Adoption of Integrated Pest Management Strategies and Ex-ante Assessment of the Red Palm Weevil Control among Egyptian Farmers

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Summary: The study aimed to analyse the adoption rates of Red Palm Weevil (RPW) integrated pest management (IPM) practices in Egypt based on data collected from 343 farmers through structured questionnaires from three governorates: Al-shargia, Alwahat El-Bahria, and Aswant in Egypt. The overall adoption of IPM categories for RPW control was 83.85%. Egyptian farmers highly adopted the categories of legislative control (89.04%), cultural practices (88.92%), mechanical control (87.27%) and chemical control (83.85%), while they moderately adopted preventive measures (70.15%). Based on the average level of adoption of IPM practices, two farmer groups, "high adopters" and "moderate adopters", were identified using cluster analysis. The "high adopters" represented 65.9% of the sample and had a higher adoption rate for all the RPW IPM practices than the "moderate adopters". All three Egypt governorates were similarly ranked in terms of perception risk related to RPW. However, compared to Aswan and Al-Wahaat Al-Bahria, As-Shargia was the most vulnerable governorate regarding governance effectiveness related to RPW, characterized by lower training and public support index levels. These results point to the need to promote awareness among farmers, citizens, municipalities, researchers, non-governmental organizations, and decision-makers about the interest in adopting IPM against the spread of RPW.

1. Introduction

Despite the invaluable role of date palms in Egyptian agriculture, diseases and pathogen pests, particularly red palm weevil, are a serious threat to date palm plantations. The Red Palm Weevil (Rhynchophorus ferrugineus) is a destructive pest that infests palm trees, causing significant damage to date palms and other palm species. It was first detected in Egypt in November 1992 in El-Hussinia, Sharquiya region (Cox, 1993) and has since spread to various areas, including Cairo, Giza, Alexandria, and the Nile Delta (FAO, 2019). The infestation now covers all 26 governorates in Egypt, with 2% to 35% infestation rates. Date palm is considered of economic importance in Bahria and Siwa oases, and Aswan, with an infestation rate exceeding 20%, and the highest infestation rate was recorded in 2014 on more than 250,000 infested date palm trees (Abbas, 2019).

The infestation of RPW can lead to severe damage and even death of palm trees. The adult weevils lay their eggs inside the palm tree trunk, and the larvae feed on the soft tissues, causing internal damage. This feeding activity weakens the tree and can lead to its eventual death if left untreated. The Egyptian Ministry of Agriculture and Land Reclamation has implemented various measures to monitor and manage the pest. These include the establishment of quarantine regulations, inspections at ports of entry, and training programs for farmers and agricultural workers to identify and control infestations.

Integrated pest management (IPM) controls pest damage by the most cost-effective means and minor hazards to humans and the environment. IPM is a decision-based process involving the coordinated use of many tactics for optimizing pest control in an economically and environmentally sound manner (Al-Zyoud, 2015). However, large agricultural production areas are facing unacceptable losses due to pests or suffering from intense use of pesticides worldwide, which led scientists to suggest that new paradigms are required (Kogan, 1998). Alotaibi et al. (2022) reveal that the IPM strategies are primarily employed to combat the RPW. These strategies involve a combination of cultural, mechanical, and chemical control methods. Cultural practices, such as proper sanitation and pruning of palm trees, can help reduce the risk of infestation. Additionally, mechanical techniques, such as trapping and removing infected palm trees, can be employed to limit the spread of the weevils. The increased and rapid movement of date palm seedlings and inappropriate management practices have contributed to the infestation and rapid spread of RPW within countries. The infestation spread almost all over Egypt, except the Toshka and East Owenite oases in the Western Desert (Ahmed and Ijaimi, 2022).

According to Mendesil et al. (2016), there is a growing demand to implement IPM due to increased concerns about pesticides environmental and human health side effects. However, Kassem et al. (2020) affirm that implementing an IPM strategy is difficult. Date palm growers are faced with various challenges in many countries, including a lack of efficient early detection methods, weak enforcement of quarantine measures, and uncontrolled movement of infested trees; an inability of biocontrol agents to be efficiently delivered and sustained in field conditions; insufficient understanding of RPW field behavior among farmers; and a lack of knowledge of symptoms and adoption of management practices by farmers (Faleiro et al., 2018; FAO, 2020; Kassem et al., 2020). The implementation of an effective IPM program for RPWs that suits small-scale farmers in developing countries needs to take into consideration the farmers' pest management knowledge, socioeconomic and farm characteristics, and practices (Grasswitz, 2019; Kassem et al., 2020).

A few studies in local and international contexts were conducted on the analyses of the RPW IPM implementation rate among farmers regarding their socioeconomic attributes and farm characteristics. In this context, only two papers published in Saudi Arabia analyzed the farmers' adoption of RPW IPM; one about the knowledge of the RPW symptom (Kassen et al., 2020) and the other with reference to the socioeconomic attributes and farm characteristics (Alotaibi et al., 2022). This study aimed to: (i) analyse the adoption rates of RPW IPM practices in Egypt with a focus on the differences in adoption levels based on the farmers' socioeconomic attributes and farm characteristics and

(ii) assess the perception risk and governance effectiveness for the control of RPW.

2. Materials and Methods

2.1. Selection of the study area

The RPW infestation spreads almost all over Egypt, with marked differences in the incidence of infestation among governorates of Lower Egypt, Upper Egypt, and the Oases. Date farming in Upper and Lower Egypt occurs all along the Nile Valley, while the oases constitute a unique agro-ecosystem spreading over both the Western and Eastern deserts of Egypt. The selection of the governorates within these three regions was based primarily on the judgement of key informants supported by secondary data on the level of RPW infestation and the intensity of date palms vis-à-vis that region (Table 1).

