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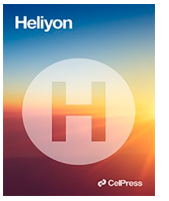

Research article

Assessment of pesticide knowledge, Safety Practices and postharvest handling among cocoa farmers in South Western Nigeria

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ABSTRACT

Cocoa beans are susceptible to fungal contamination during processing and storage. The knowledge of the use of pesticides and post-harvest handling of cocoa beans among farmers is of great importance for safe consumption. The study evaluated common cocoa production and post-harvest practices of farmers in selected study locations in South Western Nigeria. Primary data were collected through the administration of structured questionnaires, and interviews. The collected data were analyzed using inferential descriptive statistics. The results of 394 farmers showed that 52.9 % in Osun and 47.3 % in Oyo were primarily farmers by occupation, the rest had other ventures. The majority of cocoa farmers were men:83.6 % in Oyo State, 88.2 % in Osun state and 87.9 % in Ondo state. 28.6 % and 32.7 % of farmers were aged 51–60 in the Ondo and Oyo communities, respectively. Osun farming communities are dominated by young adults (51 %) of 31–50 years, followed by Ondo 40 % and36 % of farmers in Oyo State. Most cocoa farmers were married with 4–6 children as the most common household size in Osun (51 %), Ondo (60.4 %) and 49.1 % in Oyo State. The literacy level of farmers in cocoa communities was the highest in Oyo state where 47.3 % had tertiary education. Farmers in Oyo State had better knowledge of the dangers of pesticides than Ondo and Osun. However, ignorance of dangers in agrochemicals was higher among Osun farmers than in Ondo State. The highest (18 %) pesticide use during storage was recorded among Oyo farmers, while the least (11.0 %) was recorded among farmers in Ondo State. Pesticide usage was more abundant in Osun (50 %) during cocoa production than in the other study areas. The majority of farmers were positively disposed to make use of nose masks during agrochemical application, meanwhile, 69 %, 62 %, and 61 % of farmers used them already in Oyo, Ondo, and Osun states, respectively. Educational qualification ($\chi^2 = 9.176$, $p = 0.027$) of cocoa farmers was significantly related to knowledge of best practices. Farmers with higher education have a greater ability to receive and process information relating to global best practices in production, postharvest, and pesticide handling in cocoa. In conclusion, cocoa farmers' knowledge of processing, use of pesticides, and storage practices differed from one location to another. Intensive orientation and more enlightenment by extension workers against indiscriminate use of pesticides in cocoa plantations and stores must be consistently and continuously done.

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1. Introduction

Theobroma cacao has a high yield potential, but it is frequently limited by environmental and cultivation factors to levels far below the genetic potential. Africa alone accounts for 68 % of the world's cocoa production, Asia and Oceania with 18 %, and the Americas with 4 %. Cocoa beans constitute a global raw material for the chocolate industry, beverages, cosmetics, pharmaceuticals, and toiletry products [1]. Over fifty million people depend on cocoa for their livelihood with a global production capacity of 68 % in Africa, 17 % in Asia, and 15 % in the Americas [2–4].

The physics and chemistry of cocoa beans are very complex and change throughout their lifespan depending on the processing method and geographical origin [1]. As such, cocoa beans of the commercial grade should conform to specified criteria among which are their moisture content, acidity, slatiness, polyphenol content, mouldiness, and mycotoxin production. Pest and diseases infestation has been identified as one of the major contributors to poor cocoa bean quality [5,6].

Cocoa beans are susceptible to fungal contamination during many of the processing stages i.e. fermentation, which is the first stage in primary processing, thus, an adequate and monitored process is required for the best aroma in cocoa beans. This effect is caused by intrinsic parameters such as pH, water activity and various organic acids produced during cocoa bean fermentation. Besides causing deteriorative alteration of sensorial properties, the presence of filamentous fungi in cocoa and chocolate is also a cause for concern due to the possibility of mycotoxin formation. Dried beans are typically stored in bags at farms until marketed [7], but spores of fungi if present due to bad practice during drying can remain viable for long periods. Therefore, good storage conditions are crucial to maintaining the shelf life and quality of the beans.

To reduce the negative effects of pests and agrochemicals are being used in agriculture and industry. The quantities of these pesticides have raised concerns over the safety of food crops and that of the users, with attendant possible risks to consumers of treated crops, leading to extended concern about effects on the environment [8]. Pesticides cover a wide range of chemicals used for agricultural, domestic, and industrial purposes. They are used mainly in agriculture to control the destructive effects of insect pests, diseases, and weeds during cropping seasons, thereby boosting the yield of crops and maintaining the quality of crops during storage. The use of pesticides has been on the increase in the Nigerian agricultural sector since its introduction in the 1950s, due to the growing population in Nigeria and the increase in agricultural activities to feed the growing population [9]. Apart from protecting the crops in the field, pesticides play a vital role in enhancing the shelf life of stored farm produce [10].

Despite the associated advantages in agriculture, indiscriminate use of pesticides causes major environmental and health challenges all over the globe. For instance, inappropriate use of pesticides can destroy non-target species [11]. Contamination of water bodies results in mortality of aquatic species and pollution of the environment [12]. When pesticides are used in excess, they contaminate the ecosystem and pollute the environment [13]. Lack of adequate knowledge about pesticide handling has led to the rejection of some agricultural produce at the international market due to pesticide residue [14]. In addition, there have been allegations of food poisoning due to the pesticides used for storing agricultural produce [15]. Accidental exposure to pesticides inevitably occurs during their use or through the residue of pesticides in water bodies, aquatic animals, and plants [16]. Due to the high usage of pesticides, exposure has increased, thereby giving rise to complications and adverse effects of pesticides on the health of farmers. Pesticide exposure and poisoning in developing countries are more due to usage and availabilities of arrays of active ingredients

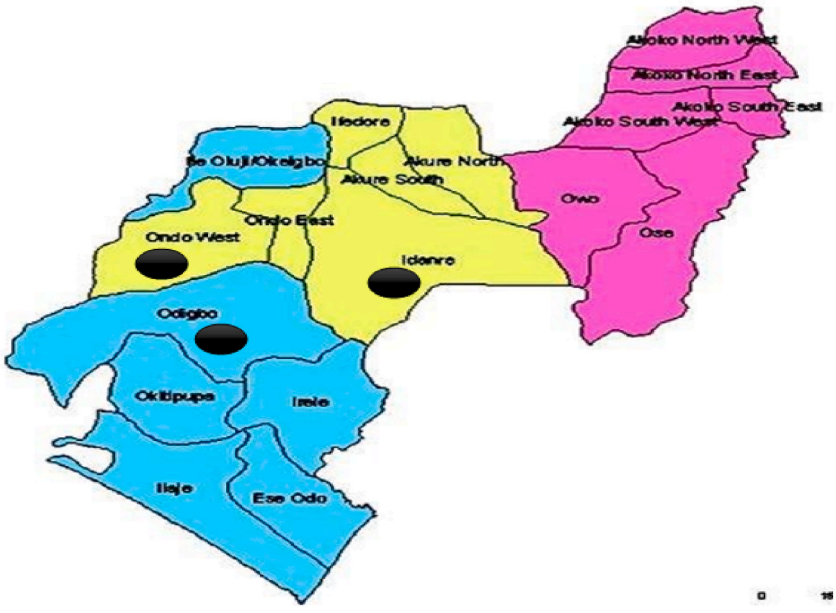

Fig. 1. Local government of Study area indicated on the map of Ondo state in Nigeria.

increasing with limited policy controls [17]. Many lack adequate understanding of necessary information on the pesticide hazards [18], risks [19], safe use, dosage, handling, storage, and disposal [20].

