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ORIGINAL RESEARCH ARTICLE

Farmer's perception on Chinese citrus fruit fly (CFFs) and its management in Solukhumbu and Sindhuli district of Nepal

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ABSTRACT

This study conducted between January and June 2022 aimed to assess the impact of precipitation on *Bactrocera minax*, a citrus pest, in Nepal's Solukhumbu and Sindhuli districts. Primary data were gathered from 84 respondents using pre-tested interview schedules, focal group discussions (FGD), and key informant interviews (KII), while secondary information was collected through literature review. The results highlighted the Chinese citrus fruit fly as a significant citrus pest causing fruit drop, particularly impacting Mandarin cultivation after sweet orange displacement. Farmers in Sindhuli exhibited greater motivation and trust in citrus cultivation compared to those in Solukhumbu. Notably, the fruit drop was lower (4.33%) in Sindhuli where the Area-wide Management Program (AWCP) utilizing protein bait and field sanitation was applied, in contrast to Solukhumbu where fruit drop was higher (35.5%), suggesting the effectiveness of AWCP. The PMAMP Sindhuli super zone played a direct role in the study, with respondents in Sindhuli demonstrating higher awareness of Chinese citrus fruit flies and AWCP. Technical and financial support for citrus cultivation was also more prevalent in Sindhuli. Furthermore, the study found that the majority of respondents perceived protein bait (AWCP) as the most straightforward, effective, and expensive management method, despite its limited application in Solukhumbu. This study underscores the importance of AWCP in mitigating citrus pest infestation, particularly in areas with high precipitation, and emphasizes the need for broader adoption of effective management strategies in citrus cultivation regions.

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INTRODUCTION

Citrus are flowering trees and shrubs that belong to the Rutaceous family and are native to the subtropical and tropical regions of Asia, Australia, Melanesia, and Polynesia. They are believed to originate from southeast Asia (Dahal *et al.*, 2020). Citrus is an important cash crop for the hill farmers of Nepal (Gautam *et al.*, 2020a). Citrus in Nepal is cultivated on a small as well as commercial scale at an altitude of 650 to 1400 m above sea level, with the mean annual temperature being 17–20 °C and annual rainfall ranging from 1000–2800 mm (Gautam *et al.*, 2020b). In Nepal, citrus cultivation is done in 68 districts covering 46,715 ha, 27,339 ha of productive area, 274,140 mt. of production, and 10.03 mt/ha of yield (MoALD, 2019; MoALD, 2021). Table 1 shows the total area, productive area, production, and yield of citrus fruits in different years in Nepal. Although the citrus cultivation area is increasing, the productivity is very low in Nepal compared to most citrus-growing countries worldwide (Chhetri *et al.*, 2021). The main problem for decreasing the productivity of citrus fruit in Nepal is the due effect of many diseases and pest infestations such as citrus fruit fly, phytophthora, citrus greening, powdery mildew, fruit sucking moth, citrus canker, etc. Thus, there is scope for increasing the production and productivity of citrus by adopting

Table 1. Statistics of citrus fruits for the last ten years (2010/11-2019/20).

Year	Total Area (Ha.)	Productive Area (Ha.)	Production (Mt.)	Yield (Mt./Ha.)
2010/11	35,576	23,607	263,710	11.17
2011/12	37,565	24,089	240,793	10.00
2012/13	36,975	23,645	216,188	9.14
2013/14	38,988	25,497	224,357	8.80
2014/15	39,035	25,261	222,789	8.82
2015/16	40,554	24,854	218,447	8.79
2016/17	46,328	26,759	239,773	8.96
2017/18	44,424	25,964	245,176	9.44
2018/19	46,392	28,411	272,620	9.60
2019/20	46,715	27,339	274,140	10.03

Source: (MoALD, 2019/20).

disease and pest control measures and proper orchard management practices (Srivastava and Singh, 2009). Among the diseases and pests mentioned above, the citrus fruit fly is threatening the citrus orchard by damaging citrus fruits up to 99%. In citrus, there is also a heavy infestation of pests and diseases that cause a heavy loss of economy. The vegetable and fruit flies also attack flowering plants such as chrysanthemums, gerberas, gypsophilas, and marigolds, aiding in their outspread (Yadav *et al.*, 2024). In the case of citrus, one of the most economically important pests was the citrus fruit fly (*Bactrocera spp.*), which falls under one of the largest families Tephritidae and order Diptera of the class insect (Sharma *et al.*, 2015) and causes heavy loss of citrus fruit on the tree. The citrus fruit fly creates a barrier to the export of citrus fruits. One of the predominately occurring fruit fly species in Nepal is *Bactrocera cucurbitae*, *B. dorsalis*, *B. zonata*, *B. tau*, *B. scutellaris*, *B. yashimoi*, *B. minax*, *B. caudatus*, *B. correcta*, and *B. diversus* (Pant *et al.*, 2019). Among the fruit flies above-mentioned, the Chinese fruit fly (*Bactrocera minax*) is a devastating pest that causes up to 97% loss of the crop at the end of the harvesting period (Sharma *et al.*, 2015).

