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Economic evaluation of cowpea production under different spraying regimes in three different southern agro-ecologies of Nigeria

Julius Oluseyi Olasoji*
Institute of Agricultural Research and Training, Obafemi Awolowo University, Moor Plantation, Ibadan, Nigeria. E-mail: juliusolasoji@ymail.com / joolasoji@iart.gov.ng

Olugbenga Aderemi Egbetokun
Institute of Agricultural Research and Training, Obafemi Awolowo University, Moor Plantation, Ibadan, Nigeria. E-mail: oaegbetokun@gmail.com

Matthew Akinyemi Kolawole
Institute of Agricultural Research and Training, Obafemi Awolowo University, Moor Plantation, Ibadan, Nigeria. E-mail: kolawolematto@gmail.com

Jelil Olaide Saka
Institute of Agricultural Research and Training, Obafemi Awolowo University, Moor Plantation, Ibadan, Nigeria. E-mail: saka_sakang@yahoo.com

* Corresponding author

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Abstract

This study was carried out to evaluate different spraying regimes for the production of two cowpea varieties (Ife Brown and IT2246) in the humid southwest agro-ecologies of Nigeria in order to recommend optimum spraying regimes for cowpea production in the zone. Agronomic data were collected from trials conducted in 2020 and 2021 in outstations representative of the broad agro-ecologies of this region of Nigeria. The data were subjected to partial budget and marginal rate-of-return analyses. The results show varying potential of the cowpea varieties and spraying regimes across locations. Ife Brown cowpea can be produced profitably under forest agro-ecologies (Ibadan) with three spraying regimes at a moderate application rate of 200 litres per hectare. In the derived savannah, the Ife Brown and IT2246 varieties were profitable with four spraying regimes at a moderate application rate of 200 litres per hectare, while planting Ife Brown with two regimes of spraying at moderate pesticide application rate of 200 litres per hectare was profitable for the southern Guinea savannah agro-ecologies.

Key words: cowpea, spraying, insects, marginal return, profitability

1. Introduction

Cowpea (*Vigna unguiculata* Walp) is one of the most economically and nutritionally important indigenous African grain legumes. It is an important crop in West Africa that provides food for people, fodder for animals and income to millions of smallholder farmers (Langyintuo *et al*. 2003; Manda *et al*. 2019). Its grains and fresh leaves are important sources of protein, minerals and vitamins and thus help to address malnutrition among rural families in West Africa (Nielsen *et al*. 1997; Maynard 2010; Santos *et al*. 2012). Cowpea is often referred to as meat for the poor (Boukar *et al*. 2013; Oyewale & Bamaiyi 2013). In addition to grains, several cowpea varieties are cultivated as fodder for livestock (Kristjanson *et al*. 2005). Smallholder farmers also prefer the crop because it is adapted to the poor soils of the dry savannah and can fix atmospheric nitrogen, contributing to soil improvement (Do Rego *et al*. 2015).

Cowpeas are highly susceptible to pests such as *Callosobruchus maculatus* (Fabricius) (Coleoptera: Bruchidae) (Çıkman & Yücel 2002), diseases (Cercospora leaf spot caused by *Pseudocercospora cruenta* (Sacc), brown blotch caused by *Colletotrichum capsici*, anthracnose disease caused by *Collectotrichum destructivum*) and drought conditions (Jackai & Adalla 1997; Inaizumi *et al*. 1999). Pests represent the most important biotic constraints to cowpea production, especially under changing weather patterns. Pests compromise plant growth and reduce yields by inflicting substantial damage to the crop if no protective measures are taken (Dugje *et al*. 2009; N'Gbesso *et al*. 2013). Cowpea seed yield is low, at less than one tonne per hectare, most especially under humid agro-ecologies found in the rain forest, southern Guinea and derived savannah agro-ecologies of southwest Nigeria (Adewuyi & Okunmadewa 2005). Yield loss under these agro-ecologies ranges between 46% and 80% due to severe insect pests, disease and weed infestations and non-availability of tolerant or resistant cowpea varieties adaptable to the ecology (Algahli 2006). It is often considered impossible to cultivate cowpea economically in the zone without the application of pesticides (Algahli 2006). Consequently, cowpea production involves a high rate of pesticide use, which is already transiting to use at the farm level. The indiscriminate application of pesticides inhibits plant-microbe interactions in the soil and decreases the symbiotic interaction between rhizobium and leguminous crops, which in turn affects nitrogen fixation, nodulation and the yield of crops, leading to soil degradation (Ibrahim & Kwaghe 2007).