However, lots of practices and inefficiencies in cocoa production led to factors that affect the quality and safe consumption of cocoa beans, and imply significant reduction. These limitations also result in environmental and human health challenges if not put in check and will hamper the capacity to improve the sustainability of production. Thus, there is a need to analyze the knowledge base capacity of cocoa farmers in respect of the global best practices in production and postharvest handlings. To effectively achieve this, baseline information is required, which informed the initiation of this study. The objectives of the study are to.

(i) determine respondents' knowledge and activities of cocoa postharvest handling and safe use of pesticides.
(ii) assess the respondents' disposition to pesticide usage for farm operations

We hypothesized that there is no significant relationship between the respondents and their knowledge of Save Practices and Postharvest Handling.

2. Methodology

Study areas and sampling procedure: Multi-stage sampling procedure was adopted for this study. The first stage involved the purposive selection of major cocoa-producing states; Ondo and Osun States, and medium producing state; Oyo. This was aimed at comparative analyses of the practices of cocoa farmers in production and postharvest handlings in the respective states. Furthermore, the second stage involved the purposive selection of three major cocoa-producing Local Government Areas (LGA) in the selected states (Fig. 1). Idanre, Odigbo and Ondo West in Ondo state, Ife East, Ife South and Ife Central in Osun states (Fig. 2), while the selected LGAs in Oyo states were Oluyole, Akinyele and Ido (Fig. 3). The selected local Government areas fall within the rain forest zone in South Western Nigeria. The areas are dominated by the dry and wet season. The areas are densely populated. Their major occupation is farming and trading. They majorly practiced mixed cropping system of farming in the selected communities. Some farmers interplant other crops with cocoa farms such as Kolanut, Walnut, Plantain, and Oil palm at different spacing.

In addition, the third sampling stage was the use of simple random sampling to select six communities in each of the LGAs which comprised Idanre LGA (Owena, Calendar camp, Elebesere camp), Odigbo: (Asewele, Ominla, Ajewe) and Ondo West: (Adebambo, Bagbe, Ogbogoro). Ife East:(Aba store, Oyere, Kuola), Ife South: (Abiri, Ara Joshua, Yaro), Ife Central: (Amonloje, Eleweran, Odan Asun). Oluyole: (Idi-Ayunre, Onipe, Adebayo), Akinyele: (Elesuru, Aba Nla, Ijaiye) and Ido (Laduni, Idiya, Ido). Finally, the fourth stage of the methodology was a snowball sampling to locate cocoa farmers with storage facility in the previously selected cocoa-growing communities. This selection was independent of affiliation with any farmers' association or group. A total of 394 farmers were selected in the study area, comprising of 182 farmers in Ondo, 102 in Osun and 110 in Oyo state.

Questionnaire administration: The purposively selected farmers in each community and LGAs were engaged in interviews using a well-structured questionnaire and focus group discussions bordering on socio-economic characteristics, knowledge of best practices, responsible pesticide uses and safety protocol, knowledge of pests and diseases, harvest and postharvest handlings techniques practiced. These parameters were assessed based on the responses of the respondents on a list of structured questions posed to them individually and their responses documented and analyzed.

Data collection and statistical analyses: The data were obtained through surveys and were analyzed using the Statistical Package

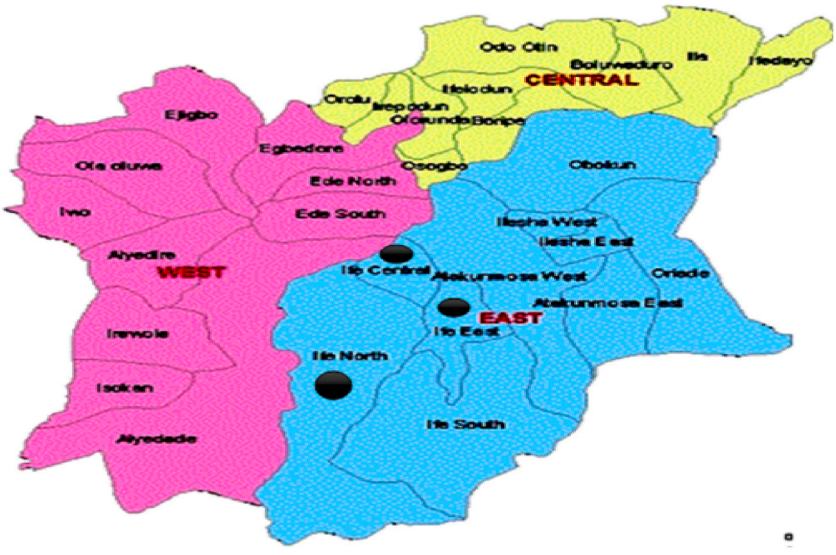

Fig. 2. Local government of Study area indicated on the map of Osun state in Nigeria.

Fig. 3. Local government of Study area indicated on the map of Oyo state in Nigeria.

for Social Sciences (SPSS) version 20. Also, descriptive statistic tools such as frequencies, percentages, mean values and inferential (Chi-square) statistics were used to analyze the data at a 0.05 level of significance. The chi-square test was used to show the relationship between some selected socioeconomic characteristics and respondents' knowledge of Safety Practices and Postharvest

Table 1
Socio-economics characteristics of farmers in study locations (n = 394).

Variable	Osun		Ondo		Oyo	
Age	**Numeric value**	**Percentage (%)**	**Numeric value**	**Percentage (%)**	**Numeric value**	**Percentage (%)**
≤30	8	7.8	8	4.4	4	3.6
31–40	14	13.7	26	14.3	12	10.9
41–50	38	37.3	48	26.4	28	25.5
51–60	22	21.6	52	28.6	36	32.7
61–70	14	13.7	34	18.6	24	21.8
>70	6	5.9	14	7.7	6	5.5
Sex						
Male	90	88.2	160	87.9	92	83.6
Female	12	11.8	22	12.1	18	16.4
Marital Status						
Single	10	9.8	12	6.6	8	7.3
Married	84	82.4	154	84.6	92	83.6
Divorced	4	3.9	10	5.5	6	5.5
Widowed	4	3.9	6	3.3	4	3.6
Number of children						
≤3	34	33.3	50	27.5	42	38.2
4–6	52	51.0	110	60.4	54	49.1
7–9	16	15.7	16	8.8	10	9.1
>9	0	0.0	6	3.3	4	3.6
Mean age	4.2 ± 2.1		4.5 ± 2.7		4.4 ± 2.3	
Educational qualification						
No formal education	16	15.7	10	5.5	2	1.8
Primary	22	21.6	30	16.5	26	23.6
Secondary	38	37.3	82	45.1	30	27.3
Tertiary	26	25.5	60	33.0	52	47.3
Primary occupation						
Farming	54	52.9	60	33.0	52	47.3
Business	20	19.6	48	26.4	14	12.7
Civil servants	18	17.6	66	36.2	40	36.4
Artisan	10	9.8	8	4.4	4	3.6

Source: Field Survey 2023

Handling.