In Solukhumbu district alone, approximately one-third of citrus production is lost annually due to the impact of fruit flies, highlighting the severity of the issue. Despite efforts to manage these pests, significant control of infection and fly populations remains elusive, compounded by financial challenges faced by farmers. While studies have examined the effects of citrus fruit flies in other districts, a comprehensive assessment specific to Solukhumbu has been lacking in research priorities. This research aims to address this gap by conducting a thorough examination of the impact of citrus fruit flies in Solukhumbu district, thereby contributing to a better understanding of the challenges faced by farmers in this region. By identifying the reasons behind Solukhumbu's struggle in reducing infestations, this study seeks to provide valuable insights for both farmers and governmental organizations to effectively address the issue and implement appropriate management strategies. Further, this study bridges the research gap by providing a detailed investigation into the challenges posed by citrus fruit flies in Solukhumbu district, thereby offering novel insights and contributing to the broader efforts aimed at enhancing citrus productivity and mitigating pest-related losses in Nepal's citrus industry.

MATERIALS AND METHODS

Site of study and sample selection

The farmer survey, conducted between April and May 2022, aimed to assess farmers' perceptions and management practices regarding the Chinese citrus fruit fly in two districts of Nepal. The study was carried out in the Mapyadudh Koshi, Thulung Dudh Koshi, Sotang, and Mahakulung rural municipalities of Solukhumbu, as well as the Golenjor rural municipalities of Sindhuli (Figures 1 and 2). A total of 84 farmers were randomly selected for the survey, comprising sweet orange and mandarin growers from both within and outside the citrus zone of Solukhumbu district, as well as from the super citrus zone of Sindhuli.

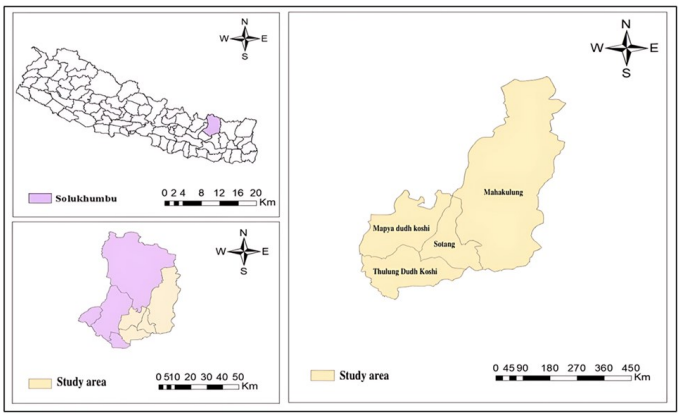

Figure 1. *Map depicting the four municipalities of Solukhumbu i.e., Mapyadudh Koshi, Thulung Dudh Koshi, Sotang, & Mahakulung rural municipalities (RM).*

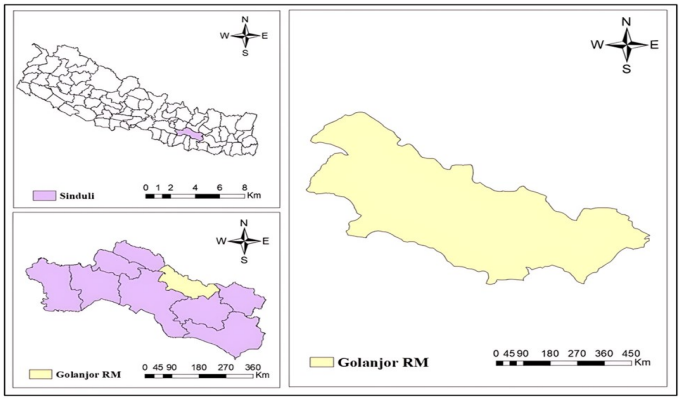

Figure 2. *Map depicting the study site of Sinduli i.e., Golanjor rural municipality (RM).*

