflavin and folate, as well as dietary minerals such as calcium, iron, magnesium, phosphorus, potassium, zinc, copper and manganese. The vegetable is also rich in lysine, an essential amino acid that is lacking in starch-based diets based on cereals and tubers (Maseko *et al*., 2015). Jute Mallow which belongs to the family Malvaceae is widely grown in the tropics for of its leaves viscosity, which are consumed either fresh or sun-dried. The leaves are a rich source of iron, protein, calcium, thiamin, riboflavin, niacin, Vitamin A, K, ascorbic acid, thiamine folate and dietary fibre (Maseko *et al*., 2015).

Irrigation is regarded as the application of water to soil to supply moisture needed for plant growth and development. This is essential to ascertain security against droughts, and for cooling the soil and atmosphere. It is the science of water supply system design and planning for optimum production of agricultural land in the face of dwindling precipitation to protect crops from the adverse effects of drought and low rainfall (Oladimeji and Abdulsalam, 2014). Hence, it is a powerful factor in increasing crop productivity, more stable incomes and employment and increasing prospects for multiple cropping and crop diversification (Joseph *et al*., 2019). Studies conducted by various researchers have shown greater profitability potential of irrigated farming compared to rain-fed farming. Ayoola (2014) performed a comparative economic analysis of tomato production (*Lycopersicon esculentum* Mill) under irrigation and rain-fed systems in some selected Local Government Areas of Kogi and Benue States, Nigeria and found the gross margins per hectare of tomato production under irrigation and rain-fed systems to be N153, 500 and N68, 000 respectively. This is an indication of investment in tomato crop production under the irrigated system being worthwhile as it gave greater revenue when compared to that of a rain-fed production system. The research conducted by Oladimeji and Abdulsalam (2014) on economic analysis of dry season irrigated farming in Asa River, Kwara State, Nigeria, revealed that irrigated farming was more profitable than rain-fed farming. Umar (2016) also found profitability ratios of irrigated farming profit margin, gross ratio and return on investment of 0.49, 0.51 and 1.96 respectively to be higher than the rain-fed of 0.46, 0.54 and 1.84 respectively. These earlier studies did not explore leafy vegetables such as amaranth and jute mallow in different cropping systems. Consequently, this study analysed the profitability of amaranth-jute mallow intercropping cultivated under irrigation and rain-fed conditions.

Materials and Methods

Location

This trial was carried out at the Research Experimental Station of the Institute of Food Security, Environmental Resources and Agricultural Research, Federal University of Agriculture, Abeokuta (07^0 15'N 03^0 25'E) in the Forest-Savanna transition of South West Nigeria under irrigation during the dry season of 2020 (November – December) and rain-fed during the early wet season (May – July) of 2021. The long-term rainfall average for this location is above 1300 mm which is bi-modally distributed. The first rainy season begins in March/April and ends in July while the second rainy season starts in late August and ends in November. There is a dry season between November and March.

Experimental Treatment and Design

The treatments were Amaranth and Jute Mallow grown sole or in intercropping with each other. The size of each plot was 3 m × 2 m with a border of 0.5m between plots. The trial was laid out in randomized complete block design (RCBD) consisting of three treatments and replicated four times.

Crop Husbandry

Soil Incorporation of manure at 20 t/ha was done before planting of seeds after manual tilling. Amaranth seeds were broadcasted at a rate of 3 kg/ha while Jute mallow was sown at a rate of 7 kg/ha using the same method on the 6th of November, 2020 and 17^{th} of May, 2021. Manual weeding was carried out at 2 and 4 weeks after planting to disallow weeds effects on the cultivated crops. Pests were managed with the use of biocides such as garlic, ginger, turmeric, onions, pepper and neem leaf extracts. The spices (garlic, ginger, turmeric, onions, and pepper) were blended in water and decanted. Neem leaves were soaked for 48 hours. These extracts were sprayed on the crops to discourage the infestation of mostly insect pests.