3. Results and discussion

3.1. Socio-economics characteristics of respondents

The cocoa farmers in selected study areas were predominantly men ranging from 83.6 % in Oyo to 88.2 % in Osun farming communities (Table 1). However, there were more women among cocoa farmers in Oyo (16.4 %) compared to other states. The dominance of males is attributed to the drudgery associated with cocoa production. More men participated in agricultural production than women. This may be because women involve themselves more in off-farm agricultural activities such as processing and marketing of farm produce. The majority of the farmers in Ondo (28.6 %) and Oyo communities (32.7 %) were between 51 and 60 years but only 4.4 % and 3.6 % were youth below 30 years. The majority population of cocoa farmers in Cross River, Ogun, Ondo and Osun were between 51 and 60 years old. However, most of them are fairly aged and has passed the economic age of productive life hence practices of global best in production may be beyond their strength [21,22]. Osun farming populations were dominated (37.3 %) by young adults of 41–50 years, in contrast to the age of farmers in Ondo and Oyo states (Table 1). Very few (5.9 %) aged farmers in Osun, although still less than farmers of the same category in Ondo (7.7 %) but similar to (5.5 %) of Oyo farmers. Adebiyi and Okunlola [23] and Leonard et al. [24] reported that most cocoa farmers have passed their productive age and have no formal education hence a strong indication to lag in best practices. A greater percentage of cocoa farmers were married across study locations and the occurrence was similar with 82.4, 84.6 and 83.6 % in Osun, Ondo, and Oyo respectively, most farming households have families by marriage. Marriage is cherished among these farmers and the fact that household members provide labor support in farming activities. Likewise, 4–6 children as the most common household size in Osun (51 %), Ondo (60.4 %), and 49.1 % in Oyo state. The household size of the majority of farmers was less than 6 children in farming communities except for a small number of households with 3.3 and 3.6 % with

Table 2
Population distribution of common insects and diseases in study locations.

Common of pest and disease		Osun	Ondo	Oyo
	Response options	%	%	%
Pests of cocoa				
Leaf eater/defoliators	Never	13.7	13.2	16.4
	Mild	29.4	20.9	20.0
	Severe	56.9	65.9	63.6
Mirid	Never	11.8	9.9	9.1
	Mild	31.4	7.7	16.4
	Severe	56.9	82.4	74.5
Capsid	Never	29.4	25.3	16.4
	Mild	29.4	16.5	36.4
	Severe	41.2	58.2	47.3
Pod borers	Never	23.5	15.4	7.3
	Mild	15.7	16.5	38.2
	Severe	60.8	68.1	54.5
Termites	Never	25.5	17.6	7.3
	Mild	19.6	13.2	38.2
	Severe	54.9	69.2	54.5
Stem borer	Never	17.6	18.7	12.7
	Mild	27.5	23.1	23.6
	Severe	54.9	58.2	63.6
Mistletoes/climber	Never	58.8	85.7	60.0
	Mild	19.6	4.4	32.7
	Severe	21.6	9.9	7.3
Disease of cocoa				
Black pod	Never	7.8	4.4	10.9
	Mild	5.9	7.7	7.3
	Severe	86.3	87.9	81.8
Cocoa swollen shoot virus	Never	13.7	9.9	10.9
	Mild	25.5	12.1	40.0
	Severe	60.8	78.0	49.1
Die-back	Never	19.6	9.9	10.9
	Mild	29.4	17.6	27.3
	Severe	51.0	72.5	61.8
Cherelle wilt	Never	15.7	13.2	12.7
	Mild	41.2	38.5	56.4
	Severe	43.1	48.4	30.9
Yellow okra	Never	43.1	60.5	32.7
	Mild	17.6	24.2	34.5
	Severe	39.2	25.3	32.7

Source: Field Survey 2023

more than 9 children in Ondo and Oyo respectively. The literacy level of farmers in cocoa communities was highest in Oyo state where 47.3 % had tertiary education and 27.3 % completed secondary education. education among rural farmers brings about a change in their productivity and standard of living. This enhances their chance of adhering to the processing standards that will ensure high-quality cocoa beans [25,26].

Most farmers 37.3 % in Osun and Ondo (45.1 %) had secondary education. But 15.7 % of respondents in Osun had no formal education while 5.5 % in Ondo and 1.8 % in Oyo were in this category (Table 1). The Osun (52.9 %) and Oyo (47.3 %) respondents were primarily farmers by occupation while Ondo recorded 33.0 % of the respondents with a secondary interest in farming. This implies that even though farmers may have knowledge of required global best practices but may often adopt bad practices and risky behaviors because of a lack of education, poor knowledge, and understanding of the consequences of such actions.

Overall, the cocoa producers in Osun were primarily farmers, predominantly young adults, and most were married with 4–6 children and had secondary education. However, there were much older farmers in Ondo and Oyo, similar in marital status, household size and literacy in Osun with the exception of more literate farmers in Oyo state (Table 1).

3.2. Common insects and diseases affecting cocoa production in the study areas

The experiences of farmers were evaluated on array of insects and diseases that affected cocoa in the farms. The leaf defoliator was severe on cocoa trees, severity was 63.6 % in Oyo (highest) and similarly 65.9 % in Ondo farms (Table 2). The infestation of mirid was mostly severe 82.4 % in Ondo followed by 74.5 % occurrence in Oyo farms. The severity of mirid may be due to suitable climatic condition of the southwest, being a rainforest, that is favorable for the breeding of the insect pest. Capsids, pod borer and termites were highest in Ondo farms with occurrence of 58.2, 68.1 and 69.2 % across the farms respectively. However, occurrence of stem borers was 63.6 % the highest in Oyo farms but mistletoes was not a major challenge in most farms in study areas but was 21.6 % in farms in Osun higher than other locations.

All farms have more than 80 % black pod disease severity, the disease was the most predominant affecting cocoa across the states. A fungal disease, that usually common in a humid area, positively correlation with relative humidity, thus high relative humidity could bring about increase in black pod [27]. Cocoa swollen shoot virus was 78 % (highest) in Ondo and dieback disease also range from 51 % in Osun to 72 % farms in Ondo. The severity of Cherelle's wilt and yellow okra was least (30.9 %) in Oyo and 25.3 % in Ondo respectively. The two latter diseases were mostly severe with 48.4 % in Ondo farms and 39.2 % of farms in Osun state.

