

Making sense of the science behind fruit fly control

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Abstract. The removal of traditional organophosphate sprays to control fruit fly in Australia has prompted the implementation of Area-wide management as a solution to manage Mediterranean fruit fly (Medfly) in the southwest of Western Australia, which requires participation of both commercial and backyard fruit growers. One of the reasons for the low uptake of Medfly control is people failing to recognise the importance of controlling fruit fly all year round. A fruit growth development calendar of 27 common fruit plant species was prepared to demonstrate the influence of Medfly occurrence on properties from an individual and collective perspective. This material together with information based on the fruit fly life cycle served to engage the public and to 'make sense' of the ecological principles that explain persistent Medfly populations despite control efforts. Meaningful scientific evidence helps interpret the natural processes surrounding Medfly, facilitating the communication process required to improve Medfly control.

Keywords: Medfly, pest management, tools, backyards, orchards, engagement

Introduction

Fruit flies are an important group of insect pests that globally attack a wide range of fruit and vegetables, with significant economic implications for horticultural production and market access. Mediterranean fruit fly (Medfly, *Ceratitis capitata*) is an established exotic species to Australia that inhabits the southwest of Western Australia (WA) (Sproul et al. 2001; Jessup et al. 2007; Dominiak & Daniels 2012). Medfly affects more than 250 species of fruit and vegetables. It is responsible for substantial losses to fruit production together with reductions in profits due to control and post-harvest treatment costs to comply with international and domestic market access requirements.(Cook 2012).

Backyards are a significant source of fruit fly population, affecting not only home grown fruit but also on local orchards. Since its introduction into WA in 1895, the control of Medfly populations in orchards has become increasingly difficult (Sproul et al. 2001). As the number of urban households growing fruit and vegetables continues to increase (Wise 2014), the prevalence of uncontrolled Medfly populations in urban areas increases the risk of outbreaks in commercial fruit production areas. This is a particular problem to the Perth Hills districts of Roleystone, Kalamunda, Mundaring and Jarrahdale, which are becoming less isolated from urbanised areas.

Despite changes in technology, improvement in bait formulas, a better understanding of the fruit fly ecology and innovation of trapping control methods (Sproul et al. 2001), fruit fly in the southwest of WA is spreading. Yet the increasing number of households with fruit trees alone does not explain the prevalence of fruit fly populations. The problem lies with low adoption rates of fruit fly control and with the efficacy of control methods adopted by fruit growers. A survey of commercial and backyard fruit growers from urban, peri-urban and rural areas in Western Australia (Arevalo-Vigne, White & Longnecker 2014) found that, despite the large proportion of people growing fruit on their property (85%), only 57% of fruit growers controlled Medfly.

Area wide management – The solution to fruit fly control

Efforts to reduce fruit fly numbers in commercial orchards have increased with the imminent ban of fenthion, the last cover spray available for both commercial and household use and which was seen as an effective and efficient method to eliminate Medfly from fruit growing areas. The ban, effective in Western Australia from October 2015, is a result of the Australian Pesticides and Veterinary Medicines Authority reviews on the potential risks posed by chemical residues in produce to human health and in the environment (APVMA 2011; APVMA 2012).

This has prompted leading growers and policy makers to seek long-lasting approaches to control Medfly. Area Wide Management (AWM) is one likely solution. This is an integrated pest management approach conceived to include practices that control pests while reducing the use of pesticides (FAO 2014a; FAO 2014b). Refinements of integrated pest management strategies, particularly regarding quite mobile pests have evolved from dealing with pests in localised areas into AWM – a series of coordinated and sustainable prevention strategies that target the entire pest population within a delimited geographical area (Hendrichs et al. 2007; Faust, Koul & Cuperus 2008), the influence of migration/dispersal on pest dynamics, and its ecological relationships within its ecosystem (Hendrichs et al. 2007).

