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What influences uptake of alternative pest management practices by potato farmers? Evidence from six counties in Kenya

Idah Mugambi[1*], Lucy Karanja[1], Isaac Macharia[2], Wachira Kaguongo[5], George Ngundo[2], Ruth Amata[3], Fernadis Makale[1], Jane Wanjiku[2], Duncan Chacha[1], Moses Nyongesa[3], John Wangai Kimenju[4], Willis Ochilo[1] and Joseph Mulema[1]

[1]Centre for Agriculture and Bioscience International (CABI), Canary Bird, Nairobi, Kenya.
[2]Kenya Plant Health Inspectorate Service (KEPHIS), Nairobi, Kenya.
[3]Kenya Agricultural and Livestock Research Organization (KALRO), Nairobi, Kenya.
[4]Faculty of Agriculture, Department of Plant Science and Crop Protection University of Nairobi, Nairobi, Kenya.
[5]National Potato Council of Kenya (NPCK), Nairobi, Kenya.

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Potato pest and disease management has been dominated by chemical pesticides, despite their potential undesirable effects on the environment, food safety and human health. This study explores factors influencing intensity of uptake of alternative pest management practices among potato farmers in Kenya, through a survey of 1,002 farmers in six main potato growing counties in the country. A Poisson count model was used to determine the intensity of uptake of alternative pest management practices. On average, farmers employed five practices: weeding, fertilizer application, recommended spacing, scouting, and crop rotation. Age of respondent (older farmers) and utilization of face-to-face and participatory extension approaches were significantly and positively associated with intensity of uptake of alternative pest control practices. Passive sources of extension advice such as radio and television were inversely related to uptake intensity of alternative pest control practices. These findings underscore the efficacy of agricultural information sources that are practical in approach, as they have the greatest potential to influence farmers' adoption decisions. Mass communication methods create awareness and provide information at low-cost, but are not sufficient in triggering behaviour change when used on their own. There is therefore need to integrate them with conventional extension approaches to achieve the duo benefit of scale and adoption.

Keywords: Potato, Alternative pest management practices, Poisson count model, Kenya.

INTRODUCTION

Potato (*Solanum tuberosum* L) is a major crop in tropical highland regions of Sub-Saharan Africa. It is grown both

*Corresponding author. E-mail: i.mugambi@cabi.org.

as a horticultural crop and as a food security crop. Globally, potato is the fourth most important food crop based on production, after maize, rice and wheat, with annual production estimated at 388 million tons in 2017 (FAO, 2019). In Kenya, potato is the second most important staple food crop after maize, and has been identified as a key contributor to the attainment of Sustainable Development Goal 2 on zero hunger (Kamau et al., 2020; Ndegwa et al., 2020). The crop is rich in several essential nutrients including carbohydrates, proteins, vitamin C (ascorbic acid), vitamin B6, fibre and minerals such as calcium, magnesium, phosphorous, potassium, and fibre (Gibson and Kurilich, 2013; Zaheer and Akhtar, 2016). It plays an important role as a food staple among producing households and provides income, contributing to the alleviation of poverty (Muthoni et al., 2013).

Potato production requires a cool temperature of 15 to 18°C, a soil pH of 5.5 to 6 and at least 1000 mm of rainfall per annum (Muthoni and Kabira, 2015). The five major potato-growing regions are found in the highland areas of Kenya, at altitudes of 1500 to 3000 m above sea level. These are the Mt. Kenya region (Embu, Meru and Kirinyaga counties); Central region (Kiambu, Murang'a, Nyandarua, parts of Nyeri county); the Central Rift region (Bomet, Narok and Nakuru counties); North Rift region (Uasin Gishu, Elgeyo Marakwet, Trans-Nzoia, and Bungoma counties); and Coast region (Taita Taveta county) (Were et al., 2013; Muthoni and Nyamongo, 2009).