The potential hazards associated with the accumulation of pesticide residues in cowpea grains is cause for concern. Previous studies (Otitoju & Lewis 2021; Amare *et al*. 2022) have reported the presence of residues of pesticides in the classes of organochlorines, organophosphates and pyrethroids in bean samples in Nigeria and Burkina Faso, at levels capable of causing non-carcinogenic health risks for consumers. The high rate of chemical use in cowpea production does not suggest the ready affordability of the chemicals among cowpea farmers. It is rather a pointer to its necessity in cowpea production. Insecticide use in cowpea production is to increase cowpea yield because almost all the stages of the cowpea production cycle are affected by one pest or the other (Ayinde *et al*. 2022). The intensity of use of synthetic pesticides in cowpea production not only accounts for a substantial proportion of the production cost (Mohammed & Mohammed 2014; Abdullah & Tsowa 2014), but also influences technology adoption, yield and the profitability of cowpea production (Omonona *et al*, 2010; Zalkuwi *et al*. 2012; Oseni *et al*. 2015). The appropriate use of pesticides is not only considered as having the potential to achieve environmentally friendly production, bit its use also ensures a reduction in the yield-limiting effects of insect pests on cowpea production for greater yield and income among farmers (Omolehin *et al*. 2011). However, before changing from one production method to another, the farmer considers many factors, such as agro-ecological requirements, availability of the required additional production resources (labour, skill, farmland, equipment, etc.), and the additional income resulting from the change (Olasoji & Egbetokun 2017). The farmer also considers the compatibility of the new technology with sociocultural circumstances and resource endowment.

The investible fund is a major resource in farm production and its availability or otherwise has been a critical factor in the dynamics of smallholder production systems. Capital is not only scarce, but also has competing ends (Tijani & Oshotimehin 2007). Hence, farmers, under the rational decision-making economic assumption not only weigh their options based on the expected net benefit, but also adopt technology preferences on the basis of limiting resources. Farmers want to know the implications of the proposed technological change on their costs and income. They therefore consider the increase in revenue earned by changing to the new technology against the associated increase in cost as a result of the decision in that regard (Olasoji & Egbetokun 2017). Amid the increasing cost of pesticides, and the associated environmental impact of overuse, this study evaluated different pesticide-spraying regimes in producing two improved varieties of cowpea to determine economically viable options for improved cowpea production in southwest Nigeria. The study explored the attributes of the cowpea varieties with regard to their adaptability to different agro-ecologies and their potential for optimal yield under minimal pesticide application as a way of addressing the environmental and health risks posed in cowpea production.

2. Materials and methods

The trials were conducted during the cowpea planting seasons of years 2020 and 2021 at Ibadan, Ilora and Ballah outstations of the Institute of Agricultural Research and Training, Moor Plantation, Ibadan. The experimental layout was a split-split plot in a randomised complete block design, with 10 treatments sprayed with Lambda-Cyhalotrin 2.5 EC (Table 1). The same insecticide was used and the cost was the same across all locations. Two cowpea varieties (Ife Brown and IT2246), which are highly susceptible to insect pests, were used for the trials. The cowpea was planted using a spacing of 50 cm x 30 cm at two seeds per hill, and all agronomic practices for good cowpea yield were carried out. Data were collected on the quantity and cost of chemicals used under each treatment, man-days of labour used under each of the treatments, and the associated cowpea grain yield. All the data for the two years were pooled for analysis using the general linear model (GLM) procedure of the Statistical Analysis System (SAS) 9.2 (SAS Institute 2002) to compute mean squares for each character. Mean separation was done using the Duncan multiple range test (DMRT). The cost of the pesticides was estimated at the current market price. The value of cowpea yield was also estimated at the current market price in the different locations (ignoring all other costs).

