Research Article

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Integrated weed management practices and sustainable food production among farmers in Kwara State, Nigeria

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Abstract: A survey was conducted in the Kwara State of Nigeria to study the integrated weed management (IWM) practices by farmers. This was in view of the poor weed management practices adopted by farmers, which is a major factor responsible for low yields of many arable crops in Kwara State. A multi-stage sampling technique was used to select a sample size of 480 respondents, and a structured interview schedule was used to elicit information from them. Data obtained were analyzed using descriptive statistics. Factor analysis was also carried out to examine the perception of farmers' benefits of IWM. Results showed that the majority of farmers (29.4%) were youths, married (89.1%), and involved in medium-scale farming (47.2%). Furthermore, 50.8% of the farmers had primary or secondary education. Although farmers use different weed control methods, more than half of them (54.7%) use herbicides. Most farmers (92.6%) are engaged in the use of IWM, However, 73.5% of them use a combination of herbicides and hoe weeding. Although not properly practiced, farmers perceived IWM as having socio-environmental (29.229%) and techno-efficacious (23.495%) benefits over either hoe weeding or herbicides used alone. The findings suggest a need to train farmers on all aspects of IWM to achieve self-sufficiency in food production in Kwara State.

Keywords: food self-sufficiency, herbicide, weeds, weed control strategy, Nigeria

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1 Introduction

Weeds are generally plants that grow in places where they are not desired. One of the most easily observable effects of weeds is that they decrease crop yields due to competition with them for growth resources. Weeds are found everywhere causing several billions of dollars' worth of crop losses annually with the global cost of control running into many billions of dollars (Abouziena and Haggayi 2016). Yield losses of crops as a result of weed competition are estimated to be 40–90% in cereals, 50–60% in legumes, 50–53% in oilseeds, and 65–91% in root and tuber crops (Ado 2007).

Crop production in Nigeria is dominated by smallholder farmers using traditional methods that are full of drudgery (Ndarubu and Anudu 2010). These methods are reported to be time-consuming, labor-intensive, and expensive per hectare (Imoloame 2013; Imoloame and Ahmed 2018) and offer little hope for expanding the present farm size.

Chemical weed control is playing an increasing role in Nigerian agriculture due to the increasing cost and widespread unavailability of labor required to carry out traditional weed management. It is considered a practical and economic alternative to manual weeding; it is cheaper, faster, minimizes drudgery, gives better control of weeds, and increases the economic and biological yield of crops (Chikoye et al. 2004; Haider et al. 2009). Although herbicides use has revolutionized farmers' approach to weed management, the public is very much concerned about its effect on the environment and human health (Olsen et al. 2006). This is one of the reasons that has triggered interest in Integrated Weed Management (IWM), to cut down the rates of herbicide applied, minimize environmental pollution and build-up of herbicide residue in crops, provide season-long effective weed management, and increase crop yields. IWM is a more recent strategy that combines two or more methods of weed management to give results that are superior to those obtained when a single method is used (Das 2011).

One of the factors limiting agricultural productivity is poor weed management, which has resulted in significant crop yield losses on small-holder farms in Kwara State and Nigeria. Kwara is an agrarian State where farmers make up 70% of the population. The average yields of most crops obtained by farmers are reported to be very low about 1 tonne ha^{-1}, while tuber crops average below 10 tonnes ha^{-1} (Anonymous 2017). This has resulted in low earnings and a poor standard of living. Furthermore, indiscriminate application of herbicides has increased residual concentrations of herbicides and their metabolites in harvested maize cobs (Best-Ordinioha and Ataga 2017). In view of the quest of the Kwara State Government to revolutionize its agriculture and become self-sufficient in food production, farming has to be made more attractive to the present and future generations of farmers through the introduction of better methods of weed control that will increase yields, economic returns and that are environmentally friendly. Against this background, this study was conducted to examine the IWM practices of farmers in Kwara State and their implication for sustainable food production.

The objectives of this study were

1. To examine the existing weed control methods and IWM strategies of farmers
2. To describe the socio-economic characteristics of farmers in the study area
3. To investigate the types of weeds and crops grown on farmers' farms in the study area
4. To examine the perception of farmers benefits of IWM.