2.2. Sampling procedures

The sampling frame for the collection of the required information was based on the territorial distribution of Date palms within Egypt

Table 1. Intensity of date farming by region and selected Governorates in Egypt

Region	Date Palm Trees in the Region		Selected Governorates	Date Palm Trees in Selected Governorates	
	Number	%		Number	%
Lower Egypt	6,761,886	34	Al-shargia	2,212,908	33
Oases	6,331,717	32	Alwahat El-bahria	1,945,608	31
Upper Egypt	6,026,595	30	Aswan	1,974,816	33
Canal and Red Sea	887,868	4	-	0	0
Total	20,008,066	100		6,133,332	-

Source: *Own elaboration based on Ahmed and Ijaimi (2022).*

and the associated incidence of RPW infestation (i.e., Governorate Selection) and on the variations in farming systems, as follows: (1) Traditional (Scattered); are irregularly spaced date palm farming systems based on flood irrigation, (2) Traditional (Organized); are well-spaced date palm farming systems based on flood irrigation, and (3) Modernized are date palm farming systems based on localized irrigation (drip, bubblers, etc.).

2.3. Survey data collection

A structured questionnaire was used to collect data from respondents with trained enumerators. The sample is composed of 360 farmers who answered the questionnaire. The structured questionnaire was prepared in English and translated into Arabic. A sample of 334 respondents was finally selected after cleaning the database. The questionnaire included sections focused on collecting information on socioeconomic aspects, farm characteristics and farmers' level of adoption of pest management practices for RPW. The IPM practices adopted by farmers are grouped into four categories: prevention (five practices), legislative control (five practices), cultural practices (four practices), mechanical control (six practices), and chemical control (three practices).

2.4. Data analysis

Descriptives and multivariate statistical analyses were done in steps. In the first step, descriptive statistics, such as frequency distributions, percentages, and arithmetic mean, were employed to analyse and report the farmers' responses. In the second step, an aggregative hierarchical cluster analysis was performed to identify the similarities and differences between the adopted practices.

2.5. Perception of risk and governance

A group of indicators were used to evaluate the perception risk of the RPW establishment and spread and the effectiveness governance of the pest management system (ex-ante interventions) for RPW in the date palm supply chain. The assessment of the concerned farms was divided into two macro areas: (i) Perception risk (P) and (ii) Governance effectiveness (G) towards RPW invasion. At the "perception risk" level, the target governorates were scored and ranked for each index (indicator), according to obtained survey data, assembled into five relative score/rank categories, and then arranged so that each governorate is positioned between the following evenly-spaced percentiles: Least risk (value 1) is below the 20th percentile; Lower risk (value 2) is between the 20th and 40th percentiles; Medium risk (value 3) is between the 40th and 60th percentiles; High risk (value 4) is between the 60th and 80th percentiles, and Highest risk (value 5) is above the 80th percentile.

3. Results

3.1. Profile of the respondents

Half of the respondents (50.7%) were between 40 and 60 years old, with a mean age of 49. Most farmers (43.7%) had an intermediate school education, while only 24.5% attended university. The farming experiences of the farmers ranged between a minimum of 1 year and a maximum of 59 years, with an average mean of 19 years of experience. The primary source of income for the interviewed farmers is dates farming, with a percentage of 46.6%. Less than half of farmers received government support for RPW control (input, chemical or technical support), and only 26% received training on inspection for early detection of RPW. In this sense, farmers did not have sufficient information about the innovative approach of extension services insofar as only a quarter of the respondents knew about the Farmers Field School. Regarding the extension programs on RPW, few farmers (4.2%) followed these programs on radio/TV.

The findings also revealed that most respondents had less than 100 trees on their farms. On average, the farmers managed 6.34 Feddans (equal to 2.64 hectares) and 186.5 trees. Most farmers (74.8%) cultivated date palms with other crops and scattered with flood irrigation (62.4%). The main sources of offshoots were the owner farm (30.3%) and the neighbouring farmers (18.7%).

3.2. Farmers' adoption of IPM for RPW control

Three of the preventive practices were highly adopted by farmers (90% by checking trees regularly to detect early infestation (93% by pruning and removing fronds in the winter, and 91% by treating lesions resulting from the pruning and offshoots detachment by using contact pesticides, one moderately adopted (60% by removing offshoots as a protective measure) and one lowly adopted (15% by using pheromone traps to detect early infestation) (Figure 1).

3.3. Cluster analysis

Using a hierarchical clustering analysis, two clusters were identified, representing the most significant difference in adopting RPW IPM practices. Cluster I represent the respondents who moderately adopted the RPW IPM practices. This group represents 34.1% of the sample (117 farmers). Cluster II consists of farmers who were highly adopting the studied practices, and this group accounts for 65.9% of the respondents (226 observations). Table 2 shows that the average adoption for the second cluster is higher than those of the first one and was statistically significantly different at the probability level of 0.01 for all the practices studied except three (P1, P2 and P4).as

3.4. Major characteristics of the clusters

The "moderate adopters" in the first cluster were composed of younger farmers than the "high adopters" in the second.