In an integrated pest management approach, biological and ecological knowledge of the pest and its environmental requirements is necessary. Understanding how the pests interact with their hosts, with the landscape and climatic conditions and with each other is important to determine the strategies to follow for effective control or eradication of the pest (FAO 2014a; FAO 2014b). This knowledge helps managers and affected users to apply the control methods suitable to each life stage of the pest, thereby improving the efficiency and effectiveness of the management strategy (Elliott, Onstad & Brewer 2008; Dauer, McEvoy & Van Sickle 2012).

However, AWM is jeopardised by poor cooperation between commercial fruit growers and the public, and of poor management practices on properties. To be successful, AWM of Medfly requires active participation from both commercial and backyard fruit growers by implementing fruit fly control on their own properties in a coordinated manner. This requires increasing the uptake of adoption of control techniques by industry and the community (Jessup et al. 2007).

Understanding behavioural responses to pest management

The literature identifies many factors likely associated with the level and rate of adoption of a technology in any particular situation (Rogers 2010). Adoption comprises socio-economic and psychological factors which mainly refer to the individual's perceived benefits and needs resulting from the implementation of the technology or innovation (Pannell et al. 2006). In general, the need to predict the potential success or failure of policy instruments have contributed to a recent increase in the application of 'behavioural approaches' to investigate the uptake of agricultural policy and to the design of more effective strategies (Burton 2004; Ellis-Iversen et al. 2010), particularly in support of emergent farmer-driven programs for integrated pest management. The Theory of Planned Behaviour (TPB) is a conceptual framework widely used to study the determinants of human action (Ajzen 2011). According to the theory, human behaviour is influenced by a) psychological beliefs about the likely consequences or other perceived attributes of the behaviour (behavioural beliefs), b) beliefs about the normative expectations of other people (normative beliefs), and c) beliefs about the requirements and demands of the behaviour itself (such as knowledge, time, money, skills, cooperation of others) that may impact on the performance of the behaviour (perceived control beliefs). Ajzen (1991) states that the performance of most behaviours depends at least to some degree on non-motivational factors such as the availability of necessary opportunities and resources, and which represent people's actual control over the behaviour and influence the sustainability of the behaviour over time.

Knowledge and the adoption of fruit fly control

Knowledge for adoption is fundamentally different from technology transfer or communication (Andrews 2012). As learning something new does not necessarily motivate a change in behaviour, it is then necessary to understand the social, political, economic and biophysical interactions of the new technology and how these interactions impact on the information and knowledge derived from applied research to facilitate change. The acquisition of knowledge helps assessing biosecurity risks, which in turn determine investments in biosecurity measures and management strategies (Roling & Jiggins 1998; Simberloff 2009; Tennant et al. 2011). From a policy maker's perspective, increased knowledge means better pest management (Price 2001), while for relatively simple innovations, a landholder's probability of making a good decision increases over time with increasing practical knowledge (Pannell et al. 2006).

Science communication can influence how the public perceives risks (Price 2001; Savadori et al. 2004) as the knowledge is leading to changes in their views, attitudes and behaviours that impact on societies. In this sense, the communication of science is essential to build the capacities of governments, industries and the public to use science and technology effectively in the pursuit of development strategies to manage and control invasive species. But which is the most effective strategy to create and disseminate knowledge regarding pest management? What type of knowledge would people trust, and from whom? One type acknowledges that the relevance of the information to the cultural and sociological elements around the pest problem can be conducive to trust if the communicator addresses the concerns of the audiences (Fiske & Dupree 2014). Another is knowledge that is based on gaining interactional expertise, through effective practice, and which is the result of learning from mistakes, from others' success and by adaptation to particular situations. Acknowledging the differences of experiential knowledge among fruit growers and bringing them into the planning of communication for integrated management can have an impact on trusting policy makers (Carolan 2012). Carolan (2012) also argues that without interactional expertise, any meaningful communication between scientists/managers and stakeholders will always be problematic and incomplete. Therefore attention should turn to better understanding how stakeholders' knowledge is communicated (or not) to experts to improve the dissemination of knowledge.