Potato production continues to be undermined by lack of quality, certified seed (Mumia et al., 2018). Most farmers obtain seed from the informal seed sector which includes either seed saved from season to season, obtained from fellow farmers or bought from the local market (Muthoni et al., 2010). The lack of quality seed leads to use of own saved tubers from previous harvests or purchased from markets, causing high build-up of pests and diseases. Coupled with this, is the problem of low soil fertility, which causes malnourished crops vulnerable to pests and diseases (Muthoni and Nyamongo, 2009). Owing to these challenges, the productivity of potato has been on the decline in Kenya, averaging 10 tons per ha, which is far below potato yield potential of 40 tons per ha as recorded in America and Europe (Were et al., 2013). This has led to low incomes among small holder potato farmers, further restricting them to subsistence agriculture.

The major diseases of potato in Kenya are bacterial wilt (*Ralstonia solanacearum*), late blight (*Phytophthora infestans*) and viruses (Muthoni et al., 2014). Bacterial wilt is mainly spread through infected seed, and key practices recommended for management comprise use of disease-free certified seed, use of resistant varieties, rotation with non-Solanaceous crops and field sanitation. Regular scouting, roguing and subsequent disposal of infected plants as well as weeding and earthing up (piling up soil around the base of the plant) are also some of the recommended practices for control of bacterial wilt (Muthoni et al., 2012; 2014). Key management practices for late blight include use of resistant varieties and use of recommended fungicides (Ojiambo et al., 2001; Misganaw, 2016). Viral diseases on the other hand can be managed by use of resistant varieties and weeding to remove volunteer Solanaceous weeds that could be virus reservoirs (Were et al., 2013), and controlling vectors, notably aphids. The fact that these major diseases of potato can be effectively managed through non-chemical practices accentuates the need to pay more attention to these practices.

Various studies have been done examining the factors affecting farmers' adoption of pest control/management practices (Bonabana-Wabbi, 2002; Balasha, 2019; Emongor and Uside, 2019). There is, however, limited literature on the factors which determine the extent to which farmers choose to apply the various alternative (non-chemical) pest management practices, particularly for the potato crop. This study seeks to fill this knowledge gap by evaluating the factors influencing level of adoption of alternative pest management practices in potato farming. The alternative pest management practices under consideration include use of improved seed, use of recommended spacing, fertilizer application, scouting for pests and diseases, crop rotation, weeding, irrigation, and intercropping. Specifically, the study addressed the following objectives: assessed farmer production systems currently used in potato production; assessed the extent of utilisation of alternative pest management practices by small holder farmers; and evaluated the effect of socio-economic factors, farmer location and source of agricultural information on pest management decisions by farmers. The study used data from a survey of 1,002 potato farmers from six counties in Kenya. Findings are expected to contribute useful data to the literature on pest management in several regards. First, potato belongs to the Solanaceae family which comprises several crops of high agricultural value in Kenya such as tomato, pepper and eggplant, and findings could be directly applicable to these crops. Findings could also offer useful information to policymakers in the development of more informed national action plans for the sustainable management of pests in Kenya.

METHODS

Study areas

The study was carried out in six major potato growing counties in Kenya: Elgeyo Marakwet, Meru, Nakuru, Narok, Nyandarua and Trans-Nzoia (Figure 1). Information on the main biophysical characteristics and crops grown in the study areas is presented in table 1.