Table 1: Spraying regime and different concentrations used during the experiment

Treatment	Spraying regime (SR)	Concentration
01	Two spraying regimes (at flowering and podding)	200 ml/ha
02	Two spraying regimes (at flowering and podding)	400 ml/ha
03	Two spraying regimes (at flowering and podding)	600 ml/ha
04	Three spraying regimes (at foliage, flowering and podding)	200 ml/ha
05	Three spraying regimes (at foliage, flowering and podding)	400 ml/ha
06	Three spraying regimes (at foliage, flowering and podding)	600 ml/ha
07	Four spraying regimes (at foliage, flowering and two poddings)	200 ml/ha
08	Four spraying regimes (at foliage, flowering and two poddings)	400 ml/ha
09	Four spraying regimes (at foliage, flowering and two poddings)	600 ml/ha
10	No spray – non-pesticide method used	

The economic potential of the treatments was determined through partial budget and marginal rate of return (MRR) analyses targeted at deriving the net benefit across treatments and identifying economically viable options for adoption by farmers, following Olasoji and Egbetokun (2017) and

Saka *et al*. (2007). Partial budget and MRR were employed to identify changes in costs and returns on investment for the different spraying regimes in order to recommend the most viable spraying regimes. In producer theory, the background view is that farmers are rational in decision-making and that profit maximisation is the ultimate goal of production. Similarly, resources invested by farmers are considered scarce, but have alternative uses of varying potentials. Within the framework of technology generation and transfer, a technology is considered adoptable if relative to it, and ceteris paribus, there is no other option that gives a greater net benefit at a lower cost. In the evaluation of the treatments, the partial budget analysis returns the net benefit accruable to each of the treatments as a preliminary indication of the economic potential of the treatment. The net benefit is of the form

$$NB_t = MV_t - CV_i\,, \quad (t = 1, 2, 3, ..,,.n), \tag{1}$$

given that

$$MV_t = Y_t^* P_c \text{ and} \tag{2}$$

$$CV_t = N_t(Q_t P_i + L_t W_l)\,, \tag{3}$$

where

NB_t = net benefit estimate under treatment t;
MV_t = monetary value of cowpea yield under treatment t;
Y* = adjusted cowpea yield under treatment t in kilogrammes (kg). This is the experimental yield scaled down by a given proportion, usually 90% or 0.9, to approximate the yield that farmers can obtain on their farms;
P_c = farm gate prices of cowpea grain per kg;
CV_t = costs that vary under treatment t;
N_t = number of spraying regimes under treatment t;
Q_t = quantity of pesticide used (litre) per hectare per spraying regime under treatment t;
P_i = price per litre of pesticide used;
L_t = person days of labour used for pesticide application per hectare per spraying regime under treatment t;
W_l = wage per person day of labour for pesticide application; and
t = treatment (t = 1, 2, 3, ……., n).

The marginal rate of return (MRR) was determined as a measure of the economic benefit derivable by farmers from their adoption decision of one treatment over the other. The index measured the ratio of additional monetary gain accruable to farmers for their decision to the additional cost incurred as a result of the potential adoption of a treatment, given by:

$$MRR = \frac{NB_t - NB_{t-1}}{CV_t - CV_{t-1}}. \tag{4}$$

In appraising treatments for the marginal rate of return, a dominance analysis was carried out to identify dominant treatments for exclusion from the marginal analysis in line with the rationality concept. A treatment is dominant if, relative to it, there is another treatment that returns a greater net benefit at lower cost. Such treatments therefore were excluded from the marginal rate of return analysis. Treatments that were *non-dominant* were subsequently compared with the next at higher cost to determine the MRR. Following Dillon and Hardaker (1993), farmers will be favourably disposed to adopt a treatment when MRR is greater than 40%. The parameters in the MRR equation were as defined earlier.

3. Results and discussion

The results of the partial budget analysis in Ibadan (Table 2) show that the net benefit was highest for Ife Brown planted with four spraying regimes at 400 litres per hectare (₦643 762), while the least was for IT2246 planted with two spraying regimes at 600 litres per hectare per spraying regime, with a negative net benefit of -₦5 896.00. There are varying degrees of net benefits accruable to technology changes, as documented by Standards Australia (2014). However, the results of the dominance analysis (Table 3) show that, of the 20 treatments, only three were ‘non-dominant’ (Ife Brown no spraying, Ife Brown 3 x 200 L, and Ife Brown 4 x 400 L), and therefore these were selected for the marginal rate of return (MRR) analysis. This is in line with the work of Alimi and Manyong (2000) on partial budget analysis for on-farm research. The results of the MRR (Table 4) show, however, that the cultivation of Ife Brown under three regimes of spraying and an application rate of 200 litres per hectare (Ife Brown 3 x 200 L) was the most economically viable treatment, with an MRR of 6.75 (675%), which implies that farmers have the opportunity to obtain an additional net benefit of ₦6.75 for every ₦1 incurred in changing from planting Ife Brown cowpea with no spraying (Ife Brown with no spraying) to planting Ife Brown cowpea with three regimes of spraying at an application rate of 200 litres/ha. However, increasing pesticide application to four spraying regimes at 400 litres per hectare (Ife Brown 4 x 400 L), which is another non-dominant treatment, did not give a commensurate return to the additional cost incurable, as the MRR was 0.28, which was below the 0.4 optimal threshold. The fact that the treatments featuring other cowpea varieties (IT2246) did not feature (i.e. dominant) suggests that the cultivation of Ife Brown was the most suitable for cultivation in Ibadan, or in agro-ecologies similar to the forest or transition forest found in Ibadan.