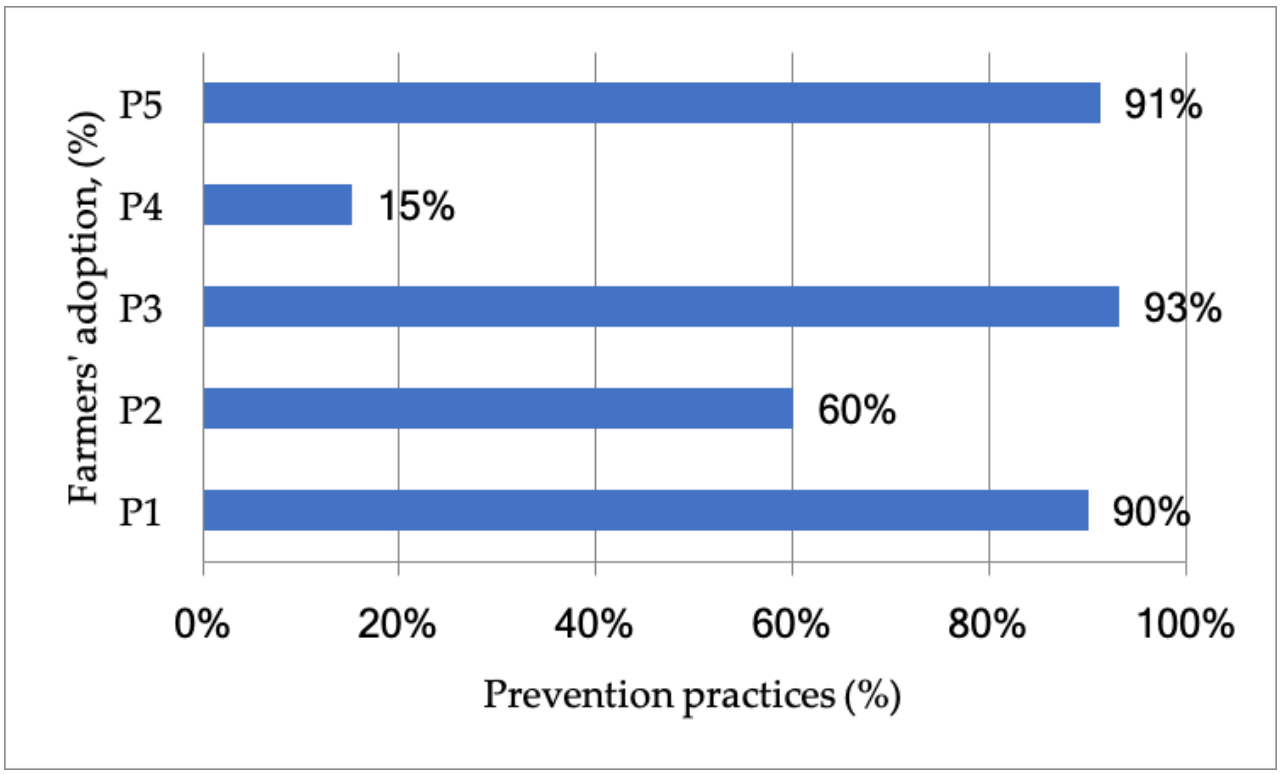

Figure 1. Farmers' adoption of prevention practices for red palm weevil control

Note: P1 = checking trees regularly to detect early infestation, P2 = removing offshoots as a protective measure, P3 = pruning and removing fronds in the winter, P4 = using pheromone traps to detect early infestation, P5 = treating lesions resulting from the pruning and offshoots detachment by using contact pesticides.

The adoption of the legislative practices investigated ranged between high and very high levels of adoption (Figure 2). The practice of "Not transferring infested trees or offshoots to non-infested areas" was the highest adopted measure by 95% of farmers, while "Surveying RPW-infested palms and informing authorities when necessary" was the measure least adopted by the respondents (82%).

The percentage of farmers with higher education (secondary and university levels) was 47.9% among the "moderate adopters" cluster, while the value was 24.1% among the "high adopters". However, the "high adopters" cluster had more farming experience than the "moderate adopters". The percentage of farmers with more than 20 years of experience was 57.1 among the "high adopters" against 30.8% among the "moderate adopters". Similarly, a quarter of the "high adopters" (24.5%) possessed off-farm incomes, compared to the "moderate adopters" (17.5%). Regarding the farm characteristics, the "high adopters" cluster had more farms with sizes superior to 5 feaddans than the "moderate adopters" cluster. However, the "moderate adopters" cluster had a higher number of trees, between 100 and 200 trees, than the "high adopters" (30.1% against 23.2%, respectively). The own farm was considered the main source of offshoots for 41.1% of "high adopters" and 32.8% of "moderate adopters".