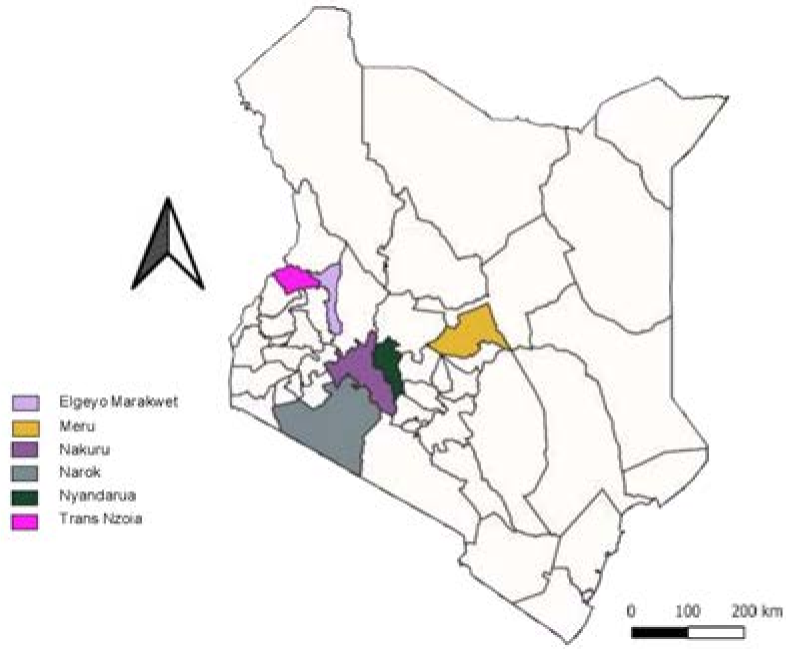

Figure 1. Counties where the survey was carried out.

Study population and samples

Nyandarua, Nakuru, Meru, Trans-Nzoia, Narok and Elgeyo Marakwet counties were chosen as they are leading potato producing counties, and/or counties with potential to produce disease-free planting material, as well as high potential to expand production of potatoes for consumption. The study population comprised potato growing households in the six counties. Sample size was calculated using the formula below (Israel, 1992):

$$n_o = \frac{Z^2 \times p \times (1-p)}{C^2}$$

Where: *Z* is the value for a selected alpha level (indicating the level of risk the researcher is willing to take that true margin of error may exceed the acceptable margin of error); p is the proportion of the population assumed to be potato farmers in the six counties as at the time of the study; and C is the confidence interval. Using 95% degree of confidence and 3% margin of error, the sample size was estimated at 1,067. Using probability proportional to size, the sample was distributed across the study counties based on the number of potato growers per county. At the end of the exercise, a total number of 1,002 households were interviewed. Table 2 shows the distribution of respondents per county.

Data collection

Data were collected in December 2019 using a semi-structured questionnaire. The questionnaire was programmed on Open Data Kit (ODK) and administered by trained enumerators. The questionnaire was pretested by the enumerators before full deployment. Informed consent was obtained from respondents before the interviews. The team leader explained the purpose of the study and that data would be used for research purposes only and would not affect the anonymity of the farmer. The questionnaire contained sections collecting information on farmer demographics, crops grown and agronomic practices used, potato varieties cultivated, potato pests and diseases, and sources of agricultural information on potato production used by the farmer.

Analytical framework

A farmer's decision to adopt a technology is dependent upon the utility gained from that technology or a combination of technologies. According to Nkegbe and Shankar (2014), adopting a technology is only considered viable if the marginal benefit of adopting it is at least equal to the marginal cost, and farmers will generally choose a technology or set of technologies that maximize their utility. Further, adoption of technologies is multivariate in nature mainly due to the complementarities and interdependencies among the different technology bundles (Kinuthia et al., 2019; Kansiime et al., 2020). This study assessed the uptake of alternative pest management practices: use of improved seed, use of recommended spacing, fertilizer application, scouting for pests and disease, crop rotation, weeding, irrigation, and intercropping. These practices either prevent the occurrence of pests and diseases and/or involve manipulation of the environment/habitat such that the disease-causing organisms already present are not able to thrive (Li et al., 2019; Kinuthia et al., 2019). In this way, they eliminate the overreliance on chemical pesticides which not only increase production costs, but also cause harm to the environment if used in an inappropriate manner (Lewis et al., 1997). Farmers employed these alternative pest management practices in combination and the intensity of use ranged from 2 to 8 practices (Figure 3). The Poisson count regression model was estimated with the dependent variable as the number of alternative pest management practices used (intensity of uptake) by each respondent. Explanatory variables were age, sex, county as well as dummy variables

Table 1. Main biophysical characteristics and crops grown in the study areas.

