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PLANT PROTECTION | ORIGINAL ARTICLE

Monitoring of fruit fly in mandarin orchards of Jajarkot, Nepal: A mixed-method approach

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ABSTRACT

The study was conducted to access the species diversity of fruit fly and their population dynamics, awareness among mandarin growers on the nature of damage, and factors affecting the awareness in the Jajarkot district of Nepal in 2021. The study consists of two parts: farmer's survey and monitoring of fruit flies. The farmer's survey was carried out in randomly selected sixty households whose orchards were at least five years old in command areas of citrus zone, Jajarkot. Fruit fly monitoring was done in three mandarin orchards of Kushe Rural Municipality and Bheri Municipality using cue-lure, methyl eugenol, and great fruit fly bait. The survey revealed that only thirty percent of the farmers were aware of the nature of fruit fly damage. Experience in mandarin cultivation was found to be significantly affecting the awareness of mandarin growers on fruit fly damage. The mandarin growers were practicing pruning, collection and destruction of fallen fruits, use of chemicals, and traps for fruit fly management. Monitoring data revealed that there were four major fruit fly species. Among the lures used, cue-lure attracted more number of fruit flies, followed by methyl eugenol and great fruit fly bait. Cue-lure trap was effective in trapping *Bactrocera nigrofemoralis*, *Zeugodacus tau*, and *Zeugodacus scutellaris* whereas methyl eugenol was found effective in trapping *Bactrocera dorsalis*. Great fruit fly bait captured *Bactrocera nigrofemoralis* and *Zeugodacus tau*, but in lesser number. The number of all the species of fruit fly started increasing in April and reached the highest during May.

Keywords: Awareness, fruit fly damage, management, population dynamics, traps

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1 Introduction

Mandarin (*Citrus reticulata* Blanco) is the most important citrus crop in the mid-hills of Nepal, considering its production and area among all citrus fruits (MoALD, 2021; Pandey et al., 2017). It is grown on a semi-commercial and commercial scale in the hilly terraces of 58 districts of Nepal (MoALD, 2021). Jajarkot district, located in the mid-hill region in northwest Nepal, is known as a potential citrus-producing districts. It has been categorized as citrus production zone under Prime Minister Agriculture Modernization Project (PMAMP) in 2018. Mandarin production in Jajarkot contributes 0.011% to the national mandarin production (MoALD, 2021).

The fruit fly is an insect of the family Tephritidae whose larva feeds on the pulp of fruits. There are about 4000 different species of fruit flies belongs to that family, and 350 of them are economically significant (Kumar et al., 2011). Their distribution is cosmopolitan covering tropical, subtropical, and temperate regions (Agarwal and Sueyoshi, 2005). According to Waterhouse (1993), they are one of the five most important pests of agriculture in South East Asia. In Nepal, 17 species of fruit flies have been reported (Adhikari and Joshi, 2018). Tephritid fruit flies are directly harmful for fruits and vegetables, which can result in yield losses of up to 90% depending on the population, location, variety, and season.

Despite the well-accepted value and importance of mandarin production in terms of income and climatic suitability, mandarin production in Jajarkot is still relatively modest. Among different causes of low production such as the traditional method of crop management, small-scale production, legal and institutional constraints, lack of sufficient water, biotic and abiotic stress, fruit drop at an early stage due to insect infestation is the major problem of mandarin production in the districts of western mid-hills of Nepal (Budathoki and Pradhanang, 1992). Among the pests damaging mandarin, the fruit fly is found to be an important pest. Fruit flies damage mandarin either by directly destroying the fruit or by degrading quality that causes loss in trade value and export, due to quarantine imposed by the importing country. In recent years, the fruit fly has been found to be problematic, causing an economic loss of mandarin produced in Jajarkot.

Farmers have been using different management practices for controlling fruit flies. However, they lack knowledge regarding the fruit fly species that affect the mandarin crop and their peak infestation time. The different management practices used by farmers for controlling fruit fly are not well documented. Farmers are not using proper trapping, bagging, and management techniques to control fruit fly Bhandari (1993). So, it is essential to find out the management practices used by farmers for fruit fly control. Thus, this study focuses on species identification and study of population dynamics of fruit flies at different locations by using pheromone traps. This study also concentrates on finding out the awareness status of mandarin growers regarding the nature of fruit fly damage as well as the factors affecting their awareness, and documentation of different management practices used by farmers for fruit fly control in Jajarkot.