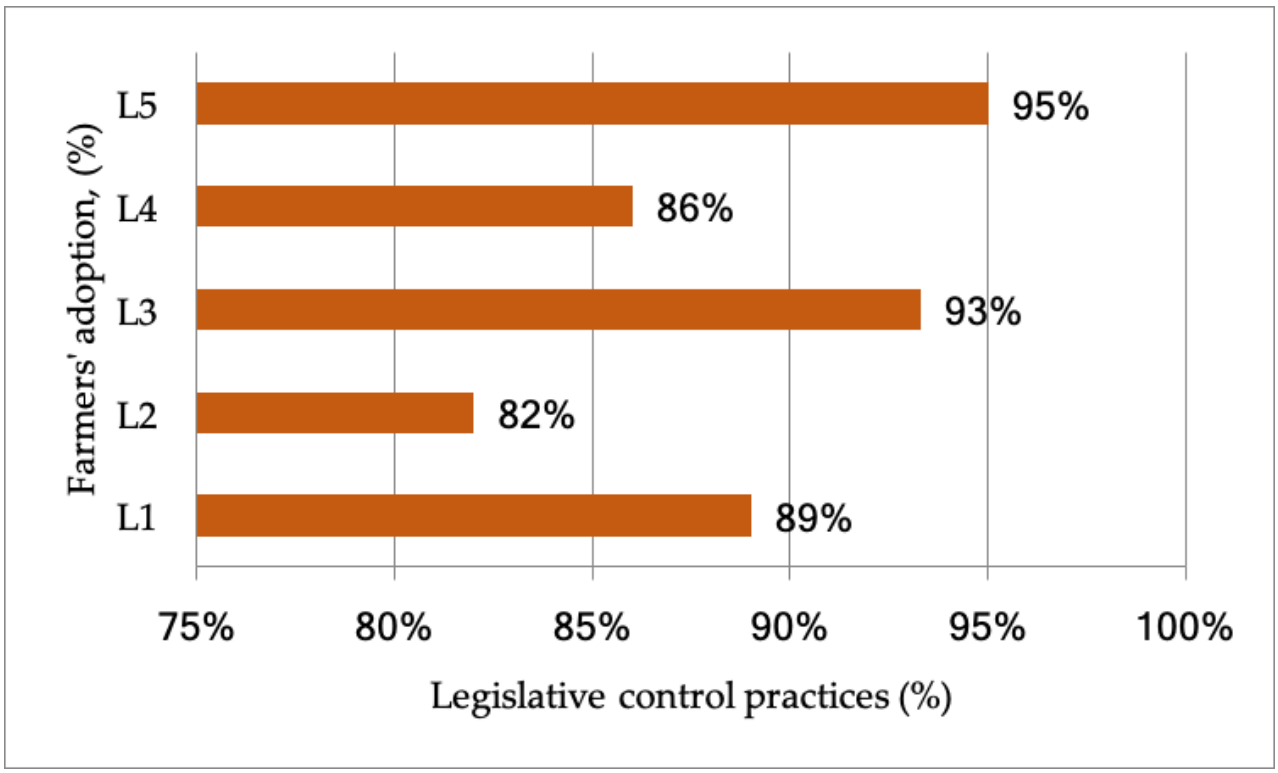

Figure 2. Farmers' adoption of legislative control practices for red palm weevil control.

Note: L1 = Not transferring infested trees or offshoots to non-infested areas, L2 = Burning and burying infested palm far away after cutting it into small portions, L3 =Not transferring infested palm waste to other regions, L4 =Surveying RPW-infested palms and inform authorities, when necessary, L5 = not allowing anyone to transfer infested offshoots from an infested farm.

As the legislative practices, the cultural ones were also highly adopted by farmers (Figure 3). The cultural control practices with the highest relevance rankings in the order of their adoption were adhering to the time and depth specified for planting offshoots (93%), applying moderate irrigation to reduce humidity on farms (91%), adhering to good ploughing before planting (87%) and maintaining the recommended distance between trees (85%).

The "high adopters" had a higher percentage of scattered date palms (irregularly spaced date palm farming systems) with flood irrigation than the "moderate adopters" (69.3% against 50% respectively). The "high adopters" cluster were also adopting the steam injection technique (73.4%) compared to the "moderate adopters" (56.1%). The "moderate adopters" showed more interest in Spraying (41.5%) than the "high adopter" group (7.3%).

The "high adopters" had received more training for RPW than the "moderate adopters" (30.1% against 18.7%, respectively). Likewise, the ratio of farmers who had received government support in the "high adopters" was 32% higher than the "moderate adopters". The "high adopters" had a higher percentage of farmers who had received technical support than the "moderate adopters" (42.5% and 11.8%, respectively). Similarly, 31.1% of the "high adopters" had an idea about the innovative extension approach "Farmers

