



Research Article

Fruit fly management in Nepal: A case from plant clinic

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ABSTRACT: Fruit fly is one of the important insect pests of horticultural crops, both fruits and vegetables. After aphids, fruit fly was reported as a major insect problem in the plant clinic sessions from September 2013 to July 2016 in Nepal. The groups of horticultural crops most affected by fruit flies were cucurbitaceous vegetables, i.e. 79% of all fruit fly queries (bitter gourd, bottle gourd, chayote, cucumber, pumpkin, snake gourd, sponge gourd and squash) followed by fruits 14% (guava, sweet orange, mandarin, mango, peach, and pomegranate) and solanaceous vegetables 6% (brinjal, chillies and tomato). The fruit fly management measures, such as use of para-pheromone lure/traps, sanitation and cultural measures were mostly referred in plant clinics by plant doctors of Nepal. The availability of para-pheromone lures/traps as well as technical know-how of application focusing integrated management measures should be adopted to manage fruit fly in horticultural crops with the least disruption to the environment and human health.

KEY WORDS: Fruits, fruit fly, para-pheromone, sanitation, vegetables

(Article chronicle: Received: 12-12-2019; Revised: 10-02-2020; Accepted: 05-03-2020)

INTRODUCTION

There are several production problems in agricultural crops in Nepal. Obviously, crop insect pests pose problem to limit agricultural production. Several fruit flies notoriously deplete vegetable and fruits qualitatively and quantitatively (Adhikari et al., 2018). Particularly, plant clinic data highlighted fruit fly problems in cucurbit vegetables, solanaceous vegetables and tree fruits (POMS, 2016). Despite yield loss, the fruit fly infestations limit export trade of fruits and vegetables from Nepal. Fruit flies (Diptera: Tephritidae) are the most important insect pests in horticulture throughout the world and are subjective trade barriers in course of international marketing under the World Trade Organization (WTO) facilities (Fletcher, 1987). Tephritid fruit flies are devastating pests, depending on their population, kinds of commodities and prevailing season; deplete the production to a tune of 90-100% (Plant Health Australia, 2011). A growing international trade has further increased the significance of fruit flies (Allwood, 1997). In Nepal, horticultural crops (fruits and vegetables) are among the basic sector of agriculture. Fruit fly problem of *Bactrocera dorsalis* (reported as *Dacus dorsalis*), *B. cucurbitae* (reported as *D. cucurbitae*)

and *Bactrocera tau* (reported as *D. hageni*) in fruits and vegetables were reported as early as 1970 in Nepal (Pradhan, 1970). GC (2001) recorded 42-68% bitter gourd fruits lost due to fruit flies invasion. Chinese citrus fly (*B. minax*) is very serious insect pest causing sweet oranges losses as high as 97% by the end of harvesting season in the eastern middle mountain regions of Nepal (NCRP, 2012) and it is moving towards the central part of the country (Adhikari et al., 2018). In the last five years, this fruit fly reported damaging sweet orange fruits in Sindhuli district, Nepal. National Plant Protection Organization-Nepal (NPPO-Nepal) is aware of the fruit fly pestilence in potentially tradable horticulture fruits of the country, and is making update on the country status of the fruit flies by means of conducting regular surveillance (Sharma et al., 2015).

Fruit fly management is to reduce the yield loss and enhance quality by eliminating fruit fly maggots in fruits and vegetables. There are several fruit fly management methods adopted in world depending on economic resources. Due to complexity in fruit fly species and coexist in the fragmented fruits and vegetable production system, combination of

all feasible methods as an integrated pest management is essential (Ekesi *et al.*, 2007). It is necessary to understand the ecology and behaviour before the formulation of management strategy (Ansari *et al.*, 2012). Theoretically, fruit fly management measures in horticultural crops comprise mainly field sanitation to preventing life cycle completion, matting disruption, food lures uses, synthetic pesticides uses, botanicals, bio-rational pesticides, cultural measures, exclusion measures and post-harvest treatment etc. These management methods differ in their efficacy and are variably adopted by farmers. Shapkota *et al.* (2009) studied the farmers' practices of fruit fly management that revealed the practices inclusions of indigenous (70%), chemical (32%), mechanical (80%) and combination of two or more methods (68%). Farmers in Nepal are in practice to use parapheromone traps, application of chemical measures and field sanitation to manage fruit fly problem. This study reveals the present status of fruit fly management practices in Nepal.