Measurements

For leaf yield in kg/ha, the leaves of the plants were harvested on a plot basis. A weighing balance was used to weigh the fresh weights of the leaves on a plot basis and leaf yield/plot was calculated from 3m x 2m ($6m^2$). Intercrop productivity and efficiency of the mixtures were assessed using the land-equivalent ratio (LER), land equivalent coefficient (LEC), benefit-cost ratio (BCR), rate of return (ROR) and gross ratio (GR). LER determines the total land productivity or agronomic advantage of the various crop combinations, determined as described by Willey and Rao (1980). Values of LER >1.00 indicates the advantage of intercrop components over their sole crops. The LEC is used to determine the biological efficiency of the cropping system in terms of intercrop compatibility of component crops because it effectively measures intercrop interaction regardless of the number of crop components, and the minimum value expected of two-crop combinations is 0.25 (Adetiloye *et al*., 1983). The higher the value of LEC >0.25, the more compatible the component crops are. The budgetary technique was used to estimate the total costs as well as total revenue accrued to each enterprise, gross margin, farm net profit and profitability of the enterprise within the specific production period. The gross margin is calculated as follows:

$$GM = GR - TVC.$$

Where GM = gross margin; GR = gross revenue; and TVC = total variable cost.
TVC = TOC+TLC Where TOC = total operating cost; and TLC = total labour cost.
The total cost of production (TC) is defined as:

$$TC = TVC+TFC = TOC+TLC+TFC.$$

Where TFC = total fixed cost; and TVC, TOC and TLC have been previously defined.

The BCR, ROR and GR used as a measure of profitability were calculated thus:

BCR = TR/TC

ROR = NR/TC

GR = TC/TR.

Where TR = total revenue; NR = net revenue and TC have been previously defined. As a rule of thumb, projects with BCR greater than one, equal to one or less than one indicate profit, break-even or loss respectively. The ROR is the gain or loss of an investment over a certain period of time which is expressed in percentages (%) (i.e. profit/ N invested). The higher the percentage the more the amount gained in the enterprise. A less than one GR is preferred for any farm business. The lesser the GR the more profitable the business is.

Data analysis

All data collected were subjected to analysis of variance to test the effects of intercropping for the two experiments using the SPSS package and where effects were statistically significant ($P < 0.05$, F-test), treatment means were separated using the Duncan Multiple Range Test.

Results and Discussion

Production cost of irrigated and rain-fed amaranth-jute mallow cropping systems

In Table 1, the total cost of fixed assets and variable inputs for each production enterprise under irrigation and rain-fed is presented. Irrigated cropping systems had higher total variable costs than rain-fed systems. This is due largely to the proportion of the variable costs incurred in the irrigation production system and could be much attributed to the labour input which is identified as the single most costly input in operating an irrigated dry season farm, a situation which is inevitable when all farm operations were carried out through manual labour.

Gross returns of irrigated and rain-fed amaranth-jute mallow cropping systems

Irrigated amaranth-jute mallow cropping systems had higher gross returns when compared to the corresponding rain-fed amaranth-jute mallow cropping systems (Table 2). Despite the higher total variable costs of the irrigation systems these returns have compensated for the higher cost of production. This situation can be attributed to the higher average market price experienced during the dry season owing to the less competitive market situation during this period. In the earlier reports Ayoola (2014), Oladimeji and Abdulsalam (2014) and Umar (2016) concluded that productions under irrigation conditions yielded greater revenue than operational and overhead expenses in comparison with that of rain-fed conditions.

Intercrop productivity and efficiency

The Biological efficiency of the cropping systems was evaluated using LER and LEC, and the economic efficiency of the systems was determined with BCR, ROR and GR. Intercropping significantly ($P < 0.05$) influenced all parameters except LEC. Sole amaranth (rain-fed) produced the highest ($P < 0.05$) amaranth leaf yield of all treatments (Table 3). Irrigated jute mallow intercrop produced the highest ($P < 0.05$) jute mallow leaf yield of all treatments (Table 3). The two intercrop production systems resulted in higher LER (>1.00) than sole crops, but they are comparable to one another. This implies that both intercrop systems demonstrated crop compatibility. The LEC values of 0.77 and 0.8, which were higher than the 0.25 expected from two-crop combinations also show the same compatibility characteristics of amaranth and jute mallow. However, the values of LEC for both crop production conditions were not significantly ($P < 0.05$) different. These two scenarios observed from LER and LEC indicate that the rain-fed intercrop systems and the irrigated intercrop systems are both the same in terms of biological efficiency. This informs that when irrigation systems are properly executed and/or managed, the yield would be potentially comparable to rain-fed systems even though deficiencies may be feared in terms of inadequate water supply.