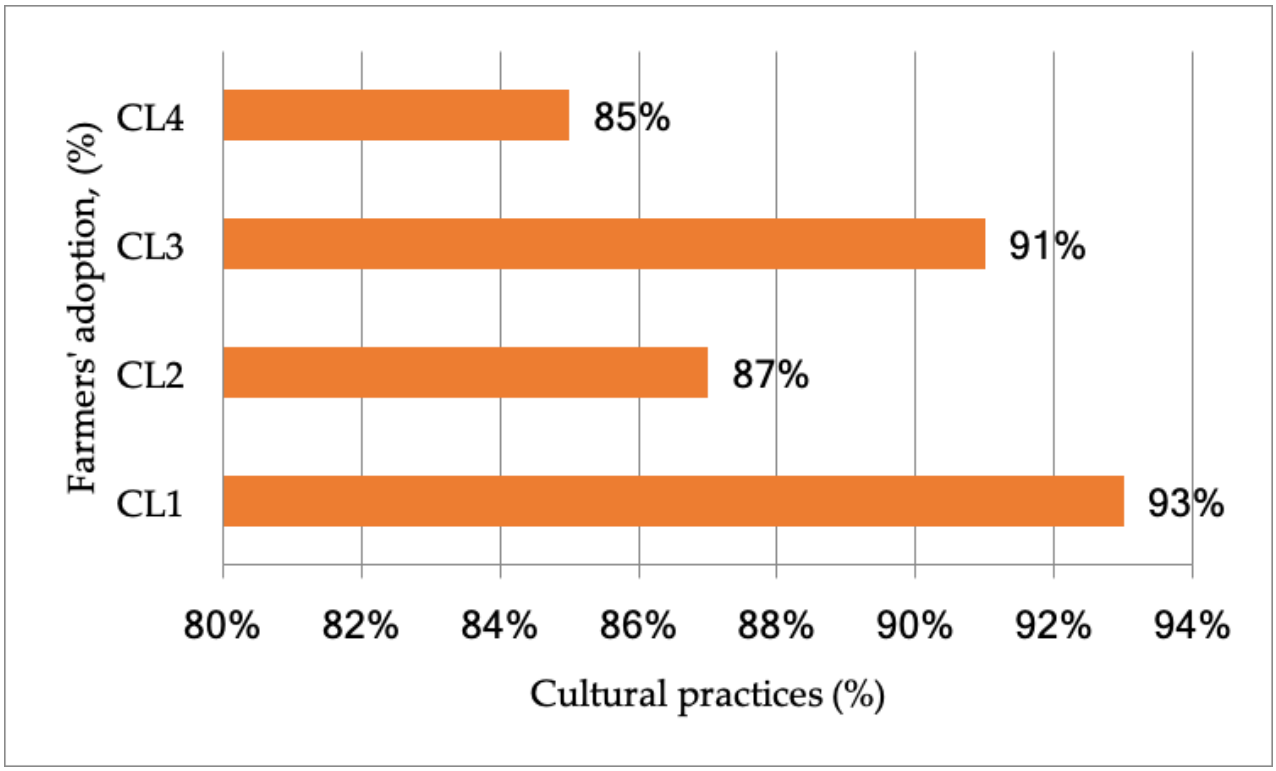

Figure 3. Farmers' adoption of cultural practices for red palm weevil control.

Note: CL1 = adhering to the time and depth specified for planting offshoots, CL2 = applying moderate irrigation to reduce humidity on farms, CL3 = adhering to good ploughing before planting, CL4 = maintaining the recommended distance between trees.

The adoption of mechanical practices was relatively high and ranged between 71% and 96% (Figure 4). The highest adopted approach by farmers was "covering roots of small trees with soil to a height of 20 cm to prevent insect attacks," with 96%, while the lowest adopted one was "scraping infested areas until healthy tissue is exposed," with a range of 71%. The four other mechanical practices were ranked in order of their adoption between 87% and 92%: removing weeds and dry trunks and disposing of them in the recommended way (92%), removing infested or dead trees and pruning products on neglected farms (90%), eradicating infested palms (88%), and closing all openings on the trunks of palms (87%).

Field School" against 14.4% of the "moderate adopters".

3.5. Perception of risk and governance effectiveness

The three governorates were ranked at the medium level with a slight difference in terms of perception risk, but on the other hand, As-Sharqia (scored 2 out of the maximum 5 index) appeared to be the most relatively vulnerable governorate in terms of governance effectiveness related to RPW (Figure 6). This governorate also ranked as most vulnerable when the risk rankings for perception risk and governance effectiveness indicators were combined. Additionally, Al-Wahaat Al-Bahria and Aswan were ranked at a medium risk level. In As-Sharqia, the training and the public support indicators (Figure 7) may explain the overall low-