2 Materials and Methods

2.1 Farmer's survey

2.1.1 Survey design and study area

The study was conducted in command areas of the Citrus zone of Jajarkot district such as Kushe Rural Municipality, Bheri Municipality, and Nalgad Municipality, from April to June, 2021. A sampling frame of mandarin growers whose orchards were at least five years old was collected from Citrus and Bee zone (Fig. 1, Table 1), PMAMP, Jajarkot. Sixty farmers were randomly selected for the survey. The sample size was determined using a sample size calculator by Raosoft, Inc incorporating a margin of error of five percent. Mandarin growing farmers were randomly selected and, through an interview schedule, information about the household, socio-economic status, the farmer's awareness regarding damage symptoms of the fruit fly, as well as management practices oriented towards control of fruit fly in the mandarin orchard, was collected. Two Focus Group Discussions (FGDs) were conducted in the study area. In the FGDs, local farmers of all ethnic groups and both males and females participated and provided the required information.

Figure 1. Map showing study area

2.1.2 Data processing and analysis

The collected data from the study were analyzed using IBM SPSS Statistics Software (Version 26). While analyzing total farm size, the farmers were categorized into three categories viz. small, medium, and large landholding farmers. The categories were determined using mean ± standard deviation. Descriptive statistics were also used to evaluate the extent of awareness about the nature of damage by fruit flies in mandarin in percentage. Other variables like the use of traps, chemical pesticides, fallen fruit management techniques, pruning, etc. were also analyzed using descriptive statistics. For the analysis of factors affect-

Table 1. Description of fruit fly monitoring locations

Location	Altitude (masl)	Latitude	Longitude
Baunthana	1350	28°44′25.562" N	82°11′31.181" E
Bhere	1550	28°43′17.757" N	82°11′14.965" E
Damdalah	1750	28°47′44.194" N	82°10′1.495" E

masl = meters above sea level

ing awareness of the nature of fruit fly damage among mandarin growers, a binary logit regression model was used. The model assumed the awareness of the nature of fruit fly damage as the binary dependent variable with a value of 1 (if a farmer is aware) and 0 (if a farmer is unaware). In this model, the explanatory variables used were age, education, household size, farm size, and mandarin cultivation experience.

2.2 Monitoring of fruit fly

2.2.1 Research design

The sites for the monitoring of fruit flies were Bheri Municipality and Kushe Rural Municipality, where three different mandarin orchards were selected at each location such that the altitude difference between each location was 200 meters. Table 1 describes the altitude, latitude, and longitude of each mandarin orchard selected. Survey protocol provided by NPPO (2019) was referred for setting traps in mandarin orchards. In each orchard, three trees of mandarin 50 m apart from each other were selected. Fruit fly male lures originated from para-hormones (methyl eugenol and cue lure) and Great fruit fly bait containing traps were installed in three different trees of each mandarin orchard. Great fruit fly bait [protein hydrolysate (25%) + abamectin (0.1%)] was kept in the McPhail trap while methyl eugenol and cue lure was kept in the Steiner trap. Altogether nine traps were used for monitoring purposes.

The three traps were baited with three different lures and placed in three trees each,1.5 m above the ground and at least 50m apart (PQPMC, 2019). The lures were changed at every 15-day interval for a more effective luring capacity. Cue-lure (1ml) and methyl eugenol (1ml) were soaked in cotton and kept in their respective Steiner trap at the top and 1ml Malathion 50 EC soaked in cotton was kept at the bottom of each Steiner trap to knock down the fruit flies. Great fruit fly bait [protein hydrolysate (25%) + abamectin (0.1%)] was kept at the bottom of the McPhail trap filling 1cm from the bottom, diluted with water in the ratio of 1:2 (PQPMC, 2019).

2.3 Data collection and analysis

The trapped fruit flies were examined for the species identification purpose and some of them were preserved in vials until counting. Fruit flies' morphological traits were investigated in each specimen to identify it to species level. A hand lens was used to observe the morphological traits on the body of a fruit fly, and the identified specimen was photographed and displayed on paper. A diagnostic key to the pest species of fruit flies dealt with in Plant Health Australia (2018) was used to identify them. The number of fruit flies trapped in each trap and the species of the fruit fly trapped was recorded in 7 days interval. All the data obtained from monitoring were analyzed using the software Microsoft Excel 2016.