A further factor that affects adoption is the actual characteristic of the innovation, which corresponds to the knowledge and understanding of the technology's useful qualities (Elsey & Sirichoti 2001). Key aspects of pest management for Medfly control relate to biological and ecological interactions: a) The life cycle of a fruit fly varies considerably between the seasons and it can be affected by changes in temperature and humidity; b) Medfly has the capability to overwinter as adults, as eggs and larvae inside fruit or as pupae buried in the ground (Broughton 2012) - the latter is the most difficult stage to control as the pupae can be buried deep in the ground and only killed with harsh chemicals that can have negative impacts on soil ecology; c) Distribution of fruit fly populations is related to the availability of host tree species which provide food and shelter; d) Moisture is the major limiting factor of fruit fly populations during summer (Dominiak, Mavi & Nicol 2006). However, artificial conditions created by irrigation within backyards, orchards and landscaped areas have an impact on fruit flies' ability to extend their survival span beyond the summer season.

Yet, this type of information is not passed on, nor is it interpreted to fruit growers so they can understand their role in the problem and in its solution. In general, backyard fruit growers describe available information regarding Medfly control as confusing and difficult to understand, an unnecessary complexity that does not address an individual's way of processing information, nor the gaps in knowledge to understand the objectives and requirements of integrated management of Mediterranean fruit fly. Furthermore, fruit growers' attitudes towards fruit fly control are affected by perceptions of the outcomes of the control activity such as efficiency, effectiveness and complexity of the treatment (Arevalo-Vigne, White & Longnecker 2014) which in turn depend on the understanding of the control in relation to the target pest. In some measure these perceptions depend on how much knowledge an individual has on the scientific concepts that regulate fruit fly control.

The purpose of this paper is to present an analysis of fruit growers' knowledge of Medfly ecology and the influence it may have on an individual's decision to adopt fruit fly control. Since knowledge is unlikely to be the only variable involved in predicting fruit growers' behaviours, we measured a range of other psychological variables, drawing from the Theory of Planned Behaviour (Ajzen, 1985, 1991). Additionally it will present the actions designed to improve the fruit growers' understanding of the science supporting fruit fly area wide management as a strategy to help them understand the reasons behind Medfly control.

Method

This study was done in three phases. First, we conducted a statewide survey to determine the role of knowledge in the intention to control fruit fly, and to evaluate the knowledge of key scientific facts related to control of fruit fly. The survey was constructed under the TPB to measure the influence of subjective norms, and attitudes towards and perceived behavioural controls regarding efficiency, effectiveness and complexity of the control treatments in the intention to control fruit fly. Second, we conducted a second survey regarding control during winter which took place in Bridgetown in the southwest of Western Australia. In the third phase, we designed information material addressing knowledge issues identified in both surveys and then ran training workshops with staff from Dawson's nursery designed to improve the delivery of Medfly control information to their customers. Feedback from the staff was collected to identify if the information helped communicate control issues to customers and if behavioural changes happened because of the information received.

Participants

Participants in the first survey (*N*=606) were drawn from the whole State of Western Australia. The participants were men (43%) or women (57%), that a) either grew (83%) or didn't grow (17%) fruit trees on their property, and that b) control (57%) or not (43%) fruit fly on their property. The survey also identified individuals growing fruit trees in the household (81%) whether in the backyard or frontyard; in orchards (18%), whether commercial growers, small landholders or hobby farmers; and in other situations like balconies and community gardens (1%). Participants in the second survey (*N*=200) were visitors to the Bridgetown Library. Participants in the pest workshops were 35 staff from the four Dawson's Nursery locations in Perth, who were surveyed before the activity and from whom feedback was sought four weeks later.