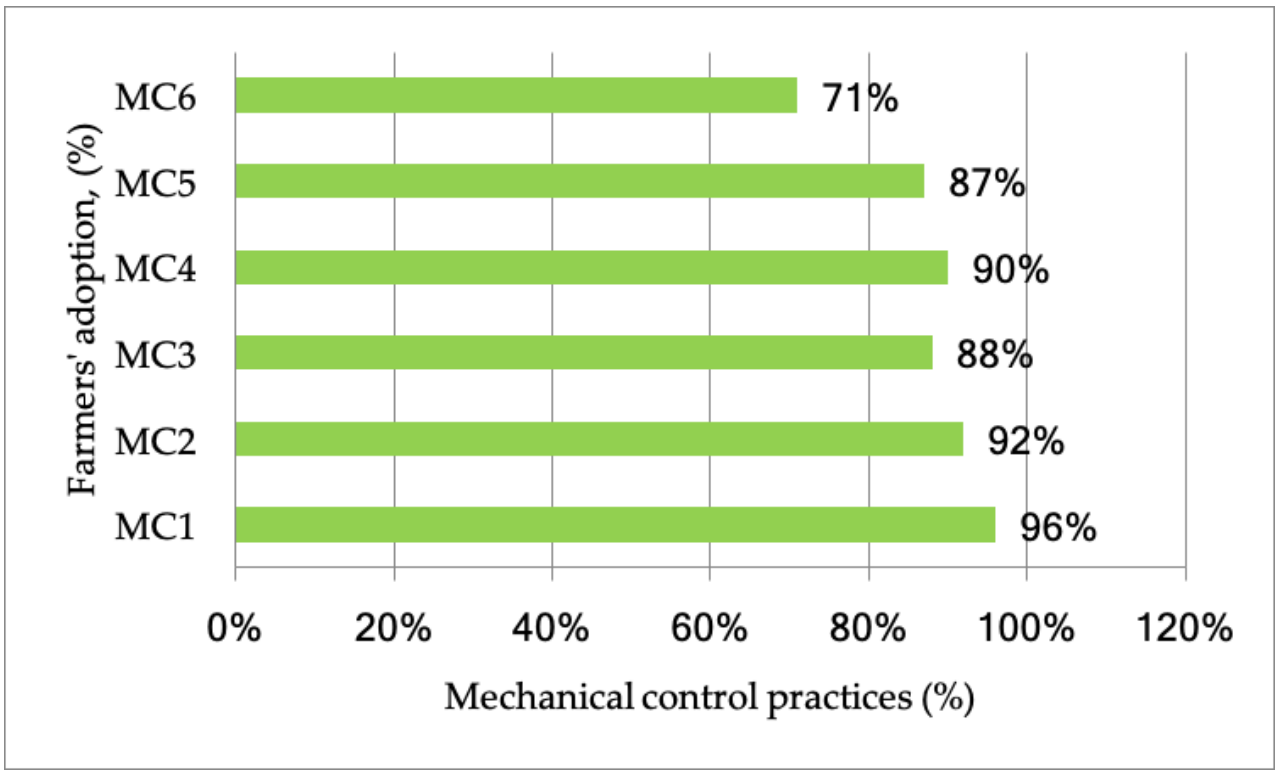

Figure 4. Farmers' adoption of mechanical practices for red palm weevil control.

Note: M1 = covering roots of small trees with soil to a height of 20 cm to prevent insect attacks, M2 = removing weeds and dry trunks and disposing of them in the recommended way, M3 = eradicating infested palms, M4 = removing infested or dead trees and the pruning products on neglected farms, M5 = closing all openings on the trunks of palms, M6 = scraping infested areas until healthy tissue is exposed.

The chemical control practices were considered moderately and highly adopted by farmers (Figure 5). In this sense, 91% and 83% of farmers had adopted the two chemical control practices, respectively, "spraying pesticides of a proper quantity and quality and within the specified time frame", and "spraying pesticides of a proper quantity and quality and within the specified time frame" and 67% of them have adopted the practice "dusting farms".

est level of vulnerability to the RPW invasion in Egypt. On the contrary, the high level of information and communication in Al-Wahaat Al-Bahria and technical management indicators in Aswan explain their combined medium level of vulnerability to RPW invasion.

4. Concluding Remarks and Policy Implications

We analyse the adoption of Integrated Pest Management (IPM) adoption for Red Palm Weevil (RPW) control among farmers in Egypt, focusing on the differences in adoption based on the farmers' socioeconomic and farm characteristics. The results highlighted that the overall adoption rate of the IPM categories for RPW control was high (83.85%), with adoption rates ranging between 89.04% for the legislative control and 70.15% for the preventive practices. In

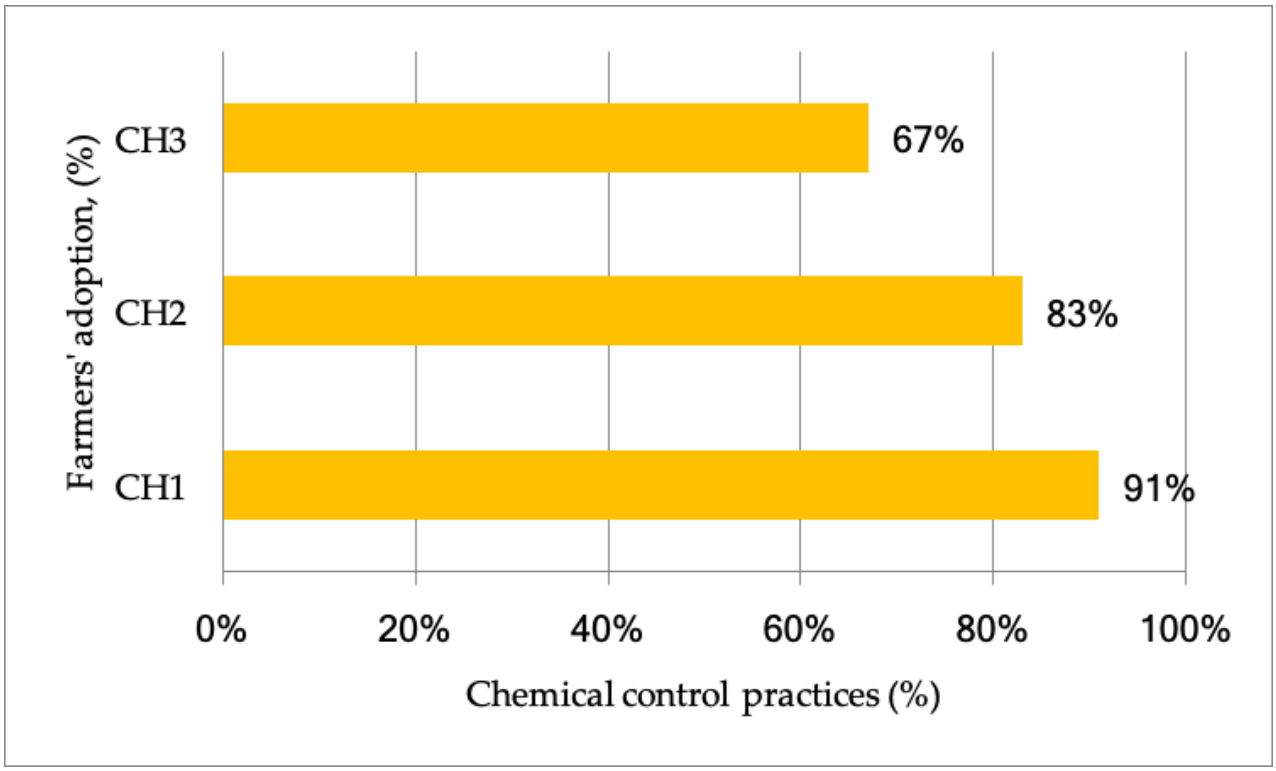

Figure 5. Farmers' adoption of chemical control practices for red palm weevil control.