Hypothesis of the study:

1. Farmers in the study area represent a predominantly workforce under 40 years
2. Existing weed control methods consists mainly of using herbicides, which is not a recommended practice to achieve sustainable yield
3. Farmers perceive that IWM could increase returns on investment, thereby supporting available food sufficiency.

2 Materials and methods

2.1 The study area

This study was conducted in Kwara State, Nigeria, located between latitude 8°30′N and longitude 5°00′E. The state comprises 16 Local Government Areas (LGAs), characterized by wooded savanna, with forested regions in the south. It also has a double rainfall maxima (Olanrewaju 2009). Farmers represent 70% of the population of Kwara State (Anonymous 2017).

2.2 Population, sampling procedure, and sample size

The target population of the study was all the crop farmers in Kwara State. A multi-stage sampling technique was used to select the respondents. First, two LGAs from each of the 4 agricultural zones that make up Kwara State were selected, making 8 LGAs: Baruten and Kiaima in Zone A, Edu and Patigi in Zone B, Asa and Moro in Zone C, and Ifelodun and Oyun in Zone D. Thereafter, three towns were selected from the above 8 LGAs leading to the selection of 24 towns from which 20 farmers, (an equal mixture of small, medium and large scale) were selected to give a total of 480 farmers, who were interviewed using a structured interview schedule.

2.3 Data analysis

Data collected were analyzed using descriptive and inferential statistical techniques. The descriptive techniques involved the use of frequency counts, percentages, and means, while the inferential statistics involved the use of factor analysis to study farmers' perception of the benefits of IWM over other weed control methods. Varimax rotation was carried out to evenly distribute the percentage variation of the extracted factors.

To justify the use of factor analysis for this study, a Kaiser–Meyer–Olkin measure of sampling adequacy of 0.826 was obtained which is considered satisfactory having surpassed the minimum standard requirement of 0.613 (IBM knowledge center 2020). Furthermore,

Table 1: Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy and Bartlett's test

Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy	0.826
Bartlett's test of sphericity approx. chi-square	1382.614
df	45
Sig.	0.00

Bartlett's Test of Sphericity produced a chi-square of 1382.614, which is significant at $p < 0.00$ (Table 1).

Ethical approval: The conducted research is not related to either human or animal use.

3 Results and discussion

3.1 Socio-economic characteristics of farmers

The socio-economic characteristics of farmers in Kwara State are listed in Table 2. The highest mean percentage (29.4%) of farmers across the state fall within the age bracket of 31–40 years, except in Zones C and D where most of the farmers (33.3 and 45.8%) were aged, from 50 years and above. This corroborates the findings of Kolo (2004) and Michael and Tijani-Eniola (2009) that majority of farmers involved in farming are youths. This shows that Nigerian youths are now venturing into agricultural production probably as a result of the collapse of white-collar jobs. However, it is not in agreement with the findings of Fadayomi (2000) that aged farmers dominate agriculture in most parts of Nigeria.

The majority of farmers across the state are married (89.1%). Many of them (47.2%) are involved in medium-scale farming, except Zone D of the State, where a higher percentage of farmers (45.0%) are still involved in small-scale farming. The fact that most farmers are aged and weak could account for the small-scale farming being operated in this Zone D.

A combination of farmers with primary or secondary education (50.8%) forms the greatest proportion of farmers in Kwara State. Education influences farmers' willingness to embrace new ideas and innovations.