County	Average annual rainfall (mm)	Mean annual temperature (°C)	Altitude (masl)	Main crops grown
Elgeyo Marakwet	700 - 1700	18 - 28	900 - 3000	Maize, Beans, Wheat, Potatoes, Avocado, Passion
Nakuru	500 - 1800	16 - 19	900 - 2700	Maize, Beans, Potato, Wheat
Narok	500 - 2500	10 - 20	1000 - 3100	Wheat, Barley, Maize, Beans, Potatoes, Horticultural crops
Trans-Nzoia	900 - 1400	10 - 30	1400 - 4313	Maize, Beans, Wheat, Tea, Potatoes
Nyandarua	700 - 1600	7 - 21	1113 - 3999	Potatoes, Maize, Garden peas
Meru	300 - 2500	8 - 32	300 - 5199	Wheat, Barley, Potatoes, Millet, Sorghum, Maize

Source: GoK (2018): https://www.cog.go.ke/downloads/category/106-county-integrated-development-plans-2018-2022.

Table 2. Number of respondents by county, gender and age category.

County	Gender		Age (years)				
	Female	Male	<30	31 to 35	36 to 45	46 to 55	>55
Nyandarua	147	170	25	37	73	92	90
Nakuru	109	159	26	34	76	66	66
Meru	50	72	3	20	37	36	26
Transnzoia	53	57	13	16	24	28	29
Narok	32	62	6	11	15	42	20
E. Marakwet	30	61	12	9	23	24	23
Total	421	581	85	127	248	288	254

representing sources of agricultural information utilised by farmers. The choice of explanatory variables is consistent with other studies (Awuni et al., 2018; Kansiime et al., 2018; Kinuthia et al., 2019).

The dependent variable was expressed as a function of the explanatory variables (Xi): Ti = α + βiXi, where Ti is the number of alternative pest management practices applied by the farmer i, and β is the estimated parameter for each explanatory variable. The marginal effects in the Poisson model were computed by differentiating the function with respect to the predictor variable X_i, as follows: $\frac{dTi}{dxi} = \beta\ (\alpha\ + \beta iXi)$. This marginal effect was interpreted as a unit change in the response variable resulting from a change in the predictor variable (Nkegbe and Shankar, 2014; Kansiime et al., 2018)

Data analysis

Data were analysed using the STATA software (Version 15, StataCorp, College Station, Texas). Frequencies, means and standard errors were calculated, and Chi-Square tests of independence used to test for significance in the relationship between different categorical variables. Poisson regression model was used to estimate the effect of explanatory variables on utilisation of alternative pest control measures.

RESULTS AND DISCUSSION

Potato production systems

The majority of respondents across all counties indicated that among the crops they cultivated, potato was the most important economically, followed by maize and beans respectively. The

Table 3. Number of farmers utilising different sources of potato seed, by county.

County	Own seed	Fellow farmers	Seed distributors	Market
Nyandarua	233	147	28	6
Nakuru	170	161	36	2
Meru	45	44	26	10
Transnzoia	9	64	12	26
Narok	48	58	64	5
Elgeyo Marakwet	16	67	6	2
Total	521	541	172	51

*Multiple responses

average acreage of each of the three crops was 1.88, 1.69 and 3.7 acres, respectively. The three crops were cultivated for both subsistence and income. The main potato varieties cultivated across all counties were Shangi (90%), Dutch Robijn (3%) and Asante (2%). The top five pests and diseases reported were late blight (85%), early blight (54%), bacterial wilt (41%), white flies (9%) and aphids (9%). The main sources of potato seed were fellow farmers and own saved seed (Table 3). A chi square test for independence showed that there was no significant association between potato seed source and gender of respondent. There was, however, a significant association between potato seed sources and respondent county ($p<0.01$).

Most of the farmers interviewed practised crop rotation and/or intercropping, mainly with maize, garden pea, beans, cabbage and coffee. Only 21% grew potatoes only, without intercropping or rotating with other crops. Some farmers (0.5%) reported rotating potato with tomato, despite the fact that both crops belong to the same family and as such experience similar pest and disease issues. This emphasizes the need for awareness about recommended crops for rotation with potato as well as the length of the rotation as these have implications on the effectiveness of crop rotation as a pest management method. A few farmers had left the land fallow for a few seasons before growing the potato crop.