In Ilora, the highest net benefit (₦306 314.40) was recorded for Ife Brown cultivated with four spraying regimes at 200 litres per hectare (Ife Brown 4 x 200 L), followed by the net benefit of ₦306 314.40 obtained for IT2246 cultivated at four spraying regimes at a rate of 200 litres per hectare (IT2246 4 x 200 L) (Table 5). In addition to these two treatments, the cultivation of Ife Brown with no spraying, IT2246 with two regimes of spraying at 200 litres/ha (IT2246 2 x 200 L), and IT2246 with three spraying regimes at 200 litres/ha (IT2246 3 x 200 L) were the non-dominant treatments (Table 6), which were subsequently considered in the MRR analysis. However, the results in Table 7 show that the cultivation of IT2246 with three spraying regimes at 200 litres/ha (IT2246 3 x 200 L), Ife Brown with four spraying regimes at 200 litres/ha (Ife Brown 4 x 200 L), and IT2246 with four spraying regimes at 200 litres/ha (IT2246 4 x 200 L) were the most economically viable options in Ilora. The results show that farmers can get a higher increase in net return by cultivating either Ife Brown or IT2246 with four spraying regimes at 200 litres/ha.

The results of the trial in Ballah (Table 8) show that the highest net benefit of ₦594 064.80 was recorded for the cultivation of the IT2246 variety with three spraying regimes at 200 litres/ha (IT2246 3 x 200 L), while the least net benefit of ₦9 280.80 was for the cultivation of ITT2246 with no spraying. There were three non-dominant treatments (Table 9): the cultivation of the Ife Brown variety with no spraying, Ife Brown with two spraying regimes at 200 litres/ha (Ife Brown 2 x 200 L), and the cultivation of IT2246 with three spraying regimes at 200 litres/ha (IT2246 3 x 200 L). However, the MRR analysis (Table 10) shows that the cultivation of Ife Brown with two spraying regimes of 200 litres/ha (Ife Brown 2 x 200 L) is the only economically viable treatment, with an MRR of 0.81, which is above the optimal threshold of 0.4.

Table 2: Partial budget analysis of cowpea spraying regimes and application rate at Ibadan Station

No. of sprayings		**2.00**	**2.00**	**2.00**	**3.00**	**3.00**	**3.00**	**4.00**	**4.00**	**4.00**	**0.00**
Concentration		200 ml/ha	400 ml/ha	600 ml/ha	200 ml/ha	400 ml/ha	600 ml/ha	200 ml/ha	400 ml/ha	600 ml/ha	
Yield (kg/ha)	Ife Brown	128.49	136.68	132.44	988.34	967.67	963.67	944.67	1,099.67	1,066.67	68.00
	IT2246	97.30	113.40	118.20	577.20	577.20	566.25	554.78	599.33	578.67	20.78
Adjusted yield	Ife Brown	115.64	123.01	119.20	889.51	870.90	867.30	850.20	989.70	960.00	61.20
	IT2246	87.57	102.06	106.38	519.48	519.48	509.63	499.30	539.40	520.80	18.70
Benefit (N)	**Ife Brown**	**92 512.80**	**98 409.60**	**95 356.80**	**711 604.80**	**696 722.40**	**693 842.40**	**680 162.40**	**791 762.40**	**768 002.40**	**48 960.00**
	IT2246	**70 056.00**	**81 648.00**	**85 104.00**	**415 584.00**	**415 584.00**	**407 700.00**	**399 441.60**	**431 517.60**	**416 642.40**	**14 961.60**
Cost of pesticide (N)	Ife Brown	17 000.00	34 000.00	51 000.00	25 500.00	51 000.00	76 500.00	34 000.00	68 000.00	102 000.00	0.00
	IT2246	17 000.00	34 000.00	51 000.00	25 500.00	51 000.00	76 500.00	34 000.00	68 000.00	102 000.00	0.00
Cost of labour for pesticide application	Ife Brown	40 000.00	40 000.00	40 000.00	60 000.00	60 000.00	60 000.00	80 000.00	80 000.00	80 000.00	0.00
	IT2246	40 000.00	40 000.00	40 000.00	60 000.00	60 000.00	60 000.00	80 000.00	80 000.00	80 000.00	0.00
Total costs that vary	**Ife Brown**	**57 000.00**	**74 000.00**	**91 000.00**	**85 500.00**	**111 000.00**	**136 500.00**	**114 000.00**	**148 000.00**	**182 000.00**	**0.00**
	IT2246	**57 000.00**	**74 000.00**	**91 000.00**	**85 500.00**	**111 000.00**	**136 500.00**	**114 000.00**	**148 000.00**	**182 000.00**	**0.00**
Net benefit	**Ife Brown**	**35 512.80**	**24 409.60**	**4 356.80**	**626 104.80**	**585 722.40**	**557 342.40**	**566 162.40**	**643 762.40**	**586 002.40**	**48 960.00**
	IT2246	**13 056.00**	**7 648.00**	**-5 896.00**	**330 084.00**	**304 584.00**	**271 200.00**	**285 441.60**	**283 517.60**	**234 642.40**	**14 961.60**