Table 2: Socio-economic characteristics of respondents in Kwara State, Nigeria

Characteristics	Zone A		Zone B		Zone C		Zone D		Mean
	F	%	*F*	%	*F*	%	*F*	%	%
Age									
≤20	3	2.5	6	5.0	1	0.9	1	0.8	2.3
21–30	18	15	37	30.9	21	17.9	15	12.5	19.1
31–40	44	36.7	44	36.7	29	24.8	23	19.2	29.4
41–50	35	29.2	26	21.7	27	23.1	26	21.7	23.9
≥50	20	16.7	7	5.9	39	33.3	55	45.8	25.4
Marital status									
Married	106	88.3	95	91.5	107	91.5	102	85.0	89.1
Single	11	9.2	25	6.8	8	6.8	6	5.0	7.0
Others	3	2.5	0	1.7	2	1.7	12	10	4.0
Scale of farming ha^{-1}									
Small scale (0.1–4.99)	33	27.5	39	33.3	45	39.5	54	45.0	36.3
Medium scale (5.0–9.99)	73	60.8	47	39.8	53	46.5	50	41.7	47.2
Large scale (≤10.0)	14	11.7	32	26.9	16	14.0	16	13.3	16.5
Educational status									
No formal education	34	28.3	46	38.4	28	23.9	32	26.9	29.4
Primary school	35	29.2	20	16.7	30	25.6	33	27.7	24.8
Secondary school	41	34.2	33	27.2	22	18.8	28	23.5	26.0
Tertiary	10	8.3	21	17.5	37	31.6	26	21.8	19.8
Source of funds									
Family	11	8.6	32	21.7	16	13.8	7	5.7	12.5
Friends	10	7.8	0	0	2	1.7	6	0	2.4
Financial institutions	8	6.3	18	11.9	5	4.3	0	4.9	6.9
Personal savings	92	71.9	95	65.3	89	76.7	100	82.0	74.0
Others	7	5.5	2	1.2	4	3.4	9	7.4	4.4
Farming status									
Full-time	17	13.5	47	39.2	41	35.3	36	30.0	29.5
Part-time	103	86.5	73	60.9	75	64.7	84	70.0	70.5

Source: Field Survey (2019). *F*, frequency.

A previous study (Riddle and Xueda 2012) found that highly educated workers adopt techniques faster than those with less education. The majority of the respondents (70.5%) across the state are part-time farmers suggesting that they are engaged in alternative businesses to diversify sources of income; this is the probable reason why most of them (74.0%) depend on personal savings to fund farm operations.

3.2 Types of crops cultivated

Table 3 shows the types of crops grown by farmers in Kwara State. Many of the farmers (57.1%) and (30.0%) grow maize and sorghum, respectively. Cowpea is a leguminous crop cultivated by 46.3% of the farmers, except in Zones A and B where soybeans and groundnuts are the major legumes grown by most of the farmers (73%) and (52.1%), respectively. With regards to root and tuber, yam is grown by a higher mean percentage of farmers (47.5%) across the state, except Zones B, C, and D where cassava is cultivated by most of the farmers (63.3, 44.4, and 48.1% respectively). Okra is a major vegetable crop cultivated by the majority of the farmers (55.1%) across the different zones of the state, while cashew is the major tree crop.

A mixed cropping system is the practice of the majority (74.7%) of farmers across the zones (Table 2). The knowledge of the cropping system of a particular zone is important in determining the choice of appropriate herbicide and weed control methods for safe and effective weed management.