3 Results and Discussion

3.1 Farmer's survey

3.1.1 Fruit fly awareness and infestation

Awareness on the nature of damage of fruit fly Although all the respondents were able to identify fruit flies, not all were aware of the damage symptoms caused by the fruit flies on mandarin. Out of 60 respondents, only 30% were aware of the nature of fruit fly damage while 70 % of respondents were unaware of the nature of fruit fly damage.

Source of information Among 18 respondents who were aware of fruit fly and their damage symptoms, 77.78% reported having obtained information about fruit flies from other farmers, 55.56% percent from extension officers, and 38.39 % from mass media as shown in Table 2.

Reasons for lack of information about fruit fly and its damage The farmers who were unaware of the fruit fly damage reported multiple reasons behind lack of information which is shown in Table 3.

Description of damage by aware respondents Among the farmers who were aware of the damage of fruit flies, 77.78 %, 55.56 %, 61.11%, and 50 % respondents described fruit drop, distorted and malformed fruits, fruit lesions, and presence of maggots respectively as the damage symptoms of fruit flies in mandarin as shown in Table 4.

The extent of damage caused by fruit flies in mandarin The survey data obtained from aware respondents revealed that 44.44 % of farmers described the extent of fruit fly damage in their orchard to be high (50-75%) followed by 33.33 %, 16.67 %, and 11.11 % who described the extent of damage as a medium (25-50%), very high (75-100%), and low (0-25%), respectively.

Farmers' knowledge of the damaging stage of fruit flies in mandarin The survey results revealed that 38.89 % of respondents mentioned that the fruit fly damage started in the fruiting stage whereas 61.11 % of respondents mentioned that the damage to fruit occurred in the ripening stage. Infestation started from the time of fruit initiation and continued as long as the crop produced fruits, suggesting the need for continuous control starting from fruit initiation until harvesting (Nasiruddin et al., 2003).

Farmer's knowledge on reasons behind infestation of fruit fly in mandarin Respondents reported multiple reasons behind the infestation of fruit flies in mandarin which are shown Table 5. The majority of farmers believed poor orchard sanitation was the reason behind fruit fly infestation.

Inspection of the farm for signs and symptoms of fruit fly damage 77.78% of aware respondents inspected their orchard for fruit fly damage whereas 22.22% of aware respondents did not inspect their orchard. Among the respondents who inspected their orchards, 50% reported that they inspected their orchards a couple of times a week, 21.43% reported that they inspected their orchards once a week and 28.57% said they didn't inspect their orchard very often.

3.1.2 Factors affecting awareness status

Various factors affect the awareness of fruit fly damage symptoms. The study analyzed the effect of such independent variables on the awareness of the nature of the damage of fruit flies. Before performing the regression, diagnostic tests were carried out to check the multicollinearity problem in the independent variable. The average VIF was found to be 1.21. None of the independent variables was found to have a significant correlation, suggesting no problem of multicollinearity.

Table 6 represents the result of a binary logit regression model to determine the most critical factors that affect the farmers' knowledge of fruit flies and their damage symptoms. For regression analysis using the logit model, five independent variables were used among which one turned out to be statistically significant. Among the independent variables, the mandarin cultivation experience of farmers had a significant effect at a 5% level of significance on the knowledge of fruit flies and their damage symptoms.

Here the model's Chi-square value(χ^2) of 16.81 and log-likelihood ratio of -28.25 indicates that all the variables in the model significantly influence the probability of awareness of fruit fly damage symptoms at a 1% level of significance. The pseudo R2 value of 0.23 indicates that about 23.0% of awareness of fruit fly damage symptoms is governed by tabulated variables i.e. the model fits 23.0% to the given data.

3.1.3 Management practices of farmers for fruit fly

Table 7 shows different management practices followed by farmers for fruit fly control. The majority of the farmers practiced pruning and fallen fruit management, whereas the use of chemical pesticides and traps was practiced by fewer proportion of farmers. Secateurs or knives were used for pruning during April and May or soon after the harvest. After the appearance of fruit flies in April, people sprayed chemical pesticides with the help of a sprayer.

In the survey, farmers reported that pesticides did not eradicate fruit flies, but kept the pest away from the orchard for a short time and needed to be applied frequently, which is a dangerous, expensive, and time-consuming process. Most of the people were unaware of traps, and traps were not commonly used.