Note: Exchange rate calculated at 250 Naira to $1

Table 3: Dominance analysis of cowpea spraying regimes and application rate at Ibadan Station

Treatments	Costs that vary	Net benefit	Dominance
Ife Brown no spraying	0.00	48 960.00	Non-dominant
IT2246 no spraying	0.00	14 961.60	Dominant
Ife Brown 2 x 200 L	57 000.00	35 512.80	Dominant
IT2246 2 x 200 L	57 000.00	13 056.00	Dominant
Ife Brown 2 x 400 L	74 000.00	24 409.60	Dominant
IT2246 2 x 400 L	74 000.00	7 648.00	Dominant
Ife Brown 3 x 200 L	85 500.00	626 104.80	Non-dominant
IT2246 3 x 200 L	85 500.00	330 084.00	Dominant
Ife Brown 2 x 600 L	91 000.00	4 356.80	Dominant
IT2246 2 x 600 L	91 000.00	-5 896.00	Dominant
Ife Brown 3 x 400 L	111 000.00	585 722.40	Dominant
IT2246 3 x 400 L	111 000.00	304 584.00	Dominant
Ife Brown 4 x 200 L	114 000.00	566 162.40	Dominant
IT2246 4 x 200 L	114 000.00	285 441.60	Dominant
Ife Brown 3 x 600 L	136 500.00	557 342.40	Dominant
IT2246 3 x 600 L	136 500.00	271 200.00	Dominant
Ife Brown 4 x 400 L	148 000.00	643 762.40	Non-dominant
IT2246 4 x 400 L	148 000.00	283 517.60	Dominant
Ife Brown 4 x 600 L	182 000.00	586 002.40	Dominant
IT2246 4 x 600 L	182 000.00	234 642.40	Dominant

Note: Exchange rate calculated at 250 Naira to $1

Table 4: Marginal rate of return analysis of non-dominant trial treatments for Ibadan Station

Treatments	Costs that vary	Net benefit	Dominance	Incremental cost	Incremental net benefit	MRR
Ife Brown no spraying	0.00	48 960.00	Non-dominant			
Ife Brown 3 x 200 L	85 500.00	626 104.80	Non-dominant	85 500.00	577 144.80	6.75***
Ife Brown 4 x 400 L	148 000.00	643 762.40	Non-dominant	62 500.00	17 657.60	0.28

Notes: *** Economically viable; exchange rate calculated at 250 Naira to $1

The economic analysis has shown variation in the potential of the varieties under different spraying regimes and chemical dosages across the locations. While the cultivation of the Ife Brown cowpea variety under three spraying regimes at 200 litres/ha (Ife Brown 3 x 200 L) was rated economically viable in Ibadan, three treatments, comprising the cultivation of IT2246 under three spraying regimes at 200 litres/ha (IT2246 3 x 200 L), Ife Brown under four spraying regimes at 200 litres/ha (Ife Brown 4 x 200 L) and IT2246 under four spraying regimes at 200 litres/ha (IT2246 4 x 200 L), were considered profitable for Ilora, with IT2246 4 x 200 L having the highest potential when farmers are not limited by funding. Ballah has the cultivation of Ife Brown under two regimes of spraying at 200 litres/ha of pesticide (Ife Brown 2 x 200 L) as the only economically viable options.