3.3. Post-harvest activities in cocoa production

The process of fermenting cocoa beans was of varied types and the practices also differed among farmers. Figs. 5A, 4B and 4C, 4D revealed that most farmers (41.2 %) in Osun and 27.5 % in Ondo practiced heap fermentation while majority (40 %) of Oyo farmers do

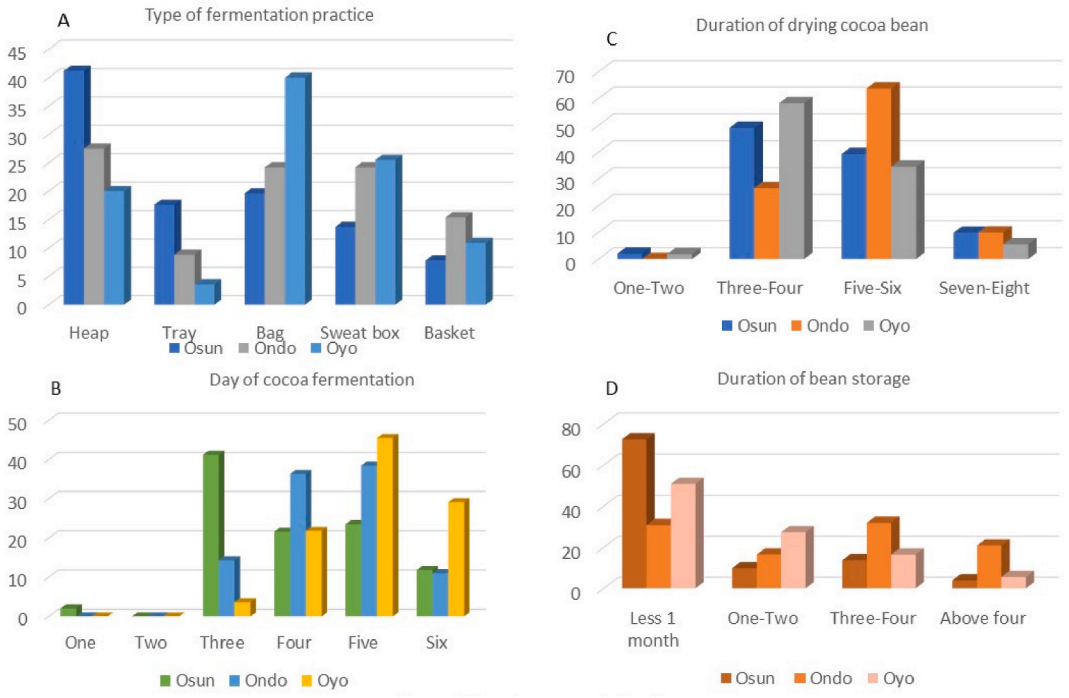

Fig. 4. Post-harvest activities in cocoa.

bag fermentation. The tray fermentation method was frequently practiced in Osun communities but least among Oyo farmers. However, they also used the sweat box method of fermenting cocoa in Osun, Oyo, and Ondo state. The use of baskets for fermentation was reduced among Osun farmers but a good number of Ondo farmers practiced basket fermentation (Fig. 4A). Once the cocoa beans are harvested, they went through a process of fermentation, which helps bring out the natural flavors of the beans and killed any bacteria inhabiting the beans. The process of fermenting started right after picking the beans. The pulp of the pod's housing was crucial to ferment correctly.

A day fermentation was observed among farmers in Osun state, although only 2.0 % of farmers, whereas none of the farmers did two-day fermentation. Around 41 % of farmers in Osun fermented cocoa beans for three days, between 21 and 23 % did ferment four-five days while only 11.8 % fermented beans up to six days. A greater number of farmers (36.3–38.5 %) in Ondo state fermented for four to five days, some 14.3 % did three-day fermentation while only 11 % fermented their beans for six days in Ondo (Fig. 4B).

The five-day fermentation was mostly (45.5 %) practiced by Oyo farmers, another 29.1 % did a six-day followed by 21.8 % practicing a three-day fermentation period. The majority of farmers in the study areas practiced four to five-day fermentation period except Osun farmers and more than double the farmers in Osun and Ondo practiced six-day fermentation in Oyo state. The number of farmers in Oyo who practiced five-day fermentation also doubled that of Osun farmers who practiced the same period. However, about an equal number in the two states fermented their beans for four days (Fig. 4C).

Depending on the farmer and location, fermenting and drying cocoa beans might vary, but most follow a similar pattern. Commonly the beans are placed in a series of wooden boxes for four to eight days to let them ferment. Rotating the beans frequently ensures they are uniformly dried, and no soft spots occur. It also helps keep the airflow around the beans. Although fermentation and drying have complementary influences on bean quality, a poor drying process of well-fermented cocoa beans might result in beans of very poor quality since heat treatments affect bean quality parameters differently [28].

Fermentation and drying constitute key farm(er)-based unit operations with strong influences on the final quality of cocoa beans and subsequent products. Recent studies on the drying process and its effects on quality point to three principal issues—method, temperature, and duration of drying [29]. Variations of these drying parameters impinge significant effects on moisture content, bean colour, pH, fatty acids, polyphenols, methylxanthines, proteins, and aromatic compounds that constitute outstanding quality parameters [30].

According to Ackah and Dompey [31], all fermentation and drying durations resulted in slaty content higher than the acceptable grade 1 limit (3 %), coupling 6, 7, or 8 days of fermentation period with 6 days drying resulted in slaty content which fell below the grade 1 limit, while coupling 5-, 6- and 7-days fermentation periods with 4 days drying duration all resulted in slaty content falling even above the acceptable grade 2 limit (8 %).

The drying period after fermentation varied from one to eight days in the study locations. Farmers in Ondo do not dry for less than three days, some farmers in Osun and Oyo 2 and 1.8 % dry for only one in the respective states. The predominant drying period among farmers was three to six days across study areas. Three to four days of drying was most common to 58.2 % of farmers in Oyo state, followed by 49 % of Osun farmers. About 64 % of farmers in Ondo communities dry their beans between five and six days and a