Fallen fruit management A group of farmers practiced collection of fallen fruit and used different methods to manage the fallen fruits for controlling fruit fly as shown in Table 8. Among the respondents, 65.96% of the farmers fed the fallen fruits to the livestock, 51.06% kept the fallen fruits in a plastic bag, 44.68% dumped the fallen fruits in a pit and 38.30% of farmers mixed the fallen fruits in the manure pit.

Traps used by farmers Among 17 respondents who used traps to manage fruit flies in their orchards, 94.12% used cue-lure, 41.18% used methyl eugenol, and 35.29 % used protein hydrolysate as shown in Table 9. In comparison to other sources (ADO/PMAMP, friends and mass media), the role of the agro vet was reported to be greater in supplying information about traps, and providing traps to the farmers as shown in Table 10.

The most effective method of fruit fly management According to respondents, 48.33% mentioned fallen fruit management as the most effective method to manage fruit flies, while 16.67% mentioned the use of traps. Likewise, 11.67% each mentioned pesticide use, pruning, and combination of different methods respectively, as the most effective methods of fruit fly management. Despite the well-established effectiveness of bagging as a means of controlling fruit

Table 2. Sources of information about fruit fly damage among the respondents (2021) (n=18)

Response	Other farmers	Extension officers	Mass media
Yes	14 (77.78)	10 (55.56)	7 (38.89)
No	4 (22.22)	8 (44.44)	11 (61.11)

Figures in parentheses represent the percentage of respondents

Table 3. Reasons behind lack of information about fruit fly damage among the unaware respondents (2021) (n=42)

Reasons	Yes	No
Lack of self-interest to know	10 (23.81)	32 (76.19)
Lack of technical know-how	28 (66.67)	14 (33.33)
Insufficient government-led activities	27 (64.29)	15 (35.71)
Lack of communication efforts from government and non-government agencies	16 (38.10)	26 (61.90)

Figures in parentheses represent the percentage of respondents

Table 4. Description of damage given by aware respondents (2021) (n=18)

Response	Fruit drop	Distorted and malformed fruits	Fruit lesions	Presence of maggots
Yes	14 (77.78)	10 (55.56)	11 (61.11)	9 (50)
No	4 (22.22)	8 (44.44)	7 (38.89)	9 (50)

Figures in parentheses represent the percentage of respondents

Table 5. Reasons for increasing fruit fly infestation in mandarin (2021) (n=18)

Response	Yes	No
Poor orchard sanitation	12 (66.67)	6 (33.33)
Lack of knowledge of insect biology	8 (44.44)	10 (55.56)
Unavailability of appropriate chemical pesticide	11 (61.11)	7 (38.89)
Lack of awareness of the use of traps	10 (55.56)	8 (44.44)
Inadequate support from service providers	11 (61.11)	7 (38.89)

Figures in parentheses represent the percentage of respondents

Table 6. Binary logit regression of factors affecting awareness status of nature of fruit fly damage in mandarin among mandarin growers

Determinants	Fruit fly aware(1=Yes)			
	dy/dx	Odd ratio	Z	p>|z|
Age (Years)	0.003 (0.010)	1.019 (0.056)	0.35	0.73
Education (Years)	0.014 (0.018)	1.075 (0.098)	0.79	0.43
Mandarin cultivation area (ropani†)	0.016 (0.013)	1.089 (0.076)	1.23	0.219
Mandarin cultivation experience (Years)	0.037 (0.017)	1.211 (0.104)	2.21	0.027**
Household size	−0.070 (0.132)	0.695 (0.175)	−1.44	0.15
Summary Statistics				
Number of observation	60			
LR Chi^2	16.81***			
Log-likelihood	−28.25			
Pseudo R^2	0.23			

† 1 ropani = 508.74 square meters; Figures in parenthesis indicate standard error; ** and *** indicate 1% and 5% level of significance respectively and dy/dx is marginal effect after logit

Table 7. Farmer's practices on management of fruit fly in mandarin (2021) (n=60)

Response	Pruning	Pesticide use	Fallen fruit management	Use of traps
Yes	53 (88.33)	14 (23.33)	47 (78.33)	17 (28.33)
No	7 (11.67)	46 (76.67)	13 (21.67)	43 (71.67)