Table 3: Crops cultivated and cropping system

Type of crop	Zone A		Zone B		Zone C		Zone D		Mean
	F	%	*F*	%	*F*	%	*F*	%	%
Cereals									
Rice	7	3.4	49	18.4	12	6.5	39	19.3	11.9
Maize	164	79.2	113	42.5	103	56.0	102	50.5	57.1
Sorghum	36	17.4	103	38.7	67	36.4	60	29.7	30.6
Others	0	0.0	1	4.0	2	1.1	1	5	2.5
Legumes									
Cowpea	24	22.9	93	43.7	77	52.0	64	66.7	46.3
Groundnut	4	3.8	111	52.1	41	27.7	15	15.6	24.8
Soybeans	77	73.3	6	2.8	25	16.9	11	11.5	26.1
Others	0	0	3	1.4	5	3.4	6	6.3	2.7
Root and Tuber									
Yam	109	83.8	48	32.0	85	41.1	62	33.2	47.5
Sweet potatoes	4	3.1	7	4.7	24	11.6	35	18.7	9.5
Cassava	17	13.1	95	63.3	92	44.4	90	48.1	42.2
Others	0	0.0	0	0.0	6	2.9	0	0	0.7
Vegetables									
Onions	0	0	2	2.2	3	1.6	1	1.0	1.2
Tomato	0	0	9	9.7	52	28.1	30	28.6	16.6
Okra	2	66.7	65	69.9	74	40.0	46	43.8	55.1
Leafy vegetables	0	0	16	17.2	55	29.7	26	24.8	17.9
Carrot	1	33.3	1	1.1	1	0.5	2	1.9	9.2
Tree crop									
Mango	7	15.9	46	51.1	38	27.9	22	22.7	29.4
Orange	1	2.3	4	4.4	10	7.4	16	16.5	7.7
Coconut	0	0.0	1	1.1	3	2.2	0	0	0.8
Cashew	35	79.5	36	42.2	73	53.7	59	60.8	59.1
Others	1	2.3	1	1.1	12	8.8	0	0	3.1
Cropping system									
Sole	5	4.2	57	33.7	2	1.7	9	7.3	11.7
Mixed	110	93.2	70	41.4	111	96.5	84	67.7	74.7
Inter cropping	3	2.5	42	24.9	2	1.7	31	25	13.5

Source: Field Survey (2019). *F*, frequency.

3.3 Perception of farmers on common weeds on their farms

Table 4 shows the types of weeds present on farmers' farms. Less than half of the population of farmers (40.2%) across the zones perceived broadleaf weeds to be more dominant than other types of weeds on their farms, except in Zone B where 36.0% of the farmers perceived grasses to be more prevalent. Though half of the population of farmers (50.4%) across the state claim that annual weeds are common on their farms, many of the farmers in Zone B (56.7%) and Zone C (54.4%) indicated that the weed population on their farms consisted of a mixture of annuals and perennials.

These results provide some information about the weed ecologies in the different zones of the state. This is important in selecting the best weed management strategy for effective and efficient weed control. Derksen et al. (2002) reported that identification of the type of and dominant weed species is important for guiding or formulating weed management strategies for effective weed control in a cropping system.

Table 4: Perception of farmers on the type of weeds on their farm

Weed type	Zone A		Zone B		Zone C		Zone D		Mean
	F	%	*F*	%	*F*	%	*F*	%	%
Broad leaf	68	36.2	99	34.6	94	42.3	88	47.8	40.2
Grasses	68	36.2	103	36.0	63	28.4	62	33.7	33.6
Sedges	44	23.4	23	8.0	33	14.9	23	12.5	14.7
Striga	8	4.3	61	21.3	32	14.4	11	6.0	11.5
Weed ontogeny									
Annuals only	63	52.9	51	41.8	48	42.1	81	64.8	50.4
Perennials only	43	36.1	3	2.5	3	2.6	7	5.6	11.7
Mixture of annuals and perennials	13	10.9	68	56.7	62	54.4	37	29.6	37.9

Source: Field Survey (2019). *F*, frequency.

3.4 Weed control methods

Generally, farmers apply different weed control methods, such as hand hoeing, hand slashing, mulching, herbicides, and cover crops (Table 5). However, 54.7% of farmers across the state use herbicides except Zone C where 47.1% practice hoe weeding. The fact that Zone C is dominated by illiterate and aged farmers could be responsible for the higher population of farmers still practicing hoe weeding while Zones A, B, and D are dominated by youth with some level of education who are open to the adoption of herbicides.

3.5 Manual weed control

The highest mean percentage of farmers (40.4%) hoe weed their farms twice. Many of them (33.6%) carry out weeding on their farms at 3 and 6 weeks after sowing (WAS) across the state, except Zones C and D, where 47.4 and 34.2% of the farmers, respectively, carry out hoe weeding three times, at 3, 6 and 9, and at 4, 8, and 12 WAS, respectively (Table 6). Two hoes weeding at 3 and 6 WAS are recommended for effective weed control, higher yield, and economic returns of crops such as maize, cowpea, groundnut, soybean, and okra. (Akobundu 1987; Imoloame 2017; Imoloame and Ahmed 2018), while the weeding regime of 3, 8, and 12 WAS for cassava and 3, 8, and 16 WAS for yam was recommended for effective weed