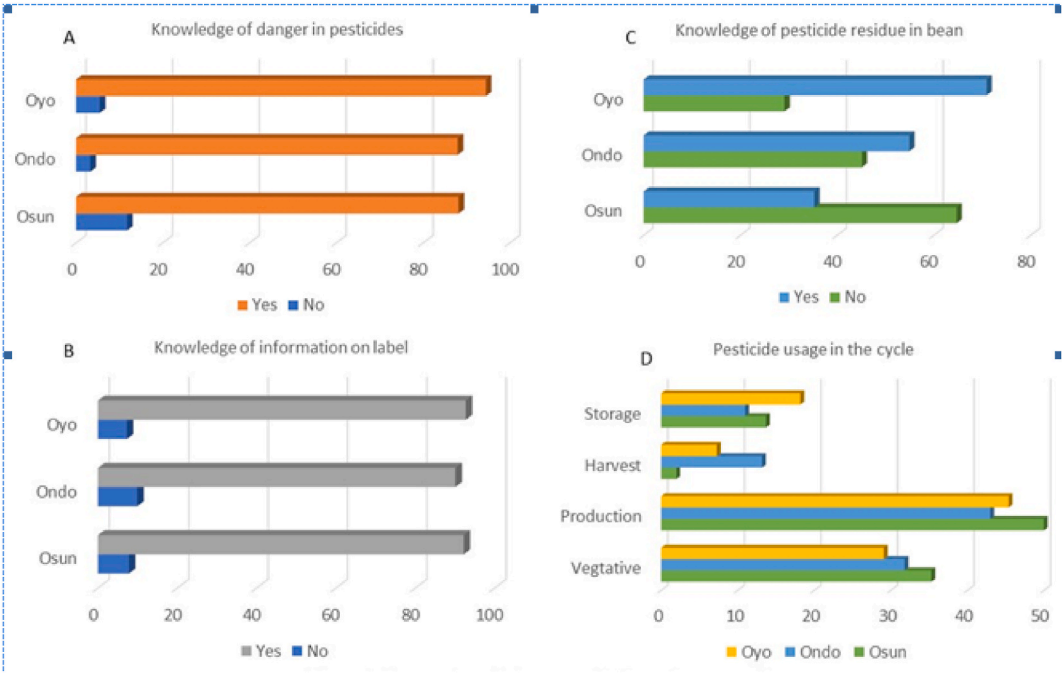

Fig. 5. Farmers knowledge on pesticides and purpose of use.

similarity of around 39 % and 35 % of farmers in Osun and Oyo dry for the same period. The seven-eight-day drying was not a popular (less than 10 %) practice among farmers in study locations (Fig. 4C). The overall effect of postharvest processing on quality revealed that 8 days' fermentation with the traditional leave heap method, coupled with 6 days of sun drying during the rainy season, resulted in superior bean quality with a percentage purity of 98 % [31]. Farmers stored their cocoa beans variedly with the majority (72.6 %)

Table 3
Respondents disposition to pesticides usage in farm operations.

S/N	Pesticide used	Response options	Osun	Ondo	Oyo
			%	%	%
Insecticide					
1	Phostoxin	Never	66.7	62.6	43.6
		Occasional	19.6	20.9	27.3
		Always	13.7	16.5	29.1
2	Cypermethrin	Never	66.7	90.1	65.5
		Occasional	27.5	7.7	23.6
		Always	5.9	2.2	10.9
3	Lambdacyhalothrin	Never	86.3	91.2	80.0
		Occasional	7.8	5.5	14.5
		Always	5.9	3.3	5.5
4	Proteus	Never	84.3	86.8	60
		Occasional	7.8	7.7	29.1
		Always	7.8	5.5	10.9
5	Actara	Never	68.6	85.7	60.0
		Occasional	21.6	7.7	27.3
		Always	9.8	6.6	12.7
6	Esiom	Never	88.2	87.9	74.5
		Occasional	7.8	8.8	20.0
		Always	3.9	3.3	5.5
7	Gammalin 20 EC	Never	51.0	57.1	34.5
		Occasional	25.5	13.2	36.4
		Always	23.5	29.7	29.1
8	Donwell	Never	84.3	87.9	76.4
		Occasional	5.9	4.4	21.8
		Always	9.8	7.7	1.8
9	Perfect Killer 20 EC	Never	54.9	59.3	58.2
		Occasional	31.4	15.4	21.8
		Always	13.7	25.3	20.0
10	Rocket 20 EC	Never	74.5	83.5	70.9
		Occasional	15.7	12.1	18.2
		Always	9.8	4.4	10.9
Herbicide					
1	Paraquat	Never	19.6	23.1	23.6
		Occasional	39.2	25.3	45.5
		Always	41.2	51.6	30.9
2	Touch down	Never	49.0	36.3	29.1
		Occasional	21.6	18.7	32.7
		Always	29.4	45.1	38.2
Fungicide					
1	Red force	Never	51.0	51.6	45.5
		Occasional	11.8	20.9	29.1
		Always	37.3	27.5	25.5
2	Ridomil gold	Never	62.7	73.6	58.2
		Occasional	23.5	12.1	25.5
		Always	13.7	14.3	16.4
3	Champ DP	Never	84.3	89.0	65.5
		Occasional	13.7	3.3	27.3
		Always	2.0	7.7	7.3
4	Ultimax plus	Never	35.3	50.5	32.7
		Occasional	27.5	14.3	29.1
		Always	37.3	35.2	38.2
5	Funguran OH	Never	66.7	48.4	40.0
		Occasional	13.7	13.2	18.2
		Always	19.6	38.5	41.8
6	Tandem	Never	60.8	85.7	67.3
		Occasional	27.5	6.6	25.5
		Always	11.8	7.7	7.3
7	Kocide 101WP	Never	82.4	90.1	69.1
		Occasional	11.8	5.5	25.5
		Always	5.9	4.4	5.5

Source: Field Survey 2023

keeping it for less than a month in Osun state, 50.9 % in Oyo keep for the same period and most farmers store for this period or for three to four months (Fig. 4D). One- and two-months' storage was mostly practiced among Oyo farmers, meanwhile three to four months' storage were observed by Ondo farmers, while 20.9 % of Ondo farmers keep their beans in storage more than four months (Fig. 4D).

3.4. Respondents knowledge on pesticide and purpose of use

The level of awareness and knowledge of farmers on agrochemicals revealed that farmers in Oyo state had better knowledge on dangers of pesticide than Ondo and Osun farmers whose level of awareness were similar (Figs. 5A, 4B and 4C, 4D). The ignorance of dangers in agrochemicals was, however, the highest among Osun farmers and least in Ondo state (Fig. 5A). The majority of farmers in study locations were highly prepared on pesticide label and information contained therein but those who failed read the label on agrochemicals among farmers were more in Ondo compared to Osun and Oyo states (Fig. 5B). This can be linked to a higher literacy recorded in Oyo. Understanding farmers' level of knowledge and practices of safe use of pesticides is key to providing sound educational and policy strategies to reduce health and environmental hazards by pesticides. Most farmers were well aware of dangers posed by pesticides but on contrary, this did not significantly influence their practices towards safe use of pesticide [32]. The findings in this study contradict the experience of [33] in Oman where most farmers are hampered in their ability to read and understand pesticide labels regarding the correct and safe use of pesticides, or written communication about how to avoid the risks of exposure.

The understanding of the residue of active ingredients in agrochemicals stored in cocoa beans were very minimal generally among farmers in the selected study communities. The high education level is expected to positively influence their knowledge level on the harmful effects of pesticides. The lack of this knowledge was predominantly higher 64.7 % among Osun farmers, around 45.1 % of farmers in Ondo also lacked adequate understanding of this concept but 70.9 % of farmers in Oyo state were well informed about residues of pesticides in cocoa beans, indicating a wide knowledge base of these farmers compared to their counterparts from other study areas (Fig. 5C). Educated farmers are more knowledgeable about pesticide safety, have better ability to read, understand and follow hazard warnings on labels, and conceptualized the consequences of poor pesticide usage practices [20].