MATERIALS AND METHODS

Resources of Nepal fruit fly management data are the literatures contained in offices and libraries along with information generated through questionnaire-based survey among officer level plant doctors in the country. The Plantwise Online Management System (POMS) is an online tool within the Plantwise knowledge bank developed by CABI that serves as a repository database. All the clinic information such as plant clinic code/location, plant doctor, date of plant clinic etc. and the data recorded in the prescription form are available in POMS. Access to POMS is confidential and is restricted to authorized users from the NPPO and Centre for Agriculture and Bioscience International (CABI). POMS stored plant clinic country data in query and field are accommodated in row and column, respectively. The query simply contains all information recorded in an individual prescription form. The query is divided into many fields, each field containing individual attributes and parts found in prescription form. Plant problem diagnosis and recommendation details are captured in the individual entry of queries. After analysis, the findings help to understand crop pest problems and develop crop pest diagnosis improvement and device recommendation. Plant clinic data of Nepal from POMS were accessed and downloaded on 9th August, 2016. Available data of September, 2013 to July, 2016 were used for the present investigation. Retrieved queries from POMS were 3268 in number. Microsoft Excel was used to analyse the data and presentation of result.

Survey of doctors who have been mostly involved in the regular plant clinics operation was conducted as a key informant to access plant doctor's recommendation for the fruit fly management measures. Semi-structured

questionnaire was prepared and sent by e-mail to plant doctors of the country. A list of 42 plant doctors was prepared through the consultation of Plant Protection Directorate (also NPPO), Hariharbhawan, Pulchowk, Lalitpur, Nepal. The survey questionnaire for plant doctors were mailed to 42 individuals. Out of them, 26 (62%) recipients participated in the survey. Information gathered through the questionnaire were analysed and presented according to the appropriate sections of the result.

The fruit fly problem in the horticultural crops in Nepal was recorded and taken as a case to examine the quality of plant health care in plant clinic. Fruit fly is one of the major pests in Nepal which is easy to diagnose in plant clinic but requires integrated measures for management. The case of fruit fly problem was purposefully selected for the un-harmonized data (to prevent mistake in diagnosis) and assessed the quality (comprehensiveness and detail) of recommendations. Furthermore, standard measures for fruit fly management was reviewed to describe and analyze the recommendations for the management of fruit fly in plant clinics. Plantwise programme has developed the clinic data validation process through the "*Plantwise validation tool v9b*" and all steps in importing data, validating the diagnoses & recommendations and lastly clicked on "*refresh data*" button in the summary sheet to view. But, to know the quality of recommendation for the fruit fly management by plant doctors of Nepal the simply validation on comprehensiveness and detail was assessed. All the recommendations for fruit fly management provided by plant doctors of the country recorded in POMS were considered as effective and safe. Then, the quality of recommendation was assessed to determine the comprehensiveness and detail. The recommendations were categorized according to the following bases presented in Table 1.

Table 1. Categories of fruit fly management recommendation

S N	Categories of recommendation	Description
1	Invalid	Wrong management measures recommended
2	Valid but not comprehensive/IPM	< 3 right management measures recommended
3	Valid but not detailed	Right recommendation \geq 3 measures with IPM approach but without detail (what, when, how much, where etc.)
4	Valid but not comprehensive/IPM and not detailed	2+3
5	Valid	all right recommendation with IPM approach and detailed

The fruit fly management measures, assessed with economic, effective, safe, practical and locally available parameters, were analyzed according to the score provided by the plant doctors of the country. Microsoft Excel analyzed scoring of fruit fly management assessment data 1-5 (lowest to highest) are presented in graphs.