Note: CH1 = spraying according to the extension recommendations, CH2= spraying pesticides of a proper quantity and quality and within the specified time frame, CH3 = dusting farms

The percentage of the overall adoption of RPW IPM practices was 83.85%, indicating a high level of farmers' adoption. By category, legislative control practices (89.04%) were ranked first in terms of RPW IPM adoption, followed by cultural practices (88.92%), mechanical control practices (87.27%), chemical control practices (80.27%), and prevention practices (70.15%).

addition, two groups of farmers were identified based on the average score of the RPW IPM: the "high adopters" and "moderate adopters".

This research has implications for policymakers. Despite the high adoption rates, there is a need to assist Egyptian farmers in adopting and applying 23 RPW IPM practices. In this sense, the government must first strengthen farmers' agricultural production knowledge, especially focusing on knowledge of IPM management. Secondly, the government should promote IPM technology using various methods in the context of farmers' individual and family characteristics. To increase IPM adoption of RPW among farmers, facilitating knowledge-sharing on the consequences of IPM compliance is essential. This can be achieved by organizing extension approaches such as farmer field schools and considering the farming context and the demographic profiles of farmers (Kassem et al., 2020). Because the adoption rate of preventive practice was the lowest among the IMP categories, specific programs should develop farmers' skills in using prevention measures (preventive insecticide treatments based on infestation foci and trap capture data, early detection devices or techniques for RPW infestation,

Table 2. Difference between clusters according to the adoption of IPM practices for RPW control

Practices	Cluster I (n = 34.1%)		Cluster II (n = 65.9%)		Mann–Whitney U	Z
	Mean	SD	Mean	SD		
P1	0.87	0.338	0.92	0.275	12.877.000	-1.432
P2	0.57	0.497	0.62	0.487	12.866.000	-0.889
P3	0.85	0.363	0.98	0.134	11.686.000	-4.833***
P4	0.13	0.338	0.16	0.371	13.076.000	-.0830
P5	0.80	0.398	0.98	0.134	11.136.000	-5.732***
L1	0.87	0.338	1.00	0.067	11.831.500	-5.130***
L2	0.63	0.484	0.99	0.095	8.703.000	-9.202***
L3	0.88	0.329	0.96	0.188	12.372.000	-3.035***
L4	0.58	0.496	0.95	0.218	8.486.500	-8.538***
L5	0.69	0.464	1.00	0.067	9.411.500	-8.505***
C1	0.82	0.385	0.99	0.095	11.233.000	-5.903***
C2	0.67	0.473	0.98	0.149	9.327.500	-8.084***
C3	0.79	0.410	0.97	0.176	11.100.500	-5.401***
C4	0.70	0.460	0.94	0.236	10.259.500	-6.075***
M1	0.89	0.309	0.99	0.095	12.223.000	-4.190***
M2	0.80	0.404	0.98	0.134	11.026.000	-5.900***
M3	0.67	0.470	0.99	0.095	9.253.000	-8.553***
M4	0.76	0.431	0.98	0.149	10.537.500	-6.480***
M5	0.67	0.473	0.99	0.116	9.204.500	-8.479***
M6	0.59	0.493	0.78	0.414	10.982.000	-3.697***
CH1	0.77	0.421	0.98	0.134	10.696.000	-6.387***
CH2	0.58	0.496	0.97	0.163	8.179.000	-9.358***
CH3	0.20	0.404	0.94	0.245	3.611.000	-13.865***

Source: Own elaboration based on filed data (2023).

*Note: ***, **, * Denotes statistical significance at the 0.01, 0.05, and 0.1 probability levels, respectively.*