Survey

This paper presents the results of an analysis of the responses to questions regarding scientific aspects behind integrated pest management elicited from the study on factors affecting adoption of fruit fly control in Western Australia (Arevalo-Vigne, White & Longnecker 2014). The survey was conducted between November 2013 and March 2014 and distributed in electronic (Internet) and hard copy formats. Invitations to participate were sent through emails for re-distribution to members and networks from community gardens groups, ethnic and cultural associations, individuals, fruit industry groups, and through gardening social media and news media networks in Western Australia. Additionally, hard copies of the survey were delivered to and collected from home properties from randomly selected street blocks in the suburbs of Willetton and Highgate, and the peri-urban location of Jarrahdale in Perth; and Bridgetown in the Shire of Bridgetown-Greenbushes. Questions addressed the following broad issues:

Ecological knowledge Respondents were asked multiple-choice questions regarding a) the best time to control fruit fly on properties (Summer, Autumn, Winter, Spring, All year round, Don't know); and b) the most important developmental stage to control fruit fly (Egg, Larvae, Pupae, Adult, All stages, Don't know). Answers of 'All year round' and 'Adult stage' were coded 1 for "correct"; all other responses were coded 2 for "wrong". Responses were then added to create a knowledge index, which indicated the respondent having Right knowledge=2; Partial knowledge=3; and Incorrect knowledge=4.

Fruit growers' intentions and perceptions of self-efficacy The *respondents' intentions to control fruit fly were measured directly by* indicating their *degree of agreement* or disagreement (1 = "strongly disagree" to 5 = "strongly agree"), whether they intended to control fruit fly on their property in the following six months. A direct measurement of subjective norm (a key variable in TPB) was obtained by evaluating respondents' *degree of agreement* or disagreement (1 = "strongly disagree" to 5 = "strongly agree") with the statement: 'People who are important to me think that I should apply fruit fly control treatments on my property'.

Respondents were asked to provide opinions on decisions and confidence influenced by the perceived characteristics of the control methods. The response choices for perception questions were given on a five-point Likert-type scale according to levels of influence of the characteristics of control into an individual's decision to control (1= Not at all; 5=extremely) and according to levels of confidence to control based on the characteristics of treatments (1= Not at all confident; 5=extremely confident).

A linear regression was used to predict individuals' intention to control fruit fly on their property from their attitudes, subjective norms, perceived behavioural control, and knowledge of key aspects governing fruit fly control. Based on TPB (Ajzen 2006) we evaluated intention using direct constructs to attitudes, and to control belief and control belief power (as components of perceived behavioural control) and calculated knowledge index:

$$Intention = \sum Attitudes + \sum SubjectiveNorms + \sum PerceivedBehaviouralControl + KnowledgeIndex$$

Fruit fly control during winter A survey was carried out during a community engagement activity in Bridgetown (Western Australia) organised at the Bridgetown Library as part of their Term 2 School Holiday activities, between 7 and 18 July 2014. To this effect, a Medfly display and information area was mounted in the foyer of the Bridgetown Library and an activity corner for kids. People attending the Library were approached to answer questions regarding the occurrence of control activities, such as baiting and trapping, during the winter season and of the reasons for not implementing them.

Results

The following results are based on the analysis of the data obtained from 606 participants in online and direct surveys in Western Australia. The analysis provides information for each answer on each group category of the percentage of respondents answering a particular question or topic (valid cases). Information regarding ecology was obtained from multi-choice questions. The results presented here correspond to the percentage of respondents that chose a particular answer therefore the sums for each group do not add 100%.

Knowledge of fruit fly ecology and control behaviour

Ecological knowledge. Responses by the group involved in the statewide survey are presented in Table 1. This shows that only 54% of all respondents who apply control indicated that all year was best to control fruit fly; for those growing fruit in households and orchards, the figure was 53% and 38%, respectively. Winter was the least preferred season to implement control.

Table 1. Seasons important to control (%) by groups

Group	summer	autumn	winter	spring	all year	don't know
statewide	24	9	4	30	40	24
without trees	8	3	8	26	36	30
with trees	27	11	3	31	41	23
without control	17	6	2	29	24	45
with control	33	14	4	33	54	7
house control	25	8	3	31	38	26
orchard control	34	23	2	34	53	11

Note: Results to multi-choice questions in the form of percentage of respondents that selected the answer.

Results in Table 2 show that 30% of fruit growers implementing control on their properties identified all stages as important while only a low proportion of householders and orchardists (26% and 35% respectively) indicated the adult stage as important.