Figures in parentheses represent the percentage of respondents

Table 8. Farmer's response on different practices adopted to manage fallen fruits (2021) (n=47)

Response	Kept in plastic bags	Dumped in a pit	Mixed in a manure pit	Fed to livestock
Yes	24 (51.06)	21 (44.68)	18 (38.30)	31 (65.96)
No	23 (48.94)	26 (55.32)	29 (61.70)	16 (34.04)

Figures in parentheses represent the percentage of respondents

Table 9. Farmer's response on types of traps used to control fruit fly (2021) (n= 17)

Response	Cue-lure	Methyl Eugenol	Protein Hydrolysate
Yes	16 (94.12)	7 (41.18)	6 (35.29)
No	1 (5.88)	10 (58.82)	11 (64.71)

Figures in parentheses represent the percentage of respondents

Table 10. Farmer's response on information sources of trap used (2021) (n=17)

Response	Agro vet	ADO/PMAMP	Friends	Mass media
Yes	14 (82.35)	12 (70.59)	6 (35.29)	7 (41.18)
No	3 (17.65)	5 (29.41)	11 (64.71)	10 (58.82)

Figures in parentheses represent the percentage of respondents

Table 11. Species-wise count of different fruit fly species at different altitudes (2021)

Fruit fly species	Altitude (meters above sea level)		
	1350	1550	1750
Bactrocera nigrofemoralis	670	301	121
Bactrocera dorsalis	200	110	50
Zeugodacus tau	196	106	74
Zeugodacus scutellaris	35	20	10
Total	1101	537	255

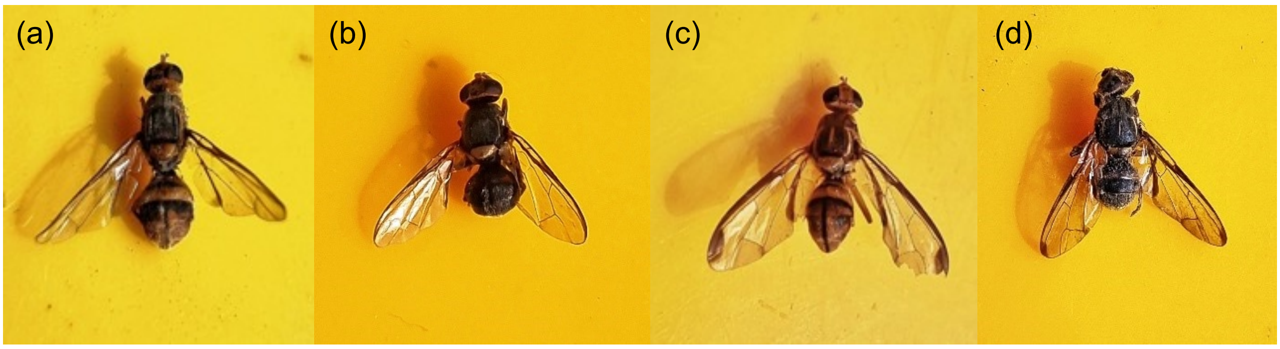

Figure 2. Fruit fly species (a). *Bactrocera dorsalis*, (b). *Bactrocera nigrofemoralis* , (c). *Zeugodacus tau*, and (d). *Zeugodacus scutellaris*

fly infestations, according to Xia et al. (2019), in various fruit crops, such as mangoes, guavas, and apples, farmers in Jajarkot were unaware of this practice.

3.2 Monitoring of fruit fly in mandarin

3.2.1 Composition of trapped species

Fig. 2 shows the photos of studied fruit fly species. *Bactrocera nigrofemoralis* was trapped in most numbers i.e. 76.39% followed by *Zeugodacus tau* (18.51%) and *Zeugodacus scutellaris* (5.09%) (data not presented). Similarly, traps baited with great fruit fly bait composed of *Bactrocera nigrofemoralis* (45.74%) and *Zeugodacus tau* (54.26%), respectively. The methyl eugenol baited trap consisted only *Bactrocera dorsalis*. This variation in the species of fruit flies attracted and trapped is due to the differences in lures used in traps and the agro-ecological condition of the orchard (Adhikari and Joshi, 2018). Each lure is specific to a fruit fly group or in some cases certain species of the fruit fly. According to Plant Health Australia (2018), *Bactrocera dorsalis* were attracted to methyl eugenol where as *Zeugodacus tau* and *Zeugodacus scutellaris* are attracted to cue-lure. Khan et al. (2015) reported having captured and identified *Bactrocera nigrofemoralis* using cue-lure. Similarly, Vasudha et al. (2020) revealed protein bait to be effective in capturing *Zeugodacus tau*.