Survey design

During the preparatory phase, a desk review of documents was conducted, and topic-related questionnaires were developed based on the information gathered from the literature review. These questionnaires were designed to collect data necessary to address the research questions and were carefully reviewed, tested, and modified based on feedback from a few reviewers. A field survey was then carried out at the targeted site, involving 84 farmers, during which a series of questions were posed to gather valuable data. Additionally, informal discussions, semi-structured questions, and field visits were conducted as part of the survey process. Before administering the interview schedule to respondents, a pre-testing phase was conducted on five individuals near the study area to ensure the reliability and validity of the schedule. Feedback from this pre-testing was incorporated into the final interview schedule. Furthermore, focus group discussions were conducted with farmers from four rural municipalities in Solukhumbu (Sotang, Mahakulung, Mapya Dudhkoshi, Thulung Dudhkoshi) and Golenjor rural municipality of Sindhuli (Magar *et al.*, 2022; Sah *et al.*, 2022). These discussions aimed to gather insights from participants regarding the research topic. Informal discussions and interviews were also held with principal key informants, including farmers, stakeholders, and zone officers. A series of questions pertaining to the study topic were posed during these interviews to gather additional perspectives and insights.

Methods of data collection

The study was based on primary and secondary data. The primary data was collected from the farmers by conducting the household survey (face-to-face interview), a focus group discussion (FGD), a key informant interview (KII), and recording information with the use of the questionnaire. The secondary data and information were obtained from various sources, such as published and unpublished literature, textbooks, libraries, study reports, the government's planning and policy documents, NARC publishing materials, the annual report of Kiwi Zone, the Program Implementation Unit, the Publication of Agriculture Knowledge Centre, and Solukhumbu. Information was also obtained through a review of different publications, mainly the Ministry of Agriculture and Livestock Development (MoALD), Central Bureau of Statistics (CBS), Krisi Diary 2077, 2078, 2079, etc. (Chaudhary *et al.*, 2023).

Data analysis and interpretation of data

The collected data were systematically analyzed to fulfill the study's objective, with a particular focus on qualitative data, which were summarized and presented descriptively in the report. Additionally, tables, and figures were utilized to effectively present the data. Furthermore, data sets obtained through the household survey underwent thorough analysis using computer packages, specifically SPSS (Ver. 25) and Excel. Statistical tools such as percentages, frequencies, and means were employed to analyze various variables including ethnicity, occupation, infection intensity, and information related to the Chinese citrus fruit fly. This analytical approach ensured a robust examination of the data and facilitated a comprehensive understanding of the research findings.

RESULTS AND DISCUSSION

Socioeconomic status of the farmers

Among the 84 respondents surveyed, 79.63% were male and 20.37% were female, with 73.33% males and 26.67% females in Solukhumbu, and 70% males and 30% females in Sindhuli. The education status of respondents was similar across both locations, categorized into illiterate (29.63% in Solukhumbu, 20.00% in Sindhuli), basic literacy (18.52% in Solukhumbu, 16.67% in Sindhuli), primary (20.37% in Solukhumbu, 20.00% in Sindhuli), secondary (12.96% in Solukhumbu, 26.67% in Sindhuli), plus two (16.67% in Solukhumbu, 13.33% in Sindhuli), and Bachelor and above (1.85% in Solukhumbu, 3.33% in Sindhuli) (Table 2). Ethnically, respondents in Solukhumbu were predominantly Janajati (90.74%), followed by Kshetri (7.41%) and Dalit (1.85%), while in Sindhuli, the distribution was 50% Janajati, 30% Kshetri, and 13.33% Dalit. Among them, 27.78% and 43.33% identified as Buddhist, 9.26% and 56.67% as Hindu in Solukhumbu and Sindhuli respectively, with 62.96% being Kirat in Solukhumbu. Regarding economic activity, 92.6% of respondents aged 15-59 in Solukhumbu and 93.5% in Sindhuli were economically active. The mean, maximum, and minimum ages of respondents were 39.6, 76, and 22 in Solukhumbu, and 44.7, 60, and 34 in Sindhuli respectively (Table 2). Additionally, 74.1% of respondents in Solukhumbu and 83.3% in Sindhuli depended on agriculture for their livelihood. The survey shows that the percentage of involvement of male farmers in production, management, and handling was higher as compared to females and could make a decision in the house in both locations, which indicates the unequal involvement of the gender. The dominant male respondent in citrus production was also recorded in Adhikari *et al.* (2022a). Further, a comparable situation of male dominance in outhouse jobs has been noted in Afghanistan (Tavva and Martini, 2014). The patriarchal society confines women to household duties and restricts their exposure outside the home.