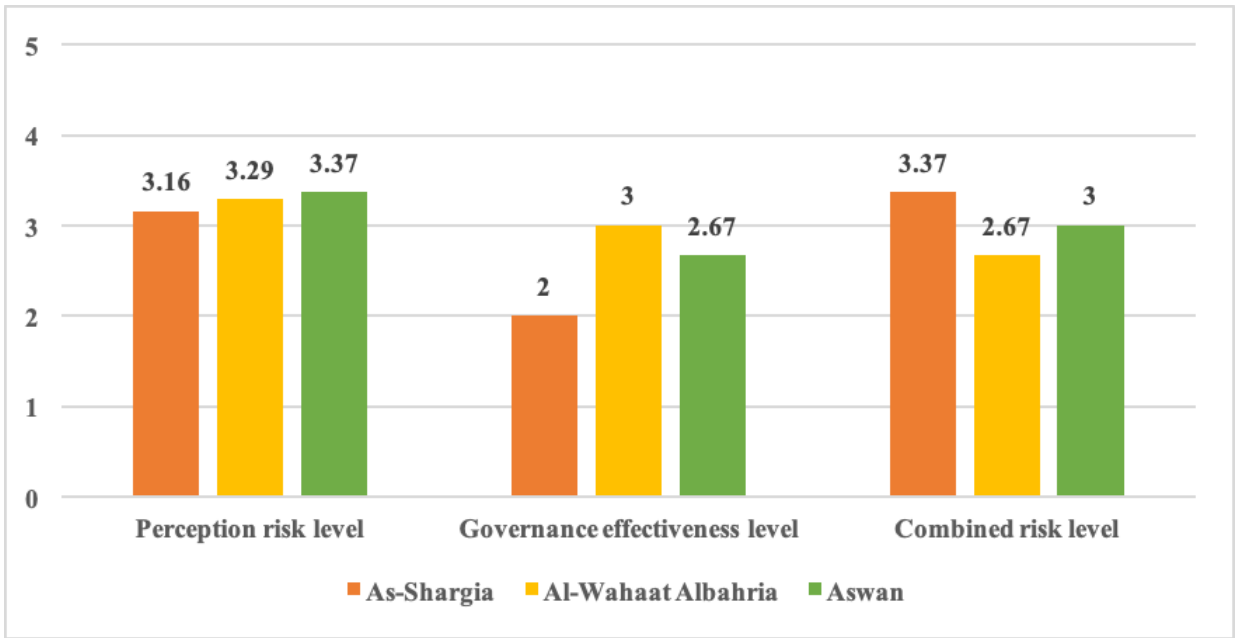

Figure 6. Red Palm Weevil in Egypt: Assessment of the perception risk and governance effectiveness.

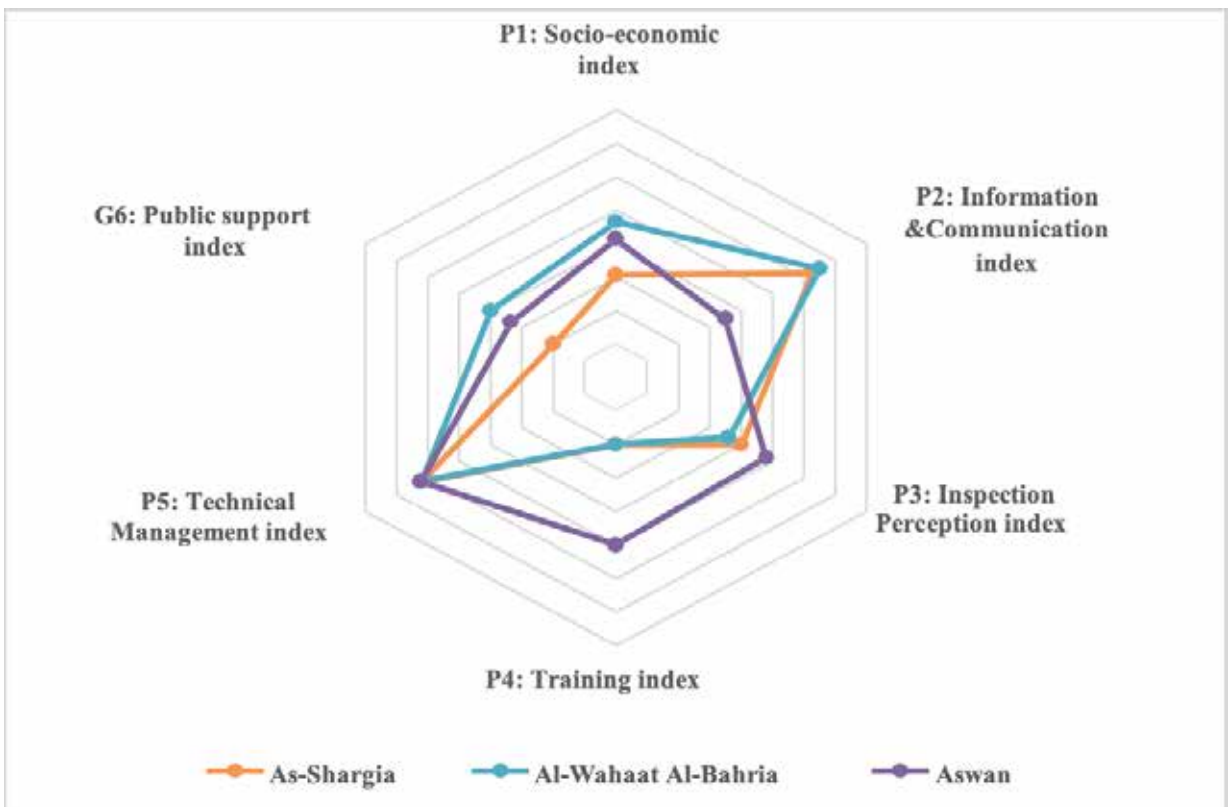

Figure 7. Rank categorization of Egypt's governorates according to six perception risk and governance effectiveness indicators of Red Palm Weevil.

and the application of follow-up plans), implementing good agronomic practices that limit the RPW attack, and adopting both visual observation and pheromone traps (Alotaibi et al., 2022). Furthermore, all Egypt governorates were similarly ranked regarding perception risk related to RPW. Compared to Aswan and Al-Wahaat Al-Bahria, As-Shargia was the most vulnerable governorate in terms of perception risk and governance effectiveness related to RPW, characterized by lower training and public support index levels.

Prospects of RPW management may include validation of management programs, testing high-tech technologies for practical field application, and using Ribonucleic Acid interference technology (RNAi) ( ) in management programs. In conclusion, managing RPW in the field is not an easy task, but with adequate resources and appropriate interventions supported by good coordination, planning, and financial resources, the pest can be effectively controlled with the current technologies. In this context, Al-Zyoud et al. (2021) recommended promoting awareness among farmers, citizens, municipalities, researchers, non-governmental organizations, and decision-makers about the significance of RPW control. Furthermore, there is a need to promote coordination and cooperation among institutions at the global level, use social media for information transmission, and well-known journalists to contribute to raising awareness, networking, capacity building, communication, extension service, and research.

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