Generally, all farmers in selected study locations used agrochemicals mostly during cocoa production and at harvest. Farmers in Osun communities recorded most heavy pesticide usage at production, vegetative growth but least at harvest. Pesticide use during storage was 18.2 % among Oyo farmers but 11.0 % recorded among farmers in Ondo state. During harvest of cocoa, agrochemical use was higher (13.2 %) among cocoa farmers in Ondo state, followed by 7.3 % usage in Oyo and 2.0 % of farmers in Osun use pesticides. However, pesticide usage was heavier in Osun (50 %) during cocoa production compared to usage in other study locations (Fig. 5D).

The knowledge, which also stems from the correct responses provided by farmers on effects of pesticides showed that the majority were aware that pesticides could be harmful to their health as well as the environment. Knowledge of this is equally important to cocoa farmers in order to prevent unsafe and indiscriminate use, which can be hazardous to human, animal, soil and water health. Knowledge on chemical usage will enable them to know the appropriate dosage of chemicals needed for the control of pests and diseases, thereby ensuring efficient but minimal use of pesticides. This is crucial because this use in has become imperative for the safety of the farmers, consumers and environment [34]. Educated farmers and farmers who had access to training on pesticide use are more likely to followed required standards of practices [35]. They are also more likely to be aware of pesticide-related adverse health and environmental effects [14].

3.5. Respondent disposition to pesticide usage for farm operations

There are many agrochemicals in open markets with varied trade names and active ingredients. The targeted farmers generally have access to ten, two, and seven trade names of insecticides, herbicides, and fungicides documented in this study. Among the insecticides, the majority 66.7 % (Osun), 62.6 % (Ondo) and 43.6 % (Oyo) have never used Phostoxin, similarly was their usage of Cypermethrin (66.7, 90.1, 65.5 %), Lambdacyhalothrin (86.3, 91.2, 80.0 %), Proteus (84.2, 87.9, 74.5 %), Actara (68.6, 85.7, 60 %), Esiom (88.2, 87.9, 74.5 %), Donwell (84.3, 87.9, 76.4 %), Perfect killer 20 EC (54.9, 59.3, 58.2 %), Rocket 20 EC (74.5, 83.5, 70.9 %). Around half of the farmers in Osun and Ondo states have never used Gammalin 20 EC but 36.4 % of farmers in Oyo use this insecticide occasionally and another 29.1 % always used the same chemical (Table 3).

The herbicides; Paraquat and Touch Down were commonly used by farmers in study locations (Table 3). About 41 % of farmers in Osun always use Paraquat and 51.6 % of Ondo farmers do likewise, but the majority 45.5 % in Oyo have occasional use of Paraquat and only 30.9 % used it always in Oyo state. The use of Touch Down varied widely across study areas. Around half of respondents in Osun never used Touch Down and 29.4 % have always used this chemical. Unlikely the experience of cocoa farmers with Touch Down in Ondo and Oyo, the majority 45.1 % and 38.2 % have always used this chemical, respectively (Table 3). Fungicides are commonly used during cocoa production as a result of heavy disease infestation on cocoa trees. The experiences of farmers in study locations were evaluated on common trade names in open markets. Most of the farmers in study locations 51 % (Osun), 51.6 % (Ondo), and 45.5 % (Oyo) have never used Red Force against cocoa disease. The experience was similar to the use of Ridomil gold (62.7, 73.6, 58.2 %), Champ DP (84.3, 89.0, 65.5 %), Tandem (60.8, 85.7, 67.3 %), Kocide 101 (82.41, 90.1, 69.1 %). However, the use of Ultimax Plus and Funguran OH varied among farmer communities. Around 37 and 38 % of farmers in Osun and Oyo always used Ultimax Plus, 35.3 and 32.7 %, respectively, have never used the Fungicide. 35.2 % of Ondo farmers used this chemical and half of them have never tried it. Meanwhile the majority of farmers in Osun (66.7 %) and Ondo (48.4 %) have never used Funguran OH but 19.6 and 38.5 % always used it in the respective states. And 40 % and 41.8 % of farmers in Oyo have never and always used Funguran OH, respectively (Table 3)

3.6. Dosage and concentration of pesticides used

The dosage preparations of agrochemicals used by farmers were shown in Table 4. Concentration of 75–750 ml were evaluated as practiced by farmers. The volume of pesticides used in a 15L spraying pump varied in study areas. Most farmers have never used 75–250 ml and 750 ml chemical in spray preparation and the farmers who used these volumes, which ranged from 3.3 % (125 ml) in Ondo to 29.1 % (75 ml) among Oyo farmers. Around 45 % of farmers in Osun used 500 ml, 61.5 % used the same volume occasionally but the majority (41.8 %) of Oyo farmers never used this concentration (Table 4).

The pesticides dosage and concentrations prepared by farmers varied widely without recourse to any standard. This implies inadequate understanding and non-uniformity of concentration across study locations.

3.7. Respondent means of agrochemical preparation

Fig. 6A, B, 6C shows that most farmers in study areas prepared agrochemicals using the spraying pump. The use of drums to prepare chemicals was similar among farmers, although practiced by about 4 % of farmers. However, Oyo farmers recorded the least (23 %) of practice of pesticide preparation in buckets and mostly 73 % farmers prepared agrochemicals in spraying pump (Fig. 6 C).

4. Respondents' dispositions to safety precautions during pesticide application

The disposition of farmers to safety protocol during pesticide application were similar in study areas. All farmers were positively disposed to make use of nose masks during treatment application through spraying; however, the use was higher (69.1 %) among Oyo farmers, 61.5 % and 60.8 % among Ondo and Osun farmers, respectively. The use of eye goggles was not a popular practice as 60.8, 53.8 and 41.8 % of farmers in Osun, Ondo and Oyo, respectively, have never used this to protect their eye during chemicals' application (Table 5). The use of overall was practiced by 52.9 % of farmers in Osun, 65.9 % of farmers in Ondo and Oyo farmers 60 % of them wore overall. Similarly, the use of rain boot during spraying were always practiced by the majority of farmers. The use of hand glove, ear plug, and cap as face shield was not a regular practice by farmers in study areas. About 69, 92 and 76 % of Ondo farmers never used these hand glove, ear plug and cap, of Osun farmers 62.7, 74.5 and 60.8 % and 47.3, 75.5 and 47.3 % in Oyo never complied with the use of these items during chemical applications (Table 5).

5. Respondents' response to pesticide application for safety

Farmers generally used multi-task in their activities with the aim to save time and achieve more per given time. This have also played out in the process of spray application on farm. Observation of rest and drinking of water after spray application was higher among Osun farmers compared to other locations (Fig. 7). The habit of eating during spraying was completely avoided by farmers in

Table 4
Dosage and concentration of pesticides used.