Table 5: Weed control methods

Weed control methods	Zone A		Zone B		Zone C		Zone D		Mean
	F	%	*F*	%	*F*	%	*F*	%	%
Hoe weeding	107	45.5	92	39	81	47.1	43	21.1	38.2
Herbicide	122	51.9	110	46.6	76	44.2	15.5	76.0	54.7
Use of cover crop	6	2.6	1	0.4	5	2.9	2	1.0	1.7
Hand slashing	0	0	7	3.0	2	1.2	2	1.0	1.3
Hand pulling	0	0	11	4.7	6	3.5	2	1.0	2.3
Use of crop density	0	0	15	6.4	0	0	0	0	1.6
Mulching	0	0	0	0	2	1.2	0	0	0.3

Source: Field Survey (2019). *F*, frequency.

Table 6: Weed control using manual method

Hoe weeding	Zone A		Zone B		Zone C		Zone D		Mean
	F	%	*F*	%	*F*	%	*F*	%	%
Frequency of hoe weeding									
Once	30	27.5	36	33.3	5	4.3	34	30.6	23.9
Twice	79	72.5	37	34.3	31	26.7	31	27.9	40.4
Trice	0	0	28	25.9	55	47.4	38	34.2	26.9
Four times	0	0	5	4.6	21	18.1	6	5.4	7.0
Five times	0	0	2	1.9	4	3.4	2	1.8	1.8
Time of hoe weeding									
2, 4, and 6 WAS	0	0	11	10.6	5	4.5	12	10.4	6.4
3, 6, and 9 WAS	19	16.5	21	20.2	29	26.1	39	33.9	24.2
4, 8, and 12 WAS	13	11.3	27	26.0	43	38.7	18	15.7	22.9
3 and 6 WAS	65	56.5	36	34.6	22	19.8	27	23.5	33.6
2 and 4 WAS	2	1.7	8	7.7	7	6.3	9	7.8	5.9
Weedy till harvest	5	4.3	1	1.0	4	3.6	4	3.5	3.1
Weed free till harvest	11	9.6	0	0	1	0.9	6	5.2	3.9

Source: Field Survey (2019). WAS, weeks after sowing; *F*, frequency.

control and higher crop yields (Akobundu 1987). Therefore, while most farmers carry out hoe weeding at an appropriate time for the production of grain and vegetable crops, they have missed the right time for effective weed control in the production of the root crops which could lead to poor weed control and crop yields. Hoe weeding has been reported to be expensive, labor intensive, and strenuous (Imoloame 2013), and this may discourage youths from going into farming.

3.6 Chemical weed control

A greater percentage of farmers (30.3%) use "Force Up" (glyphosate), a pre-plant herbicide followed by Atrazine (11.4%), a pre-emergence herbicide to control weeds (Table 7). Most farmers (67.5%) indicated that they do not use the same herbicide every year and 78.3% indicated that sprayers are not calibrated before their use for herbicide application. The majority of farmers (37.9%) indicated that the source of information on the number of herbicides to apply is from agro-store owners except