RESULTS AND DISCUSSION

Pest problems in plant clinic

Pest problems in Plant clinics registered in POMS were analysed. All together there were 298 diagnoses counts of crop problems recorded in POMS Nepal among 3268 entries from September 2013 to July 2016. The highest queries (233) brought in plant clinics were late blight of tomato and potato followed by 220 for aphids, 180 for fruit fly, 98 for damping off of seedlings, 89 of borers in tomato, 84 of blight, 68 of root knot nematodes, 65 of club root of crucifers, 53 of downy mildew and 51 of powdery mildew. Other important problems diagnosed in the clinic were of nutrition deficiencies, viruses, wilt, leaf spots, white grubs, cutworms, and red ants etc. among the pest groups, where insects appeared in highest frequency followed by fungus, water mould, nutritional deficiencies, virus, bacteria, nematodes and mites etc.

The problem of fruit fly

The problem of fruit fly was taken as a case to examine the quality of plant health care advice in plant clinic. Altogether there were 180 queries related to fruit fly brought by farmers in 21 different plant clinics. Highest number of queries was recorded in the plant clinic of Sunsari (31) followed by Bhaktapur (24). The percentage of queries on fruit fly was highest in Sunsari (33%) followed by Kapilvastu (14%) whereas, as a whole 6% of queries were diagnosed as fruit fly problem in the plant clinic record from September 2013 to July 2016 (Fig. 1).

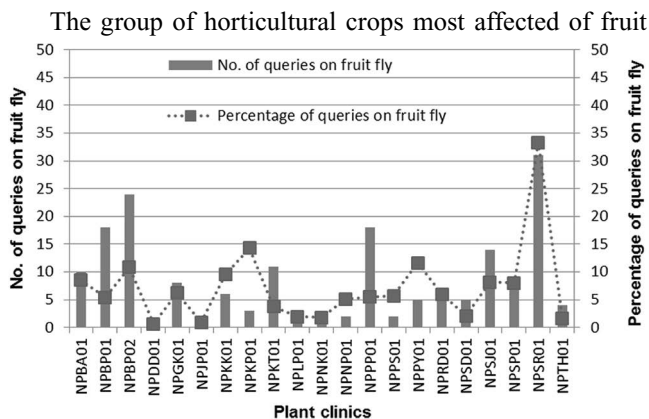


Fig. 1. Number and percentage of queries on fruit fly recorded in plant clinic (September 2013 to July 2016)

fly problems (79%) were cucurbit vegetables (bitter gourd, bottle gourd, chayote, cucumber, pumpkin, snake gourd, sponge gourd, and squash) followed by fruits (14%) (guava, sweet orange, mandarin, mango, peach, and pomegranate) and solanaceous vegetables (6%) (brinjal, chillies, and tomato). The plant doctor survey results showed a similar pattern for frequency of fruit fly attack on the crop groups, namely cucurbit vegetables (4.7) followed by fruits (3.2) and solanaceous vegetables (2.4) responded by 26 plant doctors of Nepal with 1 to 5 score.

Fruit fly management

The fruit fly management measures assessed in the standard guidelines, review of literature in journal and recommended practices in plant clinics Nepal are presented in Table 2 of the 10 listed management measures, management heading of sanitation measures, use of para-pheromone trap, application of chemical insecticides, botanicals, cultural measures, exclusion measures and application of food lure were observed in the clinic data. In contrast, the application of bio-pesticides/biological measures, post-harvest treatments and sterile insect technique recommended in standard guidelines from literature review but had not been recommended to farmers by plant doctors.

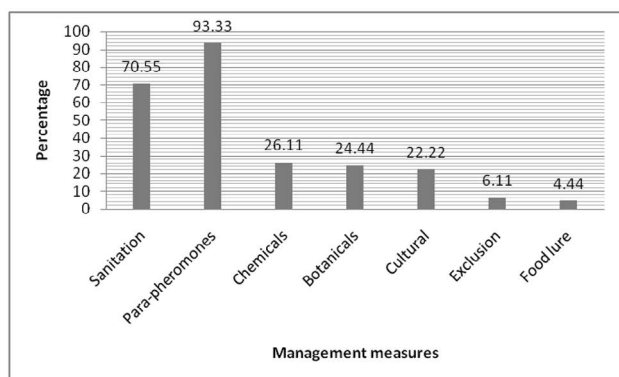
The comprehensive recommendation is presented in the Table 3. The combination of sanitation measures and use of para-pheromone were recommended for the highest number of queries, i.e., 25 % followed by the para-pheromone sole recommendation, i.e., 17% and combination of sanitation, para-pheromone and botanical 11% and combination of sanitation, para-pheromone and chemical 10%. Overall, it was observed that in about 61.11% of cases farmers were provided 2-3 integrated approaches for managing this pest (Table 3). Fruit fly management measures recommended by the plant doctors in the plant clinic sessions from September 2013 to July 2016 reflected that, the use of para-pheromone lures/traps was found having highest number of recommendations (93.33%) followed by sanitation (70.55%) and use of chemical pesticides (26.11%), botanicals (24.44%) and cultural measures (22.22%) (Fig. 2).