Intensity of uptake of alternative pest management practices

A summary of the percentage of farmers using different alternative pest management practices, and the frequency distribution of the number of alternative pest management practices employed is presented in Figures 2 and 3, respectively. On average, farmers applied five practices, with fertilizer application and weeding being the most common practices, while irrigation had the lowest percentage of users. Irrigation is infrequently used in the study area most likely because these counties enjoy good rainfall and the potato crop is not planted year-round.

Only 0.6% of the farmers applied all eight practices, emphasizing the need for more awareness creation. If used in an integrated manner, each of these practices provides some level of protection against pests and diseases and/or minimizes the damage resulting from such attacks and therefore the more practices a farmer can apply, the better protected the crop shall be. Efficient fertilizer use makes crops healthy, and consequently, less susceptible to pest attacks. Such crops are also able to recover quickly from a pest invasion (Sarwar, 2011). Weeding gets rid of unwanted plants which could potentially serve as alternative hosts for insect pests and disease vectors. It also minimizes competition for nutrients, thereby enabling the growth of healthy crops which are able to withstand attack by insect pests and diseases (Norris and Kogan, 2005). Observing the recommended spacing prevents overcrowding of plants and consequently, checks the spread of pests and diseases from one plant to another (Sarwar, 2008). In some cases, however, high plant density has been reported to reduce pest infestation (Dara, 2019). Scouting enables the farmer to quantify pest pressure and thereby make evidence-based pest management decisions (Dara, 2019). Crop rotation on the other hand prevents build-up of soil-borne pathogens in the soil, improves nutrient cycling and enhances soil structure (Peters et al., 2003; Kakuhenzire et al., 2013). Intercropping has the potential to minimize pest damage by making target plants difficult to find since they are more dispersed, with the intercrop serving as an alternative resource for the pests to feed on (Murrell, 2017). Improved seed is seed that has been bred for good traits including the capacity to withstand adverse conditions as well as pest and disease resistance. Using improved seed, as opposed to recycled owned seed or seed from unknown sources will help reduce the incidence of seed-borne diseases (Gildemacher et al., 2009). Irrigation is important to reduce moisture stress which could make crops susceptible to pest attacks. Drip irrigation has also been

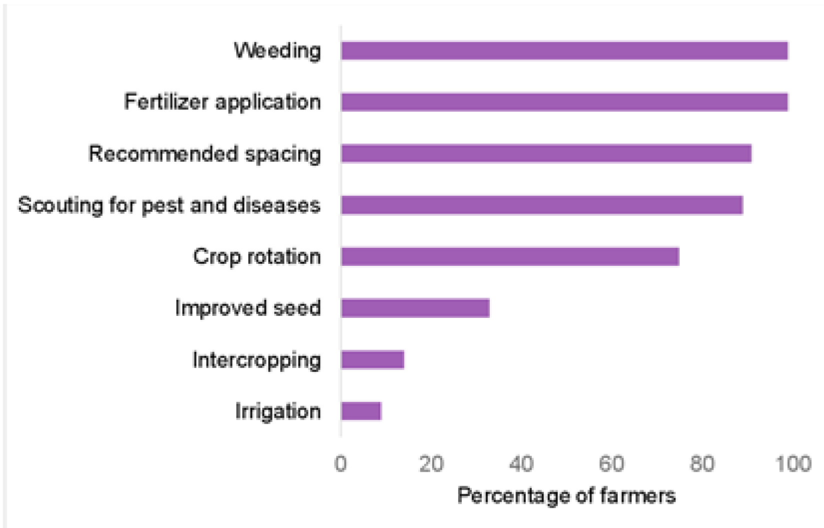

Figure 2. Alternative pest management methods used by farmers.