Table 7: The use of herbicides for weed control

Type of herbicides used	Zone A		Zone B		Zone C		Zone D		Mean
	F	%	*F*	%	*F*	%	*F*	%	%
Uproot (Glyphosate)	17	8.7	5	2.8	11	5.7	18	10.6	7.0
Force up (Glyphosate)	31	20.2	48	31.8	7	31.4	69	37.6	30.3
Bush clear (glyphosate)	30	15.6	9	4.8	0	0.0	5	2.7	5.8
Tackle (glyphosate)	29	14.7	16	8.6	0	0.0	0	0.0	5.8
Glyphosate	19	9.5	21	11.5	17	9.1	7	4.3	8.6
Paraforce (paraquart)	17	8.7	8	4.5	25	15.1	14	7.3	8.8
Dragon (paraquart)	10	3.8	14	7.8	5	2.6	6	3.7	4.5
2,4-D	4	1.9	6	3.4	6	2.9	5	3.3	2.9
Sticker (nicosulfuron)	14	6.8	18	10.1	22	13.3	14	7.4	9.4
Atrazine	5	2.6	19	11.0	27	15.3	33	16.8	11.4
Others	17	8.7	16	8.9	24	13.8	13	6.6	9.3
Use of same herbicide every year									
Yes	51	43.2	33	27.5	26	27.1	36	31.9	32.4
No	67	56.8	87	72.5	70	72.9	77	68.1	67.5
Calibration of sprayer before use									
Yes	1	0.9	37	31.9	38	38.2	17	15.0	21.5
No	116	99.1	79	68.1	59	60.8	96	85.0	78.3
Source of information on quantity of herbicides									
Extension worker	49	33.8	85	35.6	27	26.7	49	35.0	32.8
Other farmers	24	16.6	69	28.9	27	26.7	28	20.0	23.1
Research institution	1	0.7	1	0.4	9	8.9	4	2.9	3.2
Agro stores	71	49.0	82	34.3	30	29.7	54	38.6	37.9
Others	0	0	0	0.8	8	7.9	5	3.6	5.1

Source: Field Survey (2019). *F*, frequency.

for Zone B, where 35.6% of the farmers get their information from the extension officers. Force Up (glyphosate) and Atrazine used alone will not provide effective weed control and higher crop yield, if they are not timely integrated with other methods of weed control. Furthermore, a number of pre-emergence herbicides used for effective weed control in most of the crops cultivated are not being used by the farmers. Therefore, it is imperative that farmers are sensitized to appropriate herbicides and/or their combinations for effective weed control and sustainable increase in crop production.

Without calibration of sprayers, there is wastage of herbicides, environmental pollution, high cost of and poor weed control, reduced crop yield, and economic returns. The source of information from agro-stores and extension workers may not be very accurate due to inadequate training/refreshing on the safe and profitable use of herbicides (Ikuenobe et al. 2005; Imoloame 2013). This portends danger to farmers as excessive application and exposure to glyphosate herbicides may cause chronic toxicity. There is an urgent need to address this problem, especially now that there is a controversy on the ability of glyphosate-based herbicides to cause cancer (Anonymous 2019). Therefore, it is necessary to train and/or refresh these service providers on herbicide use so that farmers in Kwara State reduce on poor and indiscriminative use of herbicides for better crop yields and reduced environmental pollution.

3.7 The practice of integrated weed management

Table 8 lists the type of IWM practiced by farmers. The majority of the farmers (92.6%) across the 4 zones of Kwara State indicated that they practice IWM. A greater percentage of farmers (45.5%) moderately agree that they use herbicides alone (pre-plant followed by the application of pre- and post-emergence herbicides), except Zones

Table 8: Perception of farmers on IWM

Integrated weed management	Zone A		Zone B		Zone C		Zone D		Mean
	F	%	*F*	%	*F*	%	*F*	%	%
Application of IWM									
Yes	95	87.2	78	98.7	95	90.5	95	94.1	92.6
No	14	12.8	81	1.3	10	9.5	6	5.9	7.4
Type of IWM practiced use of herbicides alone (pre and post-emergence)									
SA	0	0	26	21.6	32	28.6	23	19.7	17.5
MA	39	65.8	50	42.0	39	34.8	46	39.3	45.5
SD	41	34.2	43	36.1	41	36.6	48	41.0	37.0
Use of herbicides plus hoeing between 3 and 8 WAS									
SA	77	64.2	85	71.4	103	90.4	80	67.8	73.5
MA	35	29.2	19	16.0	6	5.3	27	22.9	18.4
SD	8	6.7	15	12.6	5	4.4	11	9.3	8.3
Biological plus herbicide									
SA	13	10.9	68	57.1	29	25.7	40	35.4	23.3
MA	30	25.2	7	5.9	27	23.9	28	24.8	20.0
SD	76	63.9	44	37.0	57	50.9	45	39.8	47.9
Herbicide plus mechanical									
SA	62	51.7	9	7.6	33	29.7	34	28.8	29.5
MA	44	36.7	32	26.9	35	31.5	51	43.2	34.6
SD	14	11.7	78	65.5	43	38.7	33	28.0	36.0
IWM is relatively new and not adopted									
SA	24	20.0	25	21.0	23	20.2	45	38.8	25
MA	71	59.2	77	64.7	54	47.4	41	35.3	51.6
SD	25	20.8	17	14.3	37	32.5	30	25.9	23.4
Deficient in the use of IWM and will require training									
SA	85	70.8	88	73.9	100	87.0	63	52.5	71.1
MA	28	23.3	18	15.1	11	9.6	33	27.5	18.9
SD	7	5.8	13	10.9	4	3.5	24	20.0	10.1