Fruit Fly management recommendation validation

Among 180 queries of the POMS recorded fruit fly problems, the recommended measures for 75 (42%) queries were valid, 102 (57%) recommendations were conditionally valid (valid but not comprehensive or lacking details) and 3 (2%) recommendations were invalid. Similarly, 55% and 33% recommendations were comprehensive and not detailed, respectively (Fig. 3). The comprehensiveness and detail of recommendations is important for the effective and practical implementation of management measures of fruit fly. The

Table 2. Fruit fly management from standard guidelines and POMS Nepal

S.N.	Management measures	Practices in standard guidelines	Practices recommended by plant doctors (No. of Recommendation reported in POMS among 180 entries)
1	Sanitation	Collect, remove, destroy, bury infested fruits	Collect, remove, destroy, bury infested fruits (127) i.e. 70.55%
2	Para-pheromone lure/trap	Methyl eugenol, Cue lure	Methyl eugenol, Cue lure, composite lure (168) i.e. 93.33%
3	Chemical insecticides	Chemical insecticides	Malathion and other insecticides (47) i.e. 26.11%
4	Botanicals	Neem based (Azadiractin) and tobacco extract	Neem based (Azadiractin) and JHOLMAL ¹ (44) i.e. 24.44%
5	Cultural methods	Soil treatment/tillage, Removal of host plants, Crop rotation, Clean cultivation, Weeding, Pruning, Conservation of natural enemies, Early harvesting, Traps and repellent crops	Soil treatment/tillage, Removal of host plants, Crop rotation, Clean cultivation, Weeding, Pruning (40) i.e. 22.22%
6	Exclusion measures	Netting whole plants, bagging (wrapping fruits)	Netting whole plants, bagging (wrapping fruits) (11) i.e. 6.11%
7	Food lure/ Protein hydrolysate	Ripened fruits (pumpkin, banana + insecticide) as bait Protein hydrolysate (Nu-lure), Livestock/ poultry manure	Ripened fruits (pumpkin, banana + insecticide as bait (8) i.e. 4.44%
8	Bio-pesticides/ Biological measures	<i>Metarhizium anisopliae</i> Parasitoids Weaver ants	-
9	Post-harvest fruit treatment	Heat treatment, cold treatment and irradiation	-
10	Sterile Insect Technique (SIT)	Sterile insect releases	-

**Fig. 2. Fruit Fly management measures recommended by the plant doctors in the plant clinic sessions from September 2013 to July 2016**

low proportion of fully valid recommendations for fruit fly management by the plant doctors in Nepal might be due to the limited know-how in the technical matter.

Table 3. Count of recommended measures for fruit fly management

S.N.	Recommendation	No. of recommendations
1	One measure recommendation	37
2	Two measures recommendations	62
3	Three measures recommendations	48
4	Four measures recommendations	24
5	Five measures recommendations	2
6	Six measures recommendations	4
Sub total		177
Invalid recommendations		3
Grand total		180

Assessment of fruit fly management measures

A survey with plant doctors was conducted to assess the fruit fly management measures. The economic, effective, safe,