Table 2. Most important developmental stages to control (% of respondents)

Group	egg	larva	pupa	adult	all stages	don't know
statewide	17	11	3	21	34	14
without trees	36	19	4	15	27	22
with trees	18	12	3	28	44	17
without control	25	12	2	21	30	26
with control	13	13	4	33	54	9
house control	20	13	3	26	43	17
orchard control	11	12	5	35	51	14

Note: Results to multi-choice questions in the form of percentage of respondents that selected the answer.

In general, respondents from the whole sample and those that do and do not control showed a very low percentage of correct knowledge (10%, 15% and 6 % respectively) in regards to the important stage and time for control (Table 3).

Table 3. Knowledge degree regarding season and life stage (% of respondents)

Group	Correct knowledge	Partial knowledge	No knowledge
statewide	10	43	47
without control	6	33	61
with control	15	56	29

Note: analysis based on valid cases

A comparison of how the knowledge of *correct stage* and *season to control* may affect the intention to act is presented in Table 4. The perceived controls of complexity and effectiveness as well as knowledge are highly significant for the whole sample and for fruit tree owners. The overall results indicate that knowledge is important as a predictor of whether people do or do not apply control – indeed, it is by far the biggest predictor. However, knowledge is not significant for those who apply or don’t apply control. From these regressions and from the results in Table 1, the *apply control* group probably all have high knowledge so knowledge no longer predicts intention. Similarly the *don’t control* group all have equally low knowledge. Those who control fruit fly are influenced by the complexity and the effectiveness of the control treatment while those that do not control may be influenced by the speed and their confidence on the complexity of the treatment. In all groups the attitude towards effectiveness of the control is significant to highly significant.

Fruit growers’ perceptions of self-efficacy. Table 5 lists the percentage of respondents controlling fruit fly and how the characteristics of the control influence their intention to undertake fruit fly control. Effectiveness and safety strongly influence intentions, while speed (32%), complexity (33%) and cost (41%) have less influence.

Table 4. Multiple linear regression analysis of individuals' intention to control Medfly

Behavioural constructs	Statewide (N=522) Coef.	P>t	Have trees (N=442) Coef.	P>t	Apply control (N=255) Coef.	P>t	Don't control (N=187) Coef.	P>t
Attitudes								
Attitude demand	-0.03	0.497	-0.03	0.511	-0.03	0.380	0.08	0.233
Attitude complexity	-0.01	0.783	-0.04	0.393	-0.02	0.601	-0.05	0.506
Attitude effectiveness	-0.07	0.020*	-0.09	0.004*	-0.10	0.000**	-0.11	0.031*
Subjective Norm	0.10	0.005*	0.07	0.054	-0.02	0.658	0.00	0.979
Behavioural controls								
Influence speed	0.07	0.141	0.07	0.195	0.04	0.314	0.19	0.031*
Influence complexity	-0.24	0.000**	-0.23	0.000**	-0.09	0.038*	-0.18	0.064
Influence effectiveness	0.24	0.000**	0.22	0.001*	0.20	0.000*	-0.06	0.566
Confidence slow	0.12	0.098	0.12	0.112	0.02	0.701	0.24	0.061
Confidence complex	-0.09	0.249	-0.07	0.390	0.07	0.242	-0.31	0.017*
Confidence irregular	0.04	0.596	0.04	0.625	0.03	0.603	0.19	0.112
Knowledge index	-0.38	0.000**	-0.38	0.000**	-0.05	0.469	-0.12	0.388

* $p < .05$ ** $p < .01$

(Note: analysis based on valid cases)

Table 5. Influence of treatment features on the decision to control fruit fly (%), by fruit growers currently controlling fruit fly

Treatment features	not at all influenced	very little influenced	somewhat influenced	quite a lot influenced	very much influenced
speed	8	17	32	30	13
complexity	6	17	33	32	13
effectiveness	2	2	7	35	55
cost	5	12	41	25	17
safety	2	3	12	30	53

Note: Each result is presented in the form of percentage of respondents that selected the answer.