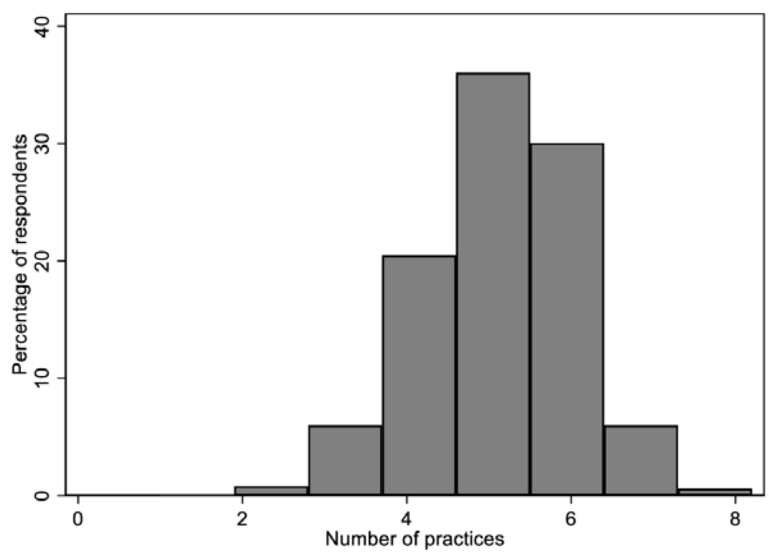

Figure 3. Frequency distribution of the number of alternative pest management practices used by farmers.

used to apply agricultural chemicals to the crop's root zone (Ghidiu et al., 2012).

A Poisson regression model was used to estimate the effect of explanatory variables on utilisation of alternative pest control practices and Table 4 presents results from this regression. Compared to respondents aged more than 55 years, respondents aged less than 30 years were more likely to apply significantly fewer alternative pest management practices. On the other hand, uptake of alternative pest management practices did not differ between respondents in the other age categories, and those aged above 55 years. According to Mahama et al. (2020), as farmers grow older and assume more responsibilities, they tend to take up new technologies that will maximize their yield and enable them to meet the needs of their dependents. Findings by Obuobisa-Darko (2015) also showed that older farmers were more likely than younger ones to adopt new technologies, due to better access to capital and availability of labour from household members. This is especially so for

Table 4. Parameter estimates for the determinants of the intensity of uptake of alternative pest management methods.

Variable	Marginal effect	Std. error
Age: <30 years[a]	-0.328***	0.113
Age: 31-35 years[a]	-0.046	0.090
Age: 36 to 45 years[a]	0.030	0.079
Age: 46 to 55 years[a]	0.108	0.075
Sex of respondent (1=male)	-0.089	0.057
Source of information (1=access, 0=otherwise)		
Own experience	0.145	0.136
Demonstration plots/ field days/FFS	0.264***	0.065
Neighbours, family and friends	-0.048	0.059
Farmer cooperative	0.046	0.069
Lead farmer or village-based advisor	0.093	0.075
Mobile SMS	-0.007	0.088
Magazine, newspaper, leaflets	0.073	0.078
Agricultural program on radio/TV	-0.248***	0.068
Government extension officer	0.140**	0.067
Agro-dealer	0.084	0.064
County		
Trans-nzoia[b]	-0.119	0.124
Nyandarua[b]	0.722***	0.107
Nakuru[b]	0.832***	0.107
Narok[b]	1.229***	0.112
Meru[b]	1.852***	0.124

[a]Base category= age >55 years; [b]Base category=Elgeyo Marakwet county
*** p<0.01, ** p<0.05

technologies that requires significant capital and labour investments. Claims that youth are generally innovative and have a higher propensity than older people to adopt new technology are not supported by empirical evidence (Sumberg and Hunt, 2019).

The sex of the respondent was not statistically significant, implying that the level of adoption did not differ between male and female farmers. This is in tandem with findings by Gebre et al. (2019) that the rate and extent of adoption of improved maize varieties did not differ between male and female headed households. Sulo et al. (2012) posits that the uptake of technologies by female farmers is largely contextual and cultural, and also depends upon the type of technology. Other studies have shown a higher likelihood of technology adoption among male than female farmers, mainly due to access and control of resources, decision making dynamics at the household level and cultural factors (Adekemi, 2014; Hailu et al., 2014; Namonje-Kapembwa and Chapoto, 2016; Awuni et al., 2018).