3.2.2 Population dynamics of fruit fly

The population dynamics of fruit fly species at different altitude were recorded during monitoring in selected orchards of mandarin.

Fruit fly species captured in cue-lure The number of *Zeugodacus tau* trapped in cue lure baited traps was the lowest on 7th April across all three altitudes with 5, 2 and 1 catch(es) in 1350 m, 1550 m and 1750 m altitudes, respectively, as indicated by Fig. 3. The catches started increasing after the onset of April and reached their peak on 12th May at 1350 m (26 catches), on 19th May at 1550 m (15 catches) and on May 26th at 1750 m (11 catches). A similar study by Vasudha et al. (2020) showed that male fly captures increased from mid to late March and reached their peak in mid-May. The rise in captures after April is likely due to the increasing temperature and the availability of hosts, particularly cucurbits like cucumber, pumpkin, wax gourd, sponge gourd, and bitter gourd, which are typically abundant from April onwards (Li et al., 2020).

The number of *Zeugodacus scutellaris* trapped in cue lure-baited traps was the lowest on April 7th and 14th across all three altitudes, with zero catches at 1350 m, 1550 m, and 1750 m, respectively. On June 2nd and 9th, no catches were obtained at 1750 m (Fig. 4). The catches began increasing in mid-April and reached their peak on May 15th at 1350 m (9 catches), May 12th at 1550 m (5 catches), and May 19th at 1750 m (3 catches). Similar findings were observed for *Zeugodacus cucurbitae*, whose main hosts are cucurbits like those of *Zeugodacus scutellaris*, by Nahid et al. (2021). Fruit fly captures increased until May and then declined, coinciding with the peak availability of tender fruits of cucurbits. Factors such as high temperature, prolonged sunshine, and plantation activity influenced the abundance of fruit flies (Lee et al., 1992). The decrease in the population of Zeugodacus scutellaris is likely due to changes in weather parameters, as temperature and rainfall are reported as significant factors affecting fruit fly population dynamics (Khan et al., 2003).

The number of *Bactrocera nigrofemoralis* trapped in cue lure-baited traps was the lowest on April 7th across all three altitudes, with 20, 3, and 1 catch(es) at 1350 m, 1550 m, and 1750 m, respectively (Fig. 5). The number of trapped fruit flies began increasing at the onset of April and reached its peak on May 5th at 1350m (210 catches), May 12th at 1550 m (66 catches), and May 19th at 1750 m (26 catches). A similar study by Khan et al. (2015) showed that the number of *Bactrocera nigrofemoralis* catches increased from March and was highest in April. The seasonal occurrence of *Bactrocera nigrofemoralis* was found to largely depend on the availability of host plants, particularly pomelo (Khan et al., 2015).

Fruit fly species captured in methyl eugenol The number of *Bactrocera dorsalis* trapped in methyl eugenol-baited traps was the lowest on May 19th at 1350 m and 1550 m altitude (2 and 3 catches respectively), and on April 7th at 1750 m altitude (1 catch) (Fig. 6). The captures began increasing after April and reached their peak on April 28th at 1350 m (50 catches), May 5th at 1550 m (23 catches), and May 26th at 1750 m (10 catches). Similar results were reported by Yin et al. (2018) in traps set in mango orchards, where high numbers of fruit flies were captured. Chen and Ye (2007) observed an increase in *Bactrocera dorsalis* population from April, peaking in August. The rise in fruit fly population at the end of April is likely due to the proximity of mango trees to the mandarin orchards, coinciding with the mango harvesting season.

The number of *Bactrocera nigrofemoralis* trapped in Great fruit fly bait containing traps was the lowest on 9th June at 1350 m altitude (1 catch), and on 26th May, 2nd June and 9th June at 1550 m altitude (no catches). On 21st April at 1750 m altitude, and on 26th May, 2nd June and 9th June in all three altitudes, no fruit flies were caught in traps (Fig. 7). The captures began increasing at the end of April and reached their peak on 5th May at 1350 m (16 catches), 12th May at 1550 m (11 catches) and May 19th at 1750 m (7 catches).