S/N	Volume per 15 L sprayer	Response options	Osun			Ondo			Oyo		
			F	%	Mean	F	%	Mean	F	%	Mean
1	75 ml	Never	74	72.5	0.37	158	86.8	0.18	70	63.6	0.65
		Occasional	18	17.6		16	8.8		8	7.3	
		Always	10	9.8		8	4.4		32	29.1	
2	150 ml	Never	68	66.7	0.43	136	74.7	0.35	48	43.6	0.75
		Occasional	24	23.5		28	15.4		42	38.2	
		Always	10	9.8		18	9.9		20	18.2	
3	300 ml	Never	64	62.7	0.63	104	57.1	0.58	66	60.0	0.62
		Occasional	12	11.8		50	27.5		20	18.2	
		Always	26	25.5		28	15.4		24	21.8	
4	450 ml	Never	88	86.3	0.20	132	72.5	0.45	80	72.7	0.37
		Occasional	8	7.8		18	9.9		20	18.2	
		Always	6	5.9		32	17.6		10	9.1	
5	125 ml	Never	82	80.4	0.25	152	83.5	0.20	78	70.9	0.47
		Occasional	14	13.7		24	13.2		20	18.2	
		Always	6	5.9		6	3.3		10	9.1	
6	250 ml	Never	58	56.9	0.53	132	72.5	0.36	48	43.6	0.82
		Occasional	34	33.3		34	18.7		34	30.9	
		Always	10	9.8		16	8.8		28	25.5	
7	500 ml	Never	26	25.5	1.20	32	17.6	1.03	46	41.8	0.89
		Occasional	30	29.4		112	61.5		30	27.3	
		Always	46	45.1		38	20.9		34	30.9	
8	750 ml	Never	62	60.8	0.65	92	50.5	0.84	56	50.9	0.75
		Occasional	14	13.7		28	15.4		26	23.6	
		Always	26	25.5		62	34.1		28	25.5	

Source: Field Survey 2023

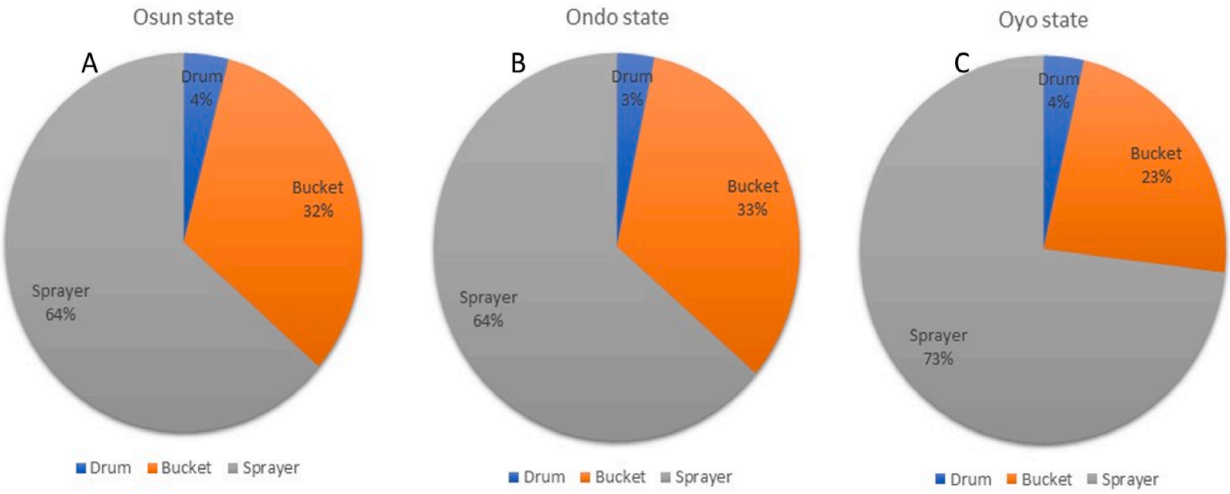

Fig. 6. Means of Agrochemical Preparation for spray in study areas.

Table 5
Respondents' dispositions to safety precautions during pesticide application.

Protective kits	Response options	Osun			Ondo			Oyo		
		F	%	Mean	F	%	Mean	F	%	Mean
Nose mask	Never	24	23.5	1.73	22	12.1	1.49	10	9.1	1.60
	Occasional	16	15.7		48	26.4		24	21.8	
	Always	62	60.8		112	61.5		76	69.1	
Eye goggle	Never	62	60.8	0.67	98	53.8	0.78	46	41.8	0.95
	Occasional	12	11.8		26	14.3		24	21.8	
	Always	28	27.5		58	31.9		40	36.4	
Over – all	Never	30	29.4	1.23	40	22.0	1.44	14	12.7	1.47
	Occasional	18	17.6		22	12.1		30	27.3	
	Always	54	52.9		120	65.9		66	60.0	
Rain boot	Never	14	13.7	2.06	34	18.7	1.53	12	10.9	1.56
	Occasional	6	5.9		18	9.9		24	21.8	
	Always	82	80.4		130	71.4		74	67.3	
Hand glove	Never	64	62.7	0.64	126	69.2	0.51	52	47.3	0.89
	Occasional	10	9.8		20	11.0		18	16.4	
	Always	28	27.5		36	19.8		40	36.4	
Ear plug	Never	76	74.5	0.411	168	92.3	0.11	82	74.5	0.38
	Occasional	10	9.8		8	4.4		14	12.7	
	Always	16	15.7		6	3.3		14	12.7	
Cap	Never	62	60.8	0.69	18	75.8	0.40	52	47.3	0.89
	Occasional	10	9.8		16	8.8		18	16.4	
	Always	30	29.4		28	15.4		40	36.4	

Source: Field Survey 2023

Ondo state but washing of face and body were mostly practiced by farmers in Ondo (28.6 %) and Oyo (69.1 %) respectively. And farmers in Oyo gave better attention to handlings of spray pumps than farmers in other locations. Overall, the washing of body was the most practiced of all the activities expected as safety measures by farmers in all study areas (Fig. 7).

5.1. Respondents means of cocoa storage

The facilities and methods of storage of cocoa beans varied with farmers in the locations (Table 6). The use of wooden pallets to store cocoa beans was generally practiced by the majority of farmers in the locations. Farmers in Osun (68.6 %) and Oyo farmers (47.3 %) used jute bags but more than half (54.9 %) of Ondo farmers store cocoa beans in polythene sack. The Ondo farmers (4.4 %) used little pesticides in stores but rat killer and sanitation were mostly used to control rodents. The majority of storage pests' management in Oyo were done quarterly (41.8 %), followed by 37.3 % in Ondo but Osun farmers used pesticides in store on monthly basis. However, the frequency of pesticide used in store was 7 % in Osun and lesser in Oyo. Most farmers in Osun and Ondo sourced their pesticide inputs from vendors but the majority farmers in Oyo bought from chemical company (Table 6).

The safe consumption of cocoa beans from study areas was evaluated on the basis on pre-harvest interval practiced by farmers. Around 50 % of farmers in Oyo state (Fig. 8C) harvested their cocoa pods any time after agrochemical application, 24 % of Ondo

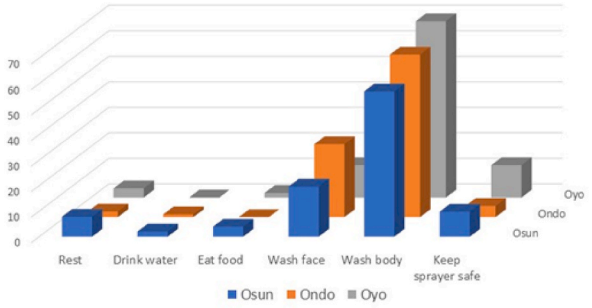

Fig. 7. Farmers response to pesticides applications safety procedures.