These results have shown the agro-ecological influence on the performance of the varieties under the different spraying regimes. The trend points to a gradual reduction in spraying regimes, moving from three regimes at 200 litres/ha for Ife Brown in Ibadan (forest zone), through three spraying regimes at 200 litres/ha and four spraying regimes at 200 litres/ha for IT2246, and four spraying regimes at 200 litres/ha for Ife Brown cowpea varieties in Ilora (derived savannah), to two spraying regimes at 200 litres/ha for Ife Brown in Ballah (southern Guinea savannah).

Table 5: Partial budget analysis of cowpea spraying regimes and application rate at Ilora outstation

No. of sprayings		**2.00**	**2.00**	**2.00**	**3.00**	**3.00**	**3.00**	**4.00**	**4.00**	**4.00**	**0.00**
Concentration	**Concentration**	200 ml/ha	400 ml/ha	600 ml/ha	200 ml/ha	400 ml/ha	600 ml/ha	200 ml/ha	400 ml/ha	600 ml/ha	
Yield (kg/ha)	Ife Brown	12.67	136.67	143.33	477.34	489.67	522.33	583.77	563.89	577.87	34.9
	IT2246	132.67	146.67	143.33	487.34	488.67	512.33	583.77	543.89	569.87	15.9
Adjusted yield (kg/ha)	Ife Brown	11.403	123.003	128.997	429.606	440.703	470.097	525.393	507.501	520.083	31.41
	IT2246	119.403	132.003	128.997	438.606	439.803	461.097	525.393	489.501	512.883	14.31
Benefit (N)	Ife Brown	9 122.4	98 402.4	103 197.6	343 684.8	352 562.4	376 077.6	420 314.4	406 000.8	416 066.4	25 128
	IT2246	95 522.4	105 602.4	103 197.6	350 884.8	351 842.4	368 877.6	420 314.4	391 600.8	410 306.4	11 448
Cost of pesticide (N)	Ife Brown	17 000	34 000	51 000	25 500	51 000	76 500	34 000	68 000	102 000	0
	IT2246	17 000	34 000	51 000	25 500	51 000	76 500	34 000	68 000	102 000	0
Cost of labour for pesticide application (N)	Ife Brown	40 000	40 000	40 000	60 000	60 000	60 000	80 000	80 000	80 000	0
	IT2246	40 000	40 000	40 000	60 000	60 000	60 000	80 000	80 000	80 000	0
Total costs that vary	**Ife Brown**	**57 000**	**74 000**	**91 000**	**85 500**	**111 000**	**136 500**	**114 000**	**148 000**	**182 000**	**0**
	IT2246	**57 000**	**74 000**	**91 000**	**85 500**	**111 000**	**136 500**	**114 000**	**148 000**	**182 000**	**0**
Net benefit (N)	**Ife Brown**	**-47 877.60**	**24 402.40**	**12 197.60**	**258 184.80**	**241 562.40**	**239 577.60**	**306 314.40**	**258 000.80**	**234 066.40**	**25 128.00**
	IT2246	**38 522.40**	**31 602.40**	**12 197.60**	**265 384.80**	**240 842.40**	**232 377.60**	**306 314.40**	**243 600.80**	**228 306.40**	**11 448.00**

Note: Exchange rate calculated at 250 Naira to $1

Table 6: Dominance analysis of cowpea spraying regimes and application rate at Ilora outstation

Treatment	Costs that vary	Net benefit	Dominance
Ife Brown no spraying	0.00	25 128.00	Non-dominant
IT2246 no spraying	0.00	11 448.00	Dominant
Ife Brown 2 x 200 L	57 000.00	-47 877.60	Dominant
IT2246 2 x 200 L	57 000.00	38 522.40	Non-dominant
Ife Brown 2 x 400 L	74 000.00	24 402.40	Dominant
IT2246 2 x 400 L	74 000.00	31 602.40	Dominant
Ife Brown 3 x 200 L	85 500.00	258 184.80	Dominant
IT2246 3 x 200 L	85 500.00	265 384.80	Non-dominant
Ife Brown 2 x 600 L	91 000.00	12 197.60	Dominant
IT2246 2 x 600 L	91 000.00	12 197.60	Dominant
Ife Brown 3 x 400 L	111 000.00	241 562.40	Dominant
IT2246 3 x 400 L	111 000.00	240 842.40	Dominant
Ife Brown 4 x 200 L	114 000.00	306 314.40	Non-dominant
IT2246 4 x 200 L	114 000.00	306 314.40	Non-dominant
Ife Brown 3 x 600 L	136 500.00	239 577.60	Dominant
IT2246 3 x 600 L	136 500.00	232 377.60	Dominant
Ife Brown 4 x 400 L	258 000.80	258 000.80	Dominant
IT2246 4 x 400 L	148 000.00	243 600.80	Dominant
Ife Brown 4 x 600 L	182 000.00	234 066.40	Dominant
IT2246 4 x 600 L	182000	228 306.40	Dominant