The costs and returns analysis for each enterprise in $N.ha^{-1}$ under irrigation and rain-fed vegetable cropping systems is shown in Table 4. The gross margin, benefit-cost ratio, rate of returns and gross ratios were calculated for each vegetable enterprise and expressed in $N.ha^{-1}$. Irrigated intercrop production had the highest gross margin (Table 3). This means that irrigated intercropping system was the most profitable vegetable production. The BCR greater than one, equal to one or less than one indicates profit, break-even or loss respectively. In Table IV, irrigated intercrop, rain-fed intercrop and sole amaranth had BCR greater than one; this shows the enterprises were profitable. Conversely, the BCR of other enterprises computed as negative BCR, indicate a loss. Furthermore, there was a significant ($P < 0.05$) difference among the BCR of these vegetable production cropping systems (Table 4). Intercrop production under irrigation had the highest ($P < 0.05$) BCR indicating it to be the most profitable vegetable production enterprise. Results of the ROR analysis revealed that irrigated intercropping system was the highest with a ROR of 0.55 which implies that for every N1.00 invested in this production, the enterprise yields N55.00 as profit. The ROR of 0.25 calculated for the rain-fed intercropping system also means that for every **N**1.00 invested in this production, N25.00 was gained. This also applies to the sole amaranth production under irrigation, with the ROR of 0.15, meaning that for every N1.00 invested, the farmer gains N15.00. However, the ROR for other production systems which were negative implies that for every N1.00 invested, N2.00, N50.00 and N69.00 were lost in rain-fed sole amaranth, irrigated sole jute mallow as well as irrigated sole jute mallow respectively. The ROR of irrigated intercrop was significantly ($P < 0.05$) higher than those for other cropping systems (Table 3). This indicated that the gain realized from this system cannot be compared with gains from other systems. GR of both irrigated and rain-fed intercrop as well as sole amaranth vegetable production under irrigation were less than unity (Table 4). These ratios indicate profitability since they were all less than unity. However, irrigated intercrop production system is the least ($P < 0.05$) among these GR (Table IV). This indicates intercrop production has the highest profitability compared with other vegetable productions.

Conclusions

The intercropping of amaranth-jute mallow is a compatible crop combination, with both irrigated and rain-fed intercrop productions profitable. Irrigated amaranth-jute mallow intercrop is the most profitable. Vegetable farmers should therefore practise more amaranth/jute mallow intercrop under irrigation as it gives higher yield and higher profit than rain-fed production. To ensure food and income security, the irrigated intercropping of amaranth/jute mallow is, therefore, recommended for farmers for vegetable production in the humid tropics.

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Table 1: Production cost of irrigated and rain-fed amaranth and jute mallow cropping systems

Fixed Costs	Amaranth/Jute (₦.ha^{-1})		Sole Amaranth (₦.ha^{-1})		Sole Jute (₦.ha^{-1})	
	Irrigated	**Rain-Fed**	**Irrigated**	**Rain-Fed**	**Irrigated**	**Rain-Fed**
Land Purchase	120,000	120,000	120,000	120,000	120,000	120,000
Bowl	500	500	500	500	500	500
Pan	1,000	1,000	1,000	1,000	1,000	1,000
Weighing Scale (20kg)	6,000	6,000	6,000	6,000	6,000	6,000
Hoe	1,500	1,500	1,500	1,500	1,500	1,500
Overhead Tank 500 Ltr	18,000	-	18,000	-	18,000	-
Pumping machine 0.75hp	25,000	-	25,000	-	25,000	-
Well	140,000	-	140,000	-	1400,00	-
Generator 2.5kva	80,000	-	80,000	-	80,000	-
Total Fixed Cost	**392,000**	**129,000**	**392,000**	**129,000**	**392,000**	**129,000**
Variable Items						
Land clearing, seed bed preparation, manuring and planting	224,000	224,000	224,000	224,000	224,000	224,000
Watering, Weeding and Spraying	520,000	320,000	514,000	314,000	514,000	314,000
Cost of bio-pesticide	67,000	67,000	67,000	67,000	67,000	67,000
Cost of Fuel (petrol)	81,080	-	81,080	-	81,080	-
Cost of Manure with Transportation	26,000	26,000	26,000	26,000	26,000	26,000
Cost of Seeds	24,000	24,000	24,000	24,000	24,000	24,000
Cost of Harvesting	90,000	90,000	84,000	84,000	84,000	84,000
Total Variable Cost	**1,032,080**	**751,000**	**1,020,080**	**745,000**	**1,020,080**	**745,000**