Analysis of elements of self-efficacies involved in the intention to control fruit fly are presented in Table 6. Few people report feeling confident on any dimension of the treatment. Fruit growers controlling fruit indicated that slow (43%), complex (41%) and expensive (46%) treatments gave them a fair confidence to control fruit fly. Additionally 44% believed that they were not very confident if the treatment was irregular while 60% of respondents controlling fruit fly indicated that they were not at all confident if they perceived the control treatment was toxic.

Table 6. Fruit growers' confidence to control Medfly (%) based on treatment's quality, by fruit growers currently controlling fruit fly

Perception of treatment	not at all confident	not very confident	somewhat confident	very confident	extremely confident
slow	14	32	43	8	2
complex	16	34	41	7	2
irregular	34	44	20	1	1
expensive	17	31	46	5	1
toxic	60	19	12	5	3

Comparing Table 5 and Table 6, the use of safety control methods is important in the decision to control. If a treatment is safe, having 'confidence to be able to' is important in sustaining users' control behavior. The perception of toxicity may result in fruit growers looking for alternative solutions or moving completely away from controlling or minimising applications.

Fruit fly control during winter. The results shown in Table 2 prompted further investigation to explain the low uptake of control during winter. A display regarding fruit fly control was set up at the Bridgetown Library with material provided by the Department of Agriculture and Food and

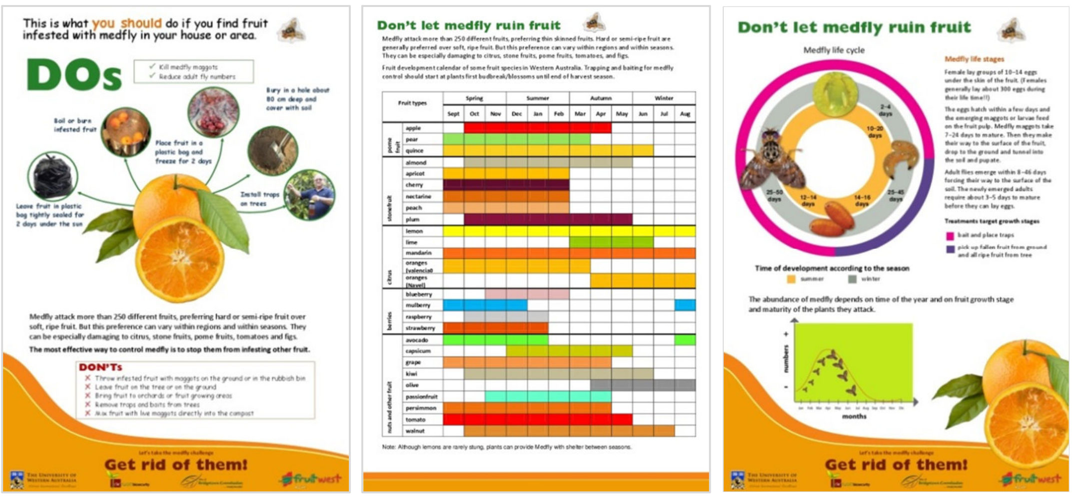
FruitWest. Two hundred visitors to the library were engaged at a display, asked if they had fruit trees, and if they were baiting or controlling Medfly on their properties that winter. A total of 107 out of 200 customers questioned indicated that they had fruit trees, but only one indicated that they were baiting during winter. Two reasons for not implementing controls were because trees were not bearing fruit (94%) or because trees were too young (6%).

Addressing knowledge gaps

Based on the information collected through the two surveys, and informal conversations with the public, the project designed and ran a campaign under the banner of *This is a No Fly Zone* – a community engagement and awareness package that addressed the necessity of acting against the problem in urban and rural properties in WA, but most importantly to be involved in the solution as a community. Both surveys provided information about issues where control treatment is linked to the fruit fly life cycle and its developmental stages. The perceived effectiveness, efficiency, and complexity of a control treatment may affect an individual's performance to control fruit fly. Additionally, reduced or lack of control during winter has a major potential to increase fruit fly numbers in the following spring and summer seasons

A series of materials (Figure 1) and activities were designed to overcome weaknesses in the understanding of concepts that affect the results of Medfly control. For example, information from the Department of Agriculture and Food (DAFWA 2010; DAFWA 2011) and from Woods et al. (2005) was used to prepare a fruit growth development calendar (Figure 1b) of 27 common fruit plant species found in backyards. As the timing of control depends on the lifecycle as well as on tree growth phenology, the calendar was also used to engage individuals attending major field days and community garden events to explain the impact that fruit trees outside the property may have on their own problem and the need to control fruit fly all year round. After the explanation, the common observation by the participants was 'it makes sense'.