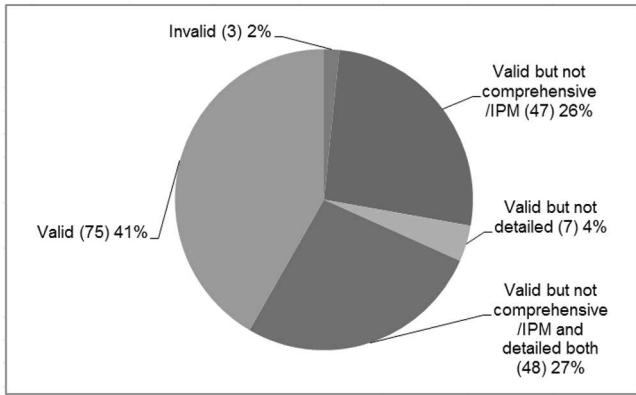


Fig. 3. Validation of recommendation for fruit fly management

practical and locally available parameters were scored 1 – 5 (lowest to highest) to assess each of the management measures and presented in (Fig. 4). Based on the survey feedback, plant doctors felt that the most economic management measure of fruit fly was the use of botanical insecticides (3.96 (Fig. 4d); 9 respondents scored 5), followed by sanitation measures (3.92 (Fig. 4b); 13 respondents scored 5) and cultural measures (soil tillage/treatment) (3.54 (Fig. 4h); 9 respondents scored 3). The management measure considered most effective was the use of para-pheromone lure/traps (4.35 (Fig. 4a); 14 respondents scored 4), followed by sanitation measures (3.96 (Fig. 4b); 12 respondents scored 4) and exclusion measures (3.85 (Fig. 4f); 10 respondents scored 4). The use of pheromene lure/traps (4.85 (Fig. 4a); 22 respondents

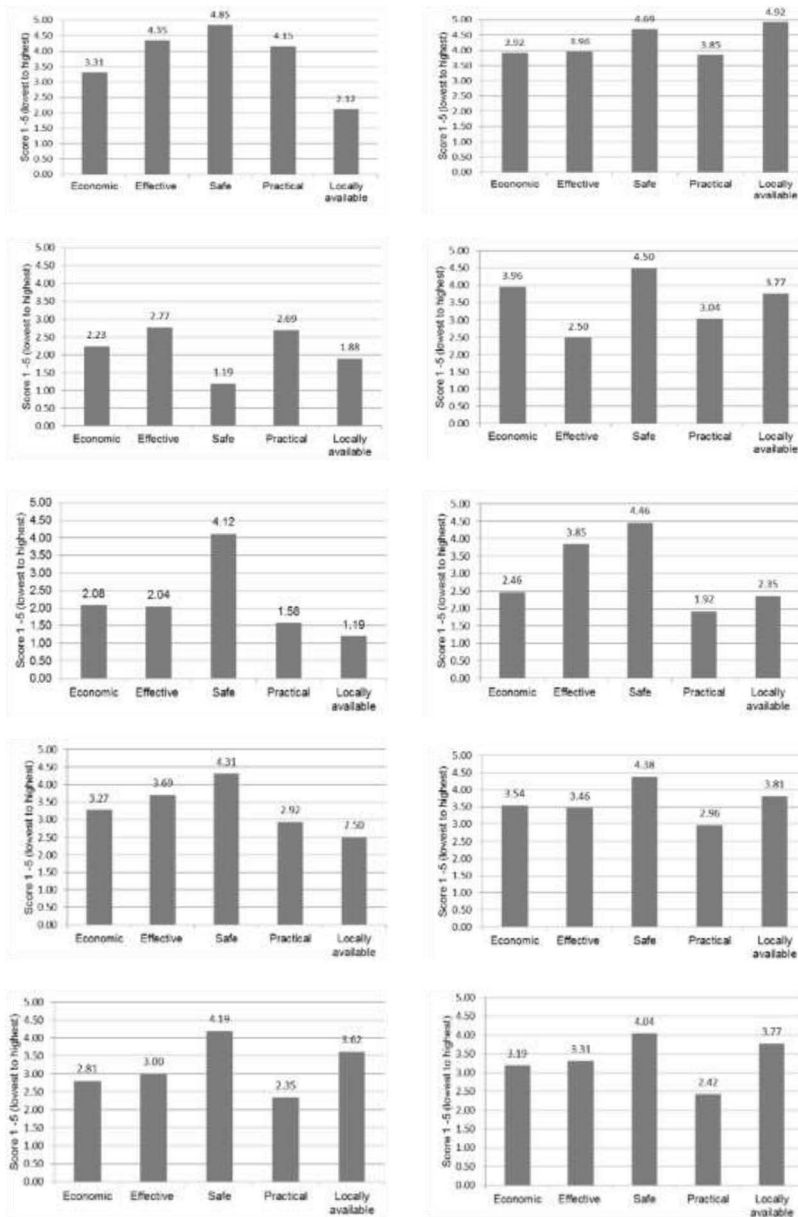


Fig. 4. Analysis of plant doctors' perception of fruit fly management measures (Fig 4a, 4b, 4c, 4d, 4e, 4f, 4g,4h, 4i, 4j)