Reason for citrus farming

Various factors have driven respondents to engage in citrus farming, including the utilization of marginal land (11.1%), traditional operational systems (16.7%), ease of operation (24.1%), and the potential for high income (48.1%). In Solukhumbu, respondents are primarily motivated by traditional operational systems (10%), ease of operation (13.3%), and high-income potential (76.7%). In Solukhumbu, 55.56% of respondents express dissatisfaction with citrus production, compared to 0% in Sindhuli. Conversely, 44.44% of Solukhumbu respondents report moderate satisfaction, whereas 23.3% of Sindhuli respondents do so. Additionally, 0% of Solukhumbu respondent's express satisfaction, while 76.67% of Sindhuli respondents report satisfaction with citrus production (Table 2). Analysis

Table 2. Socio-economic characteristics of respondents.

Characteristics	Frequency (N = 84)		Percentage (%)	
	Solukhumbu	Sindhuli	Solukhumbu	Sindhuli
Gender				
Male	43	22	79.63	73.33
Female	11	8	20.37	26.67
Age				
0-14 Years	0	0	-	-
15-59 Years	50	28	92.6	93.5
Above 60 Years	4	2	7.4	6.5
Educational status				
Illiterate	16	6	29.63	20
Basic literacy	10	5	18.52	16.67
Primary school	11	6	20.37	20
Secondary school	7	8	12.96	26.67
High school (+2)	9	4	16.67	13.33
Bachelor & above	1	1	1.85	3.33
Ethnic status				
Janajati	49	15	90.74	50
Kshetri	4	9	7.41	30
Dalit	1	4	1.85	13.33
Brahmin	0	2	-	6.67
Religious status				
Buddhist	15	13	27.78	43.33
Hindu	5	17	9.26	56.67
Kirat	34	0	62.96	-
Source of Income				
Agriculture	40	25	74.1	83.3
Teacher	4	2	7.4	6.7
Business	10	3	18.5	10
Reason for citrus farming				
Marginal land	6	-	11.1	-
Tradition	9	3	16.7	10.0
Easier	13	4	24.1	13.3
High income	26	23	48.1	76.7
Production satisfaction				
Fully satisfied	0	23	-	76.67
Moderately satisfied	24	7	44.44	23.33
Unsatisfied	30	0	55.56	-
Technical and financial support				
No support	30	0	55.56	-
Cooperatives	2	0	3.70	-
NGOS/INGOS	12	0	22.22	-
AKC & PMAMP	10	30	18.52	100

Source: Field survey, 2022.

indicates that Sindhuli benefits from greater accessibility to technical and financial support from PMAMP compared to Solukhumbu. According to Adhikari *et al.* (2022b) and Chauhan *et al.* (2020) the present and future status of citrus farming can be improved with greater accessibility to technical and financial support. While Solukhumbu farmers require focused attention from PMAMP, various cooperatives, NGOs, and INGOs have provided support despite the ongoing challenge of controlling the Chinese citrus fruit fly. In Sindhuli, successful trials of the Area-wide Management Program (AWCP) utilizing protein bait, supported by PMAMP and Karma Group China, resulted in a 50% subsidy for every orchard, including AWCP in the second year, demonstrating the effectiveness of coordinated efforts in pest management. Although the involvement of the different organizations is increasing, the support that the agency must provide has decreased, which was also noted by Acharya and Shrestha (2021). Despite of involvement of more than 70% of the farmers in citrus production, the adaptation of modern technology could be better in the citrus orchard.

Status of citrus orchard

The study examined various aspects related to citrus orchards, including the number of trees cultivated, cultivation practices, orchard age, prevalent diseases and pests, effectiveness of management practices, and production per tree. In terms of the number of citrus trees cultivated, respondents in Sindhuli showed a higher average of total planted citrus plants and non-fruiting citrus plants compared to Solukhumbu, indicating greater motivation for citrus farming in Sindhuli. Additionally, while the average fruiting citrus plants per respondent were higher in Solukhumbu (77.33) than in Sindhuli (59.53), the data on non-fruiting citrus plants suggested a stronger inclination towards citrus farming in Sindhuli, with averages of 184.23 and 125.03, respectively in Sindhuli compared to 152.24 and 74.91 in Solukhumbu (Table 3).

Table 3. Status of citrus orchard.