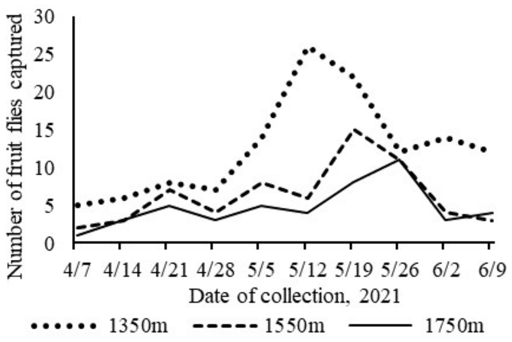

Figure 3. Population dynamics of *Zeugodacus tau* in cue-lure baited traps during the study period (2021)

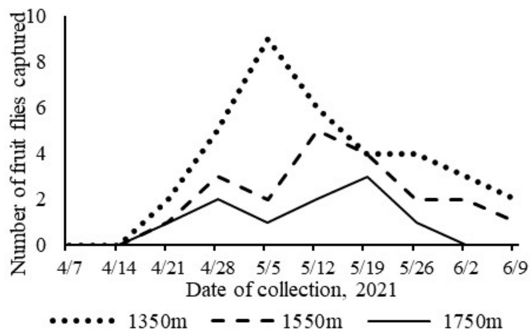

Figure 4. Population dynamics of *Zeugodacus scutellaris* captured in cue-lure baited traps during study period (2021)

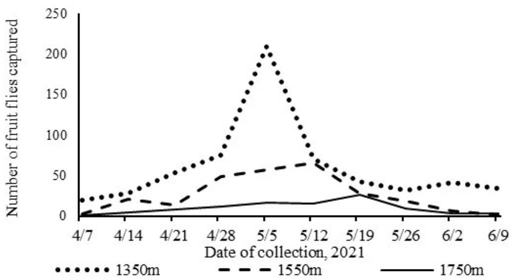

Figure 5. Population dynamics of *Bactrocera nigrofemoralis* captured in cue-lure baited traps during the study period (2021)

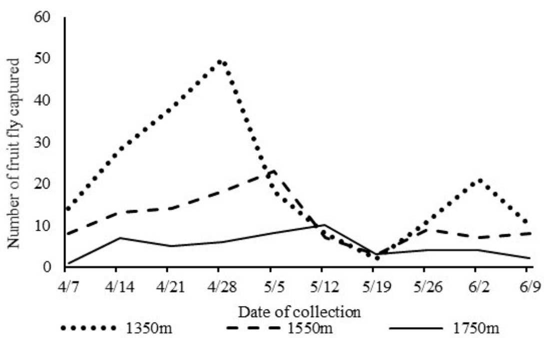

Figure 6. Population dynamics of *Bactrocera dorsalis* captured in methyl eugenol baited traps during study period (2021)

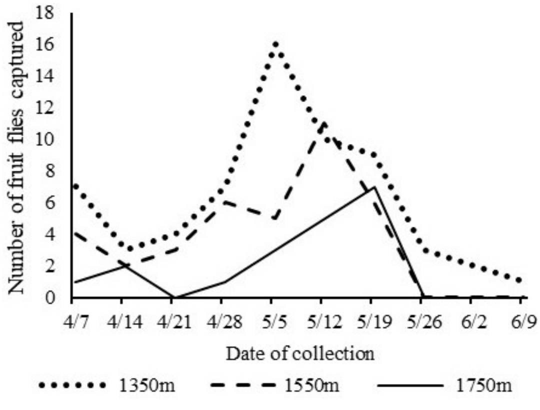

Figure 7. Population dynamics of *Bactrocera nigrofemoralis* captured in traps baited with Great fruit fly bait during study period (2021)

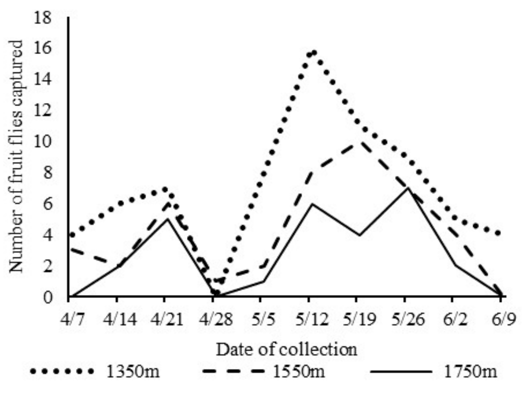

Figure 8. Population dynamics of *Zeugodacus tau* captured in traps baited with Great fruit fly bait during study period (2021)