Source: Field Survey (2019). *F*, frequency; SA, srongly agreed; MA, moderately agreed; SD, strongly disagreed.

C and D which strongly disagree with this strategy. However, most of the farmers (73.5%) across the zones use a combination of herbicides plus hoe weeding to manage weeds any time between 3 and 8 WAS. A larger percentage of farmers (47.9%) and (36.0%) strongly disagree using other types of IWM, namely biological plus herbicide and herbicide plus mechanical, respectively (Table 8).

The fact that most farmers across the state strongly agree to use a combination of herbicide and hoe weeding shows the popularity of this type of IWM across the zones and a strong indication that farmers will respond positively to any training that will improve their skills in this type of IWM. More than half of the farmers (51.6%) across the State strongly agree that IWM is relatively new and not fully adopted. This may account for the response of most farmers for strongly disagreeing or moderately agreeing to use other types of IWM.

The supplementary hoe weeding (SHW) carried out by farmers any time between 3 and 8 WAS following herbicide application shows that this operation is carried out based on intuition and not on the recommended time of application, and this could result in low crop yields. According to Das (2011), IWM is a strategy that uses the synergy of a combination of two or more weed management methods in a coordinated way to bring down the weed population below economic threshold levels. Imoloame (2017) and Imoloame and Ahmed (2018) reported that a combination of a reduced dose of herbicide mixture followed by one SHW at 6 WAS resulted in effective weed control, increased crop yield, and economic returns in the production of maize, soybeans, cowpea, and okra. Similarly, the use of a low dose of herbicide plus intercrop of 80,000 plant population per hectare of cowpea plus one SHW at 6 WAS gave effective weed control and higher cassava tuber and maize yield per hectare (Ekpo et al. 2012). This implies that the application of IWM technology has the potential of minimizing the frequency of hoe weeding (drudgery), reducing the dose of herbicide applied while increasing food production.

3.8 Principal component analysis identifying key factors on the benefits of IWM

Table 9 lists the two important factors indicating farmers' perception of the advantages of IWM over other methods of weed control. These factors accounted for 52.724% variation in the dependent variable, advantages of IWM. The rest 47.276% could be attributable to other factors not accounted for.

The first factor was named socio-environmental benefits. This factor accounted for 29.229% of the total variation. The variables contributing to this naming are those with high loading in Table 10, such as IWM minimizes environmental pollution (L = 0.788), IWM reduces pest attack (L = 0.657) due to its ability to control weeds, and other pests at a low dose of herbicides integrated with one or two other methods, IWM has potential for poverty reduction (L = 0.783) by reducing the cost of weed control, increase crop yield, and enhance returns on investment (L = 0.637), IWM leads to diversification to other agricultural and non-agricultural activities (L = 0.529) due to its ability to save time and IWM is supportive of food sufficiency on a sustainable basis (L = 0.599).

Table 9: Number of extracted factors using Kaiser's Criterion and total variation explained by each factor

Component	Total variance explained								
	Initial Eigen values			Extraction sums of squared loading			Rotation sums of square loadings		
	Total	% Variance	% Cumulative	Total	% Variance	% Cumulative	Total	% Variance	% Cumulative
1	3.949	39.494	39.494	3.949	39.494	39.494	2.923	29.229	29.229
2	1.323	13.230	52.724	1.323	13.230	52.724	2.349	23.495	52.724
3	0.932		62.046						
4	0.779		69.839						
5	0.728		77.114						
6	0.581		82.923						
7	0.531		88.229						
8	0.462		92.849						
9	0.393		96.780						
10	0.322		100.000						

Extraction method: principal component analysis.