Note: Exchange rate calculated at 250 Naira to $1

Table 7: Marginal rate of return analysis of non-dominant treatments at Ilora outstation

Treatment	Costs that vary	Net benefit	Dominance	Incremental cost	Incremental net benefit	MRR
Ife Brown no spraying	0.00	25 128.00	Non-dominant	-	-	-
IT2246 2 x 200 L	57 000.00	38 522.40	Non-dominant	57 000.00	13 394.40	0.23
IT2246 3 x 200 L	85 500.00	265 384.80	Non-dominant	28 500.00	226 862.40	7.96***
Ife Brown 4 x 200 L	114 000.00	306 314.40	Non-dominant	28 500.00	40 929.60	1.44***
IT2246 4 x 200 L	114 000.00	306 314.40	Non-dominant	28 500.00	40 929.60	1.44***

Notes: *** Economically viable; Exchange rate calculated at 250 Naira to $1

Table 8: Partial budget analysis of cowpea spraying regimes and application rate at Ballah outstation

		Treatments									
No. of sprayings		2.00	2.00	2.00	3.00	3.00	3.00	4.00	4.00	4.00	0.00
Concentration (ml/ha)		200	400	600	200	400	600	200	400	600	
Yield (kg/ha)	Ife Brown	232.6	256.67	301.55	768.67	778.33	867.33	897.15	889.96	845.33	56.09
	IT2246	143.76	156.55	134.89	943.84	933.45	978.45	967.56	978.88	957	12.89
Adjusted yield (kg/ha)	Ife Brown	209.34	231.003	271.395	691.803	700.497	780.597	807.435	800.964	760.797	50.481
	IT2246	129.384	140.895	121.401	849.456	840.105	880.605	870.804	880.992	861.3	11.601
Benefit (₦)	**Ife Brown**	**167 472**	**184 802.4**	**217 116**	**553 442.4**	**560 397.6**	**624 477.6**	**645 948**	**640 771.2**	**608 637.6**	**40 384.8**
	IT2246	**103 507.2**	**112 716**	**97 120.8**	**679 564.8**	**672 084**	**704 484**	**696 643.2**	**704 793.6**	**689 040**	**9 280.8**
Cost of pesticide (₦)	Ife Brown	17 000	34 000	51 000	25 500	51 000	76 500	34 000	68 000	102 000	0
	IT2246	17 000	34 000	51 000	25 500	51 000	76 500	34 000	68 000	102 000	0
Cost of labour for pesticide application	Ife Brown	40 000	40 000	40 000	60 000	60 000	60 000	80 000	80 000	80 000	0
	IT2246	40 000	40 000	40 000	60 000	60 000	60 000	80 000	80 000	80 000	0
Total costs that vary	**Ife Brown**	**57 000**	**74 000**	**91 000**	**85 500**	**111 000**	**136 500**	**114 000**	**148 000**	**182 000**	**0**
	IT2246	**57 000**	**74 000**	**91 000**	**85 500**	**111 000**	**136 500**	**114 000**	**148 000**	**182 000**	**0**
Net benefit (₦)	Ife Brown	110 472	110 802	126 116	467 942	449 398	487 978	531 948	492 771	426 638	40 385
	IT2246	46 507.20	38 716.00	6 120.80	594 064.80	561 084.00	567 984.00	582 643.20	556 793.60	507 040.00	9 280.80

Note: Exchange rate calculated at 250 Naira to $1

Table 9: Dominance analysis of cowpea spraying regimes and application rate at Ballah outstation