scored 5) was found highly safe fruit fly management measure followed by use of botanicals (4.50 (Fig. 4d); 17 respondents scored 5) and exclusion measures (4.46 (Fig. 4f); 18 respondents scored 5). The use of pheromone lure/traps (4.15 (Fig. 4a); 11 respondents scored 5) was considered most practical management measure followed by sanitation measures (3.85 (Fig. 4b); 9 respondents scored 5) and use of botanicals (3.04 (Fig. 4d); 13 respondents scored 3). The highest locally approachable management measure of fruit fly was sanitation measure (4.92 (Fig. 4b); 24 respondents scored 5) followed by cultural measure (soil tillage/treatments) (3.81 (Fig. 4h); 9 respondents scored 5) and use of botanicals and cultural measure (crop rotation) both received 3.77 score (Fig. 4d), (Fig. 4j). The analysed results show that the most relevant fruit fly management measures in Nepal promoted by the Nepalese plant doctors are the use of pheromone lures/traps, sanitation measures, cultural measures (soil tillage/treatment, crop rotation), use of botanical pesticides and exclusion measures.

Management measures of fruit fly were accessed in review of literature and POMS data of Nepal. POMS data on fruit fly management measures in the country revealed 98% valid and 2% invalid recommendations provided by the plant doctors of Nepal in the plant clinic sessions from September 2013 to July 2016. In Zambia, 80% of diagnoses and 86% of recommendations were reported valid (Matimelo, 2016). The fruit fly management measures included pheromone lure/traps, sanitation measures, cultural measures, botanicals uses, exclusion measures and chemical measures. Most of the plant doctors of Nepal perceived the use of pheromone lures/traps was effective, safe and practical for the fruit fly management. However, the sanitation measure (4.92; 24 respondents scored 5), the most locally approachable one, had a very low score. Lucrative price fetching to the pesticide dealers in the market for the sale of para-pheromone lures might have read availability of these lures for farmers. But certainly most of the farmers are not well aware of the inbuilt technology in this stuff but remained attracted to purchase them in market price. Jha (2008) reported that 95.8% IPM FFS participant farmers and 97.0% IPM FFS non-participant farmers didn't know of pheromone trap in Bhaktapur district. Thus, an availability of pheromone traps in economic prices as well as their technical know-how to apply in field should be more focused in the coming days. The use of chemical pesticides for management of fruit fly is not economic, effective, practical, safe or locally available in Nepalese context as perceived by plant doctors. The cultural measure as host plant removal is safe, locally available and effective but uneconomic and less practical. Other cultural measures such as soil tillage/treatment are effective, economic, safer, locally available but not much practical. Moreover, unlike field crops, the removal of host plants is difficult activity in

orchards. So, the community effort for the implementation of appropriate management measures is important for the successful fruit fly management. The biological measures has not been applied by farmers in Nepal to manage fruit fly. Further, the use of entomopathogenic fungus, *Metarhizium anisopliae* (microbial bio-pesticide) is found safe but this microbial pesticide is not readily available throughout the country. Moreover, encouragement of natural control in the premises of crop fields and orchards is not much appreciated which, otherwise, automatically regulates the populations of insect pests in field environment. Though, the natural biological control by predation and parasitization could be promoted through the relevant local level administrations based on advises from the local extension machinery or through plant clinics. Farmers seem very less interested in this aspect and that may be due to their ignorance in status.

Agriculture extension service providers should have quality of services in plant health care for fruit fly management. Similarly, the local input suppliers (agro-dealers) should be able to supply effective, practical, safe and economic plant protection materials. The integrated management measures should be employed to manage fruit fly problems in horticultural crops. Some eco-friendly management measures such as use of bio-pesticides e.g. entomopathogenic fungus, *Metarhizium anisopliae* should be promoted with their ready availability to farmers in the country. Furthermore, integrated pest management of fruit fly should accommodate all applicable management components.

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