With regard to sources of information, farmers who utilized demonstration plots/field days/farmer field schools were more likely to use multiple pest management practices. This agrees with Awuni et al. (2018) who found that demonstration plots positively influenced farmer uptake of more improved agricultural technologies. Farmer field schools (FFS)/field days and demonstration plots follow a participatory experiential approach to learning, where farmers “learn by doing”. Activities at the demonstration/FFS plots take place concurrently with activities at the participating farmers’ field. This way, the farmer directly applies the technology to his individual farm, and at the same time learns from the model farm. Further, the farmer not only learns how a certain technology is applied but also why it is important and this increases the probability of adoption (Braun and Duveskog, 2008). Anandajayasekeram et al. (2007) posits that the principles of FFS, if incorporated into existing extension systems, have the potential to increase the efficiency of such systems.

Government extension officers as a source of information was also associated with uptake of more pest management practices. This is consistent with findings by Mahama et al. (2020) who reported a positive impact of extension agents on the extent of adoption of soya bean technologies and Obuobisa-Darko (2015) who found out that extent of adoption of cocoa research innovations was positively related to frequency of extension advice. This finding, however, contrasts with Awuni et al. (2018) who found that farmers who received information through extension adopted fewer improved rice technologies. This shows that inasmuch as extension officers have the potential to positively influence the adoption of new technologies, it is important for them to have a proper understanding of farmer context and needs and only recommend technologies that are suitable and practical to the farmers. It is also paramount for the extension officers to create rapport, build trust with the farmers and use a collegiate approach as opposed to displaying a sense of superiority. All these factors will heavily influence how a new technology will be received by farmers (Mwangi, 1998).

Listening to agricultural programs on radio or watching them on TV was associated with uptake of fewer alternative pest management practices. This could be due to the fact that the programmes aired on radio or TV often broadcast relatively generic advice to the heterogeneous farming population and also lack feedback mechanisms to aid learning (Steinke et al., 2020). Some programmes provide the opportunity for farmers to call in and ask questions but it may not be possible for all farmers to have their questions answered due to time and technological constraints. Further, the lack of follow up and accountability especially in the absence of platforms such as radio listenership groups implies that a farmer could miss out on some important episodes of a program because they are busy with farm labour or household chores, or because contents are perceived as irrelevant (Mwombe et al., 2014). A study by Agwu et al. (2008) on adoption of improved agricultural technologies disseminated via radio cited low adoption rates mainly due to short duration of programme, inappropriate programme scheduling, lack of opportunity to ask relevant questions and seek feedback from the radio presenter, as well as language barrier. The benefits of radio and TV as extension tools can be fully harnessed if used in combination with other methodologies such as extension visits and village-based video screenings (Ahmad et al., 2007; Tambo et al., 2019).

Compared to Elgeyo Marakwet county, farmers from Nyandarua, Nakuru, Narok and Meru were more likely to use multiple pest management practices. On the other hand, the intensity of uptake did not differ between farmers from Trans-Nzoia and Elgeyo Marakwet counties. This could be due to famers from the various counties being exposed to different information sources and having different resource endowments.

Conclusion

The use of alternative pest management practices by potato farmers can go a long way in not only reducing cost of production due to reduced expenditure on pesticides, but also contribute to environmental conservation and minimise the risks associated with pesticide misuse. This study explored the factors influencing extent of adoption of alternative pest management practices. Farmers used various alternative pest control practices besides pesticides for the management of the key potato pests. The most commonly used practices were fertilizer application and weeding. Older farmers were more likely than younger ones to make use of alternative pest management technologies. Government extension officers and demonstration plots/FFS had a positive influence on uptake of alternative pest management technologies, while the effect of radio and TV was negative. Given the importance of alternative pest management practices in managing potato pests and diseases, it is important that outreach methods that have the highest probability of inducing uptake are used. These outreach methods should however complement each other, as no method can achieve the desired result if used alone. Further, approaches such as farmer field schools that emphasize on learning by doing are more desirable in triggering sustained behaviour change as far as technologies are concerned. Socio-demographic characteristics should also be considered in the quest to encourage use of such technologies.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interest.

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