Treatments	Costs that vary	Net benefit	Dominance
Ife Brown no spraying	0	40 385	Non-dominant
IT2246 no spraying	0	9 280.80	Dominant
Ife Brown 2 x 200 L	57 000	110 472	Non-dominant
IT2246 2 x 200 L	57 000	46 507.20	Dominant
Ife Brown 2 x 400 L	74 000	110 802	Non-dominant
IT2246 2 x 400 L	74 000	38 716.00	Dominant
Ife Brown 3 x 200 L	85 500	467 942	Dominant
IT2246 3 x 200 L	85 500	594 064.80	Non-dominant
Ife Brown 2 x 600 L	91 000	126 116	Dominant
IT2246 2 x 600 L	91 000	6 120.80	Dominant
Ife Brown 3 x 400 L	111 000	449 398	Dominant
IT2246 3 x 400 L	111 000	561 084.00	Dominant
Ife Brown 4 x 200 L	114 000	531 948	Dominant
IT2246 4 x 200 L	114 000	582 643.20	Dominant
Ife Brown 3 x 600 L	136 500	487 978	Dominant
IT2246 3 x 600 L	136 500	567 984.00	Dominant
Ife Brown 4 x 400 L	148 000	492 771	Dominant
IT2246 4 x 400 L	148 000	556 793.60	Dominant
Ife Brown 4 x 600 L	182 000	426 638	Dominant
IT2246 4 x 600 L	182 000	507 040.00	Dominant

Note: Exchange rate calculated at 250 Naira to $1

Table 10: Marginal rate of return analysis for Ballah outstation

Treatments	Costs that vary	Net benefit	Dominance	Incremental cost	Incremental net benefit	MRR
Ife Brown no spraying	0	40 385	Non-dominant			
Ife Brown 2 x 200 L	57 000	110 472	Non-dominant	57 000	70 087.2	0.81***
Ife Brown 2 x 400 L	74 000	110 802	Non-dominant	17 000	330.4	0.02
IT2246 3 x 200 L	85 500	594 064.80	Non-dominant	11 500	483 262.4	0.02

Note: Exchange rate calculated at 250 Naira to $1

These results are consistent with those of previous studies (Amatobi 1995; Dzemo *et al*. 2010; Mukendi *et al*. 2019; Mansaray *et al*. 2020; Adigun *et al*. 2022) on the efficacy of two or three spraying regimes for sustainable cowpea production. The efficacy of making use of two to three spraying regimes not only enhances the cost-effectiveness of the pest management options, but also provides for environmental protection and food safety considerations in cowpea production. Even when four spraying regimes were rated as being economically viable for cowpea production in the derived savannah, the dosage of 200 litres/ha was considered moderate as the lowest among the treatments. The findings of Adigun *et al.* (2022) also suggest four spraying regimes in the early season and two spraying regimes in the late season of cowpea production. Also, the featuring of treatments involving Ife Brown cowpea varieties among the variable treatments across the locations also points to the wider adaptability of the variety to the agro-ecologies. Exploring integrated pest management (IPM) and incorporating genetic diversity, botanicals, entomopathogenic organisms and minimal pesticide application have been widely considered as good options for sustainable cowpea production (Mweke *et al*. 2020; Singh *et al*. 2020; Mofokeng & Gerrano 2021).

4. Conclusions and recommendations

This study has shown variations in the performance and economic potential of the two cowpea varieties under different pesticide-spraying regimes across the agro-ecologies in Nigeria. The study has further confirmed that, across all the agro-ecologies, cowpea cannot be produced sustainably in southwest Nigeria without spraying. Rather than the high spraying regime of four sprays at 400 litres per hectare, Ife Brown can be produced profitably under forest agro-ecologies (Ibadan) with three spraying regimes at a moderate application rate of 200 litres per hectare. Similarly, it is profitable to produce both Ife Brown and IT2246 varieties with four spraying regimes at a moderate application rate of 200 litres per hectare in the derived savannah (Ilora), while planting Ife Brown with two regimes of spraying with a moderate pesticide application rate of 200 litre per hectare is profitable for the southern Guinea savannah agro-ecology. The application rates suggested from the results of this study are considered to be moderate, in line with the need to pay adequate attention to the environment and food safety in cowpea production. It is also pertinent to point out that this study has shown that Ife Brown is more adaptable for a moderate pesticide application rate for cowpea production in the major agro-ecologies of southwest Nigeria. The cultivation of Ife Brown at two spraying regimes of 200 litres per hectare in the southern Guinea savannah undoubtedly offers wider leverage for environmental and health concerns regarding pesticide use in cowpea production and deserves to be explored further. Another option in this regard is to consider the use of botanicals, which are considered safer for the environment. The types of botanicals, and their methods of preparation, application and potency, of can be explored towards broadening opportunities for healthy and environmentally friendly cowpea production. This study did not assess the health and environmental risks associated with the spraying regime, hence the need for further studies.

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