Figure 1. Information material used in awareness and training activities



a) Disposal of infested fruit b) Fruit development calendar c) Medfly lifecycle

The information was used to train 35 staff from the four Dawson's nursery outlets. Staff participated either on a Medfly workshop (7) or received summarised information of the workshop (6). Out of the 13 staff that provided feedback, 10 indicated that they were doing something different as a result of the information received: 8 indicated that they were doing something different at home, and 5 indicated that they were doing something different in their interaction with customers in regards to fruit trees and fruit fly control. One respondent answered: 'Asking customers if they have fruit fly control in their garden when purchasing fruit trees. Every time! And also I pestered my family about their control methods which have since been updated and improved'. The overall opinion of the information was helpful (70%), instructive (54%) and with community application (31%).

Discussion

The results of both surveys present evidence of the issues affecting the adoption of fruit fly control on properties. In an integrated pest management approach, breaking the lifecycle is best done by targeting the adult stage to stop them from breeding. However, the results of this study indicate that only 33% of individuals controlling fruit fly identify the adult stage as the single stage important to control fruit fly populations. Targeting the adult stage prevents the development of the eggs into the larval stages that damage fruit. Additionally, the control of the fruit fly larvae in infested fruit requires strict procedures to minimise the risks of re-infestations. This is achieved by preventing the larvae from reaching maturity and emerging from the fruit to develop into the pupae stage (HAW-FLYPM 2014)

One of the main reasons for high fruit fly populations in WA is the low adoption rates to control the pest. Timing is an important factor; control of Medfly has to happen all year round and particularly in winter as this season provides an important window of opportunity to curb existing low populations while reducing potential damage in spring and summer fruit. The first survey indicated that 54% of fruit growers actually controlling fruit fly believe that control should happen during the whole year and 4% of the same group believed control was best in winter. However, the second survey found that only 2% of respondents were actively controlling in winter. Knowledge regarding timing of control should be improved among fruit growers, particularly those who currently control fruit fly on their properties.

Perceptions of the effectiveness and the complexity of the technologies, together with behavioural control factors such as effectiveness, speed and complexity of the control treatments, are affecting the intention to engage in control behaviour. The explanation is that control treatments may be perceived as labour or time-consuming (Sunding & Zilberman 2001), and probably affected by users' age and gender (Arevalo-Vigne, White & Longnecker 2014). Finally, the perception of toxic characteristics of a control treatment together with effectiveness, speed and complexity influence individuals' evaluation of their self-efficacy (perceived difficulty) to control fruit fly. In this respect, Sparks, Guthrie and Shepherd (1997) reported that a measure of perceived difficulty contributed to the prediction of behavioural intentions. Differentiating attitudes and perceived controls affecting the intention to perform a behaviour is not always easy. As reported by Kraft et al. (2005), sometimes it is difficult to describe if the characteristic of the instrument required to perform the behaviour is affecting both an individual's perceived behavioural controls and the attitude towards the behaviour.

The results also indicate that, because of the lack of or reduced knowledge of the Medfly ecology, fruit growers may not understand the performance of the integrated management technologies, while reduced or absent trust in control methods is probably enhanced by inconsistent results. According to Elsey and Sirichoti (2002) positive results from growers' integrated pest management strategies increased their trust in the technology as a result of knowledge acquisition of its uses and their experience of practice. Bad experiences and lack of knowledge reduce confidence in the qualities of the control methods.