Table 2: Gross returns of irrigated and rain-fed amaranth and jute mallow cropping systems

Cropping systems	Output (kg. ha^{-1})		Average market price (₦.kg^{-1})		Total Revenue(₦)	
	Irrigated	**Rain-Fed**	**Irrigated**	**Rain-Fed**	**Irrigated**	**Rain-Fed**
Jute (intercrop)	2,800	2,300	200	100	560,0000	230,000
Amaranth (intercrop)	5,200	7,100	200	100	1,040,000	710,000
Sub Total	8,000	9,400	200	100	1,600,000	940,000
Jute (sole)	2,600	2,300	200	100	520,000	230,000
Amaranth (sole)	6,000	7,300	200	100	1,200,000	730,000

Table 3: Land-equivalent ratio (LER), land equivalent coefficient (LEC), benefit-cost ratio (BCR), rate of return (ROR) and gross ratio (GR) of amaranth and jute mallow intercropping under irrigation and rain-fed conditions

Cropping system	Amaranth LY (t/ha)	Jute Mallow LY (t/ha)	Land-equivalent ratio (LER)	Land equivalent coefficient (LEC)	Benefit-cost ratio (BCR)	Rate of return (ROR)	Gross ratio (GR)
Irrigated Sole Amaranth	6.1 c	-	1.00 b	-	1.18 c	0.18 c	0.85 d
Rain-fed Sole Amaranth	7.3 a	-	1.00 b	-	(0.98) f	(0.02) d	(1.02) c
Irrigated Sole Jute Mallow	-	2.6 ab	1.00 b	-	(0.49) e	(0.50) e	(2.01) a
Rain-fed Sole Jute Mallow	-	2.3 b	1.00 b	-	(0.31) d	(0.69) f	(1.41) b
Irrigated Amaranth-Jute Mallow	5.3 d	2.8 a	1.89 a	0.77	1.55 a	0.55 a	0.65 f
Rain-fed Amaranth-Jute Mallow	7.1 b	2.3 b	1.92 a	0.80	1.25 b	0.25 b	0.80 e
S.E±	0.2	0.3	0.2	0.1	0.01	0.1	0.3
F test	**	**	**	ns	**	**	**

LY = Leaf Yield. (-) = not applicable. Values in brackets indicate negativity. n.s.= not significant (P < 0.05). ** = significant at 5% level of probability

Table 4: Cost and returns of irrigated and rain-fed amaranth and jute mallow cropping systems

Items (₦/ha)	Amaranth-Corchorus (₦.ha^{-1})		Amaranth sole (₦.ha^{-1})		Jute sole (₦.ha^{-1})	
	Irrigated	**Rain-fed**	**Irrigated**	**Rain-fed**	**Irrigated**	**Rain-fed**
Gross returns	1,600,000	940,000	1,200,000	730,000	520,000	230,000
Total variable cost	1,032,080	751,000	1,020,080	745,000	1,020,080	745,000
Gross margin	567,920	189,000	179,920	(15,000)	(500,080)	(515,000)
Benefit-cost ratio (BCR)	1.55	1.25	1.18	(0.98)	(0.49)	(0.31)
Rate of return (ROR)	0.55	0.25	0.18	(0.02)	(0.50)	(0.69)
Gross ratio (GR)	0.65	0.80	0.85	(1.02)	(2.01)	(1.41)

Values in parenthesis indicate negativity