Table 10: Key factors indicating benefits of IWM

Perception of farmers on IWM	Component	
	Socio-environmental	Techno-efficacy
IWM minimizes environmental hazards	0.788	
IWM has potential for poverty reduction	0.783	
IWM reduced pest attack	0.657	
IWM enhances returns on investment	0.637	0.433
IWM is highly supportive of food sufficiency on sustainable basis	0.599	0.365
Diversification to other agricultural and non-agricultural business is possible	0.529	0.417
Weed control is more effective and efficient		0.815
Drudgery commonest with hoeing is minimized		0.696
IWM saves time		0.690
Crop yield is increased	0.387	0.435

Extraction method: principal component analysis.
Rotation method: varimax with kaiser normalization.

The second factor was named as techno-efficacy benefits. This factor accounted for 23.495% of the total variation. The variables responsible for the naming of this factor include the following: IWM is more effective and efficient for weed control (L = 0.815) than manual or chemical methods applied alone, resulting in increased crop yield (L = 0.435) (Table 9), IWM saves time (L = 0.690); lesser time is spent controlling weeds than manual or chemical methods thereby reducing drudgery (L = 0.696) as the frequency of manual weeding can be reduced by 50–66%. The above farmers' perception about the benefits of IWM implies that this technology has a great potential for increasing crop yields, enhancing returns on investment, and sustain food production in Kwara State.

4 Conclusion

It can be concluded that the majority of farmers in Kwara State are youths with secondary or primary education and are involved in medium-scale farming. The dominant weeds on farmers' fields in Zones A and B are annual broadleaved, while Zones C and D are a mixture of annual and perennial broadleaved weeds. Though the chemical weed control method seems to be adopted by a majority of farmers across the zone, hoe weeding is still being practiced by most farmers in Zone C where farming is practiced on a smaller scale. Chemical weed control is subject to abuse as sprayers are not calibrated before herbicide applications and farmers' source of information on the number of herbicides to apply may not be reliable. IWM practiced by 71.3% of farmers across the state is the combination of herbicides and hoe weeding. However, this strategy is not being carried out properly as the operations are not timely applied and coordinated. Despite this problem, most farmers prefer IWM to solitary chemical and manual weed control, because it has socio-environmental and techno-efficacy benefits. Therefore, there is a need to train farmers on the proper use of IWM as a means for effective weed control and sustainable food production and food self-sufficiency in Kwara State.

4.1 Recommendations

1. Farmers in Kwara State should be trained on the use of IWM, including the use of minimum rates of appropriate herbicides or herbicide mixtures in combination with a supplementary hoe weeding at 6 WAS for safe and effective weed control in different weed ecologies and crops.
2. Other types of IWM used for effective weed control and an increase in crop yield and cash returns should be explored and introduced to the farmers for adoption. For example, the use of cover crops integrated with herbicide and hoe weeding in a coordinated manner.
3. Need for farmers to be trained on the calibration of sprayers before use for the application of herbicides. This will improve the effectiveness of herbicides for weed control, higher crop yields, and returns on investment.
4. Glyphosate (Force Up) and Atrazine which are the most used herbicide have to be integrated with low doses of appropriate pre-emergence herbicide mixtures plus a supplementary hoe weeding at 6 WAS

for effective and season-long weed control, higher crop yield, and cash returns.
5. The above cannot be done if extension workers and agro store owners are not trained on the IWM technology. Therefore, there is a need for the Kwara State Government and non-governmental organizations to adequately fund Kwara State Agricultural Development Programme (KWSADP) and improve its ability to organize training programs for extension workers.
6. There is a need for KSWADP through their extension workers to provide more education and encouragement to farmers in Zones C and D who are largely aged, on the benefits of IWM to encourage more youths to invest in agriculture

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