As a result of the analyses, improving knowledge to correct negative attitudes towards fruit fly control was the main objective of the *This is a No Fly Zone* campaign. Prokopy et al. (2008) showed that increasing information and awareness increased the decision to adopt, and that both awareness and information influence adoption rates. The integrated management of a pest has to consider the spatial distribution of pest hosts that allows persistence of the pest. Based on this, the timing of baiting and trapping techniques to control fruit fly is influenced by the type of fruit trees grown on each property and on adjacent properties. A property management plan that disregards the presence of other fruit types on neighbouring properties will result in ineffective management for both fruit production and pest control. Under the *This is a No Fly Zone* campaign, activities and materials were developed around reducing fruit fly pressure from neighbouring fruit trees as a means to increase benefits to fruit growers, and around the need to control Medfly all year round as an effective approach to reduce the problem. The fruit growth development calendar served to visually demonstrate the prevalence of Medfly in urbanised areas. This 'tool' was effective to demonstrate the need for control all year round by visually demonstrating that there is no gap within the year which can assure absence of a fruit fly population. The calendar was also useful to demonstrate that implementing heavy baiting and trapping on properties during the winter season was a preventative measure that will increase fruit growers' chances of harvesting fruit during spring and summer without Medfly.

The development of the calendar and other information materials used in the campaign were a response to the difficulty fruit growers have in interpreting information regarding Medfly and which may be influencing their attitudes towards control. The project attempted to overcome the limiting factors of attitudes, knowledge, and complexity of tasks by simplifying the requirements of the control techniques and demonstrating that these make minimal demands on an individual's time, effort and money. Conversations and interviews with participants at different events provided an increased understanding of the audience's knowledge and capabilities which in turn served to tune the approaches to information delivery. The final products were able to engage people in positive ways because of the ease of the explanations and the direct relation with the problems and the solutions. This was corroborated by the results of the training workshops. The use of the information by the staff from Dawson's nurseries has two positive outcomes. The first is on the community through their work with customers looking to buy fruit trees or who require advice on how to deal with a fruit fly problem on their properties, as staff felt better prepared to deal with fruit fly control queries. The second is that staff acknowledged changing the way they control Medfly on their own properties and extended information to other family members. This result demonstrates that improving science information and the way knowledge is diffused have the potential to improve the adoption rates of fruit fly control.

Addressing issues people do not understand or do not know in simple but direct language – as with the calendar – opens a dialogue channel to solve problems with fruit fly control. Introducing key scientific principles in the conversation can help explain the pervasive occurrence of fruit fly and may provide fruit growers with the elements needed to make an informed decision to adopt fruit fly control methods on their property.

Conclusion

This study showed that the attitudes and opinions expressed by fruit growers controlling fruit fly on their properties are related to the individual's understanding of key scientific facts regarding the integrated management of fruit fly, as well as to an understanding of the context where this knowledge is applied. In an AWM approach, knowledge of the pest is important in order to implement effective control. In the case of Medfly, when people do not have a clear understanding of the biology of the fruit fly and how to tune this information with fruit development on their own property and their neighbours', then it is more likely that control treatments will fail. Understanding of integrated pest management requirements is strongly influenced by the ability to recognize key issues, and that ability to recognize key issues requires some understanding of the relevant science. From a communications point of view, this requires a review of the knowledge bank of those individuals who will implement integrated pest management controls. Improving the communication of the science behind fruit fly control can help overcome the barriers to adoption of fruit fly control by increasing fruit growers' efforts to produce fruit free of fruit fly.

Easy to read, accurate and consistent information can be used to facilitate fruit growers' understanding of the requirements needed to effectively control Medfly on properties. There is not necessarily a high cost associated with these control techniques; rather, consistent effort is needed to control Medfly. The controls can be imperfect solutions if there are not enough people controlling Medfly effectively on their properties.

Low adoption rates, and more importantly inconsistencies in the application of control measures on fruit growing properties in urban, peri-urban and rural areas in WA, can be addressed by identifying and closing the knowledge gaps in those required to adopt fruit fly integrated management by making sense of the science behind fruit fly control. Additional research needs to be done to understand aspects of the process of learning and communicating science at both industry and community levels for the adoption and diffusion of Area Wide Management.

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