Similarly, the number of *Zeugodacus tau* trapped in Great fruit fly bait containing traps was the lowest on 28th April at 1350 m altitude (no fruit fly caught), and on 7th April, 28th April and 9th June at 1750 m altitude (no catches) (Fig. 8). The lowest number of fruit fly was captured on 28th April and 9th June at 1550 m altitude (zero catches). The captures started increasing at the end of April and reached their peak on 12th May at 1350 m (16 catches), 19th May at 1550m (10 catches), and May 26th at 1750 m (7 catches).

The population dynamics of *Bactrocera nigrofemoralis* and *Zeugodacus tau* trapped in Great fruit fly bait was found similar to that trapped in cue-lure, but the total number of catches were less. The efficacy of fruit fly traps is influenced in the tree canopy (Hooper and Drew, 1979; Robacker et al., 1990), the host fruit species and the surrounding habitat (Aluja et al., 1996), the host phenology (Robacker et al., 1990), thermal and water stress Robacker et al. (1990), and climatic conditions (Cunningham et al., 1978; Gazit et al., 1998).

3.2.3 Comparison of fruit fly count at different times

The peak infestation period of all four fruit fly species was recorded at 1350 m followed by 1550m and 1750m as shown in Figs. 3 to 8. The temporal dynamics of fruit fly in different altitude of the study is consistent with Gautam et al. (2020). National Citrus Research Program (NCRP) also revealed that the adult flies emerged in the second half of April. As of yet, Nepal has not carried out a detailed study of adult emergence, adult phenology patterns, crop susceptibility, fruit drop-to- pupation period and developing of controlling measures (FAO, 2003).

3.2.4 Comparison of species-wise count

The species diversity of fruit flies in mandarin orchards was found to be dominated by *Bactrocera nigrofemoralis* as shown in Table 11. The higher number of fruit fly captured were *Bactrocera nigrofemoralis* (1092) followed by *Zeugodacus tau* (376), *Bactrocera dorsalis* (360), and *Zeugodacus scutellaris* (65).

3.2.5 Comparison of fruit fly captured in different altitude

The maximum number (1101) of fruit flies was captured in 1350 m followed by 1550 m (537) and 1750 m (255) as shown in Table 11. The population phenology affects spatial pattern and the amount of captured fruit flies were higher at lower elevation (Kounatidis et al., 2008). Israely et al. (2005) found similar result where they studied the temporal population at three altitudes.

4 Conclusion

The awareness among mandarin growers regarding fruit fly and its damage is still low in Jajarkot district, which is significantly affected by mandarin cultivation experience. Majority of the aware respondents (44.44%) reported that high level of damage (25-50%) was caused by fruit fly and the damage started from the fruiting stage during April and continued till ripening. Farmers are practicing pruning, fallen fruit management, chemical pesticides, and traps to control fruit flies. As bagging has been proven to be a successful technology for controlling fruit flies in various fruit crops, including mandarins, it presents a viable and sustainable option for farmers in the region. Therefore, we suggest that educational programs and resources be developed and made available to mandarin growers in the area to promote the adoption of bagging practices. Monitoring record indicates four different species viz. *Bactrocera nigrofemoralis*, *Zeugodacus tau*, *Zeugodacus scutellaris* and *Bactrocera dorsalis* to be problematic in mandarin orchards of Jajarkot. Methyl eugenol can be effective for trapping *Bactrocera dorsalis* and great fruit fly bait for *Bactrocera nigrofemoralis* and *Zeugodacus tau*. Similarly, *Bactrocera nigrofemoralis*, *Zeugodacus tau* and *Zeugodacus scutellaris* can be effectively captured by cue-lure. Among three altitudes (1350 m, 1550 m and 1750 m), higher number of fruit flies were captured at lower altitude and peak infestation period was recorded earlier in lower altitude as compared to higher altitude. The number of all the species of fruit fly started increasing from April and the reached highest during the month of May. Fruit fly management should be initiated before May due to higher pest intensity recorded during this period.

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Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

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