Table 6
Respondents means of cocoa storage.

cocoa bags stored on wooden pallets?	Osun		Ondo		Oyo	
	F	%	F	%	F	%
No	16	15.7	10	5.5	4	3.6
Yes	86	84.3	172	94.5	106	96.4
Means of storage						
Jute bag	70	68.6	56	30.8	52	47.3
Basket	16	15.7	10	5.5	24	21.8
Nylon sack	0	0.0	8	4.4	4	3.6
Bucket	0	0.0		4.4	0	0.0
Polythene sack	16	15.7	100	54.9	30	27.3
Control of rodents						
Pesticide	22	21.6	8	4.4	14	12.7
Rat killer/poison	40	39.3	90	49.5	58	52.7
Trapping	12	11.8	18	9.9	2	10.9
Sanitation	28	27.5	66	36.3	26	23.6
Pesticide usage in store						
Weekly	8	7.8	6	3.3	0	0.0
Monthly	50	49.1	58	31.9	32	29.1
Quarterly	28	27.5	68	37.3	46	41.8
Yearly	16	15.7	50	27.5	32	29.1
Source of pesticide						
Input dealers	2	2.0	6	3.3	12	10.9
Chemical company	32	31.4	74	40.7	42	38.2
Cooperative society	10	9.8	0	0.0	28	25.5
Chemical vendor	56	54.9	100	54.9	28	25.5

Source: Field Survey 2023

farmers (Fig. 8B) did the same and 12 % in Osun (Fig. 8A) also practiced this. The number of farmers who allowed up to 10 days' spray interval before harvests was 19, 16 and 12 % in Oyo, Osun and Ondo states (Fig. 8C, A, 8B), respectively. 29 % of Osun farmers allowed 7 days after spray interval before harvest, 25 and 15 % of farmers in Ondo and Oyo practiced the same method (Fig. 8B and C).

Chi-square test showing relationship between some selected socioeconomic characteristics and respondents' knowledge of Safety Practices and Postharvest Handling.

Table 7 shows that educational qualification ($\chi^2 = 9.176$, $p = 0.027$) of cocoa farmers was significantly related to knowledge of best practices. Farmers with higher education have a greater ability to receive and process information relating to global best practices relating to production, quality, postharvest and pesticides handling in cocoa. Education gives farmers the ability to perceive, interpret and adequately determine actions that would possibly enhance their performance in farming activities [36].

6. Conclusion and recommendation

Cocoa farmers' knowledge on production, processing, handlings of pesticide use and store practices differs depending on locations. Literacy level of farmers also varied and was a key factor to information access and practices recorded in the study areas. Although awareness about pesticide effect and risks was high but adherence to safety procedure was low among farmers. However, intensive orientation and more enlightenment on the potential risks and long-term danger associated with indiscriminate use of pesticides must be a periodic task.

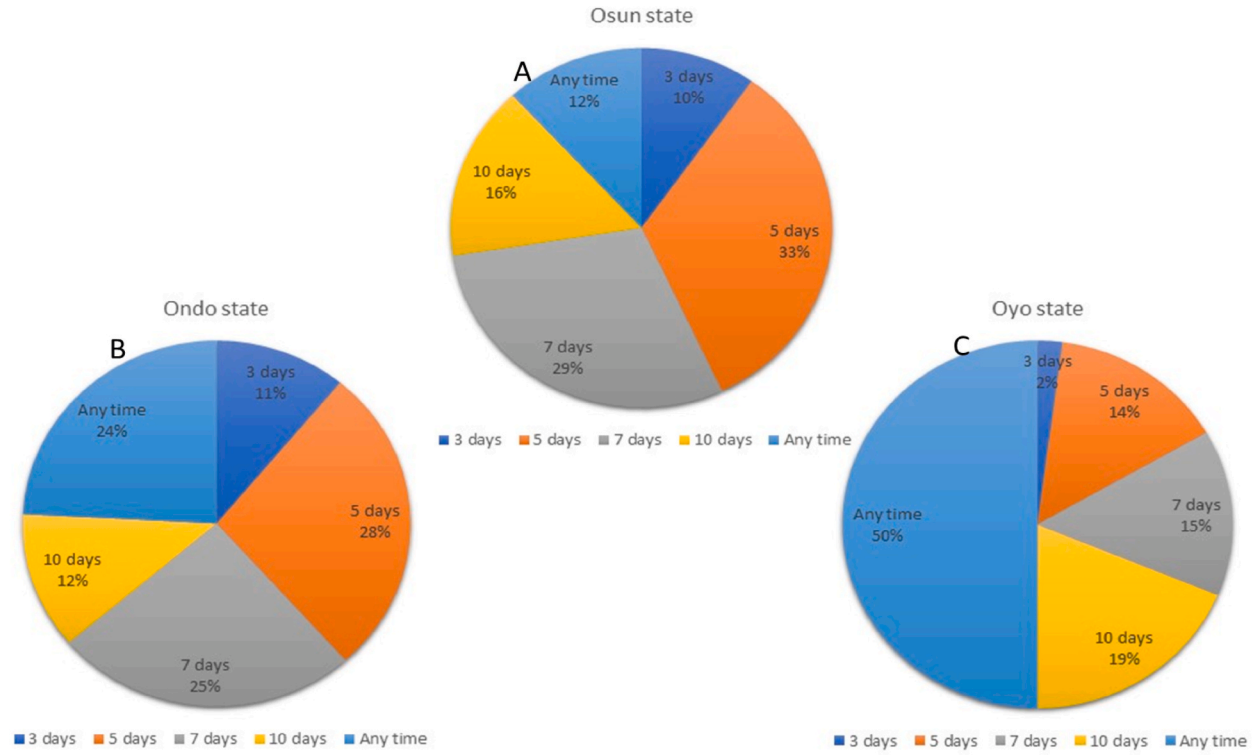

Fig. 8. Record of Pre-harvest interval Practice in Study Areas.

Table 7
Relationship of variable with knowledge of farmers on best practices.

S/N	Variables	X^2	Df	r- value	p-value	Decision
1	Sex	1.331	1	–	0.718	NS
2	Education	9.176	3	–	0.027	*
3	Marital status	2.579	3	–	0.461	NS
4	Age	–	–	−0.084	0.242	NS
5	No of children	–	–	−0.028	0.195	NS

Source: Field Survey 2023

Data availability statement

Data included in article/the raw data will be made available upon request.

CRediT authorship contribution statement

S.M. Ademola: Writing – original draft, Investigation, Formal analysis, Data curation. **V.I. Esan:** Writing – review & editing, Validation, Methodology. **T.E. Sangoyomi:** Writing – review & editing, Supervision, Conceptualization.

Declaration of competing interest

The authors declare that they have no competing interests

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