Characteristics	Solukhumbu	Sindhuli
Mean no. of citrus trees cultivated		
Total citrus tree	152.24	184.23
Fruiting tree	77.33	59.53
Non-fruiting tree	74.91	125.03
Cultivation practices		
Scientific technology	33.33%	60%
Traditional technology	66.67%	40%
Age of orchard		
Less than 3 years	5.56%	40%
3-8 Years	22.22%	23.33%
8-15 Years	42.59%	23.33%
15-25 Years	24.07%	6.67%
Above 25 Years	5.56%	6.67%
Prone disease and pest		
Fruit fly	46.30%	46.67%
Fruit fly & Phytophthora	9.26%	-
Fruit fly, Citrus canker, & Green stink bug	-	46.67%
Fruit fly, Phytophthora, and green sting bug	16.67%	-
Fruit fly & Green string bug	7.41%	-
Fruit fly and citrus greening	-	3.33%
Unknown	20.37%	-
All of the above	-	3.33%
Losses status		
Loss before management	39.9%	75.93%
Loss after management	35.5%	8.73%
Loss at the present time	35.5%	4.33%
Mean production per tree (NRs.)	2985.31	5166.67
Orchards with fruit problem	100%	100%

Source: Field survey, 2022.

Cultivation practices were categorized into traditional and scientific methods, with a higher adoption of the scientific method observed in Sindhuli (6%) compared to Solukhumbu (20.37%). This suggests a higher awareness among farmers in Sindhuli regarding advanced farming practices conducive to increased income. According to Acharya and Shrestha (2021), the infestation of the fruit fly is higher with the use of poor planting materials, unknown parent sources, lack of training pruning, and low adaptation of scientific technology. Orchard age was categorized into different groups, revealing a higher motivation for citrus farming in Sindhuli across various age categories compared to Solukhumbu. The study also identified prevalent diseases and pests in citrus orchards, with the Chinese fruit fly being the primary pest in both regions. However, additional diseases and pests, such as Phytophthora and green sting bugs, were more prevalent in Solukhumbu (24.93% and 24.08% respectively) compared to Sindhuli. In contrast, orchards in Sindhuli, where trifoliate-grafted seedlings were predominantly used, faced issues such as citrus canker and green sting bugs at a rate of 50%. According to Thapaliya *et al.* (2020), the loss of overall yield due to citrus fruit flies is directly proportional to the pupal density. In contrast, the emerged adult of the citrus fruit fly is not directly proportional to fruit loss. Analysis of the effectiveness of management practices indicated that the Area-wide Management Program (AWCP) using protein bait and field sanitation was more successful in controlling Chinese citrus fruit flies in Sindhuli compared to Solukhumbu, where management methods showed limited effectiveness. Lastly, the study analyzed production per tree and identified orchards with fruit drop problems. While fruit drop due to the Chinese citrus fruit fly was prevalent in both regions, it was not entirely controlled in Sindhuli despite management practices, indicating the need for further intervention. These findings were in line with Gautam *et al.* (2020b) who reported about 52.6% of farmers faced the fruit drop issues because of CFF.

Chinese citrus fruit fly surveillance and its information

In Solukhumbu, 50% of farmers noted heavy infestation despite limited awareness about the Chinese citrus fruit fly morphology, highlighting the potential impact of morphological knowledge gaps on surveillance. Conversely, in Sindhuli, 56.7% of farmers reported surveillance of Chinese fruit flies, reflecting a higher awareness level. Furthermore, while 53.7% of respondents in Solukhumbu possessed information about these flies, a significantly higher percentage (96.7%) in Sindhuli were knowledgeable about their morphology (Table 4). In Sindhuli, 96.7% of respondents could identify the flies morphologically, attributable to the Sindhuli citrus super zone's involvement in fly management. Conversely, only 31.48% of respondents in Solukhumbu were aware of fly morphology. Yadav *et al.* (2023a) and Sharma *et al.* (2022) reported that the proper screening of the invasive pests can significantly aid in the identification and management

Table 4. Farmer's knowledge, perception, and information on Chinese citrus fruit fly and its management.

Characteristics	Solukhumbu	Sindhuli
CCFs surveillance	50%	56.7%
CCFs information	53.7%	96.7%
Information on morphology		
Basic	16.67%	53.33%
Intermediate	9.26%	33.33%
High	5.56%	10.00%
Unknown	68.52%	3.33%
Information on damage symptoms		
Basic	31.48%	33.33%
Intermediate	14.81%	50.00%
High	5.56%	10.00%
Unknown	48.15%	6.67%
Information on lifecycle & and behavior		
Basic	7.41%	43.33%
Intermediate	7.41%	16.67%
High	0%	6.67%
Unknown	85.19%	33.33%
Information on management		
Basic	25.93%	26.67%
Intermediate	9.26%	53.33%
High	5.56%	13.33%
Unknown	59.26%	6.67%
Management practices followed		
Field sanitation	42.59%	-
Field sanitation and pheromone trap	11.11%	-
Field sanitation & Protein bait	5.56%	-
None of the above	40.74%	-
AWCP uses Protein bait and sanitation	-	100%
Information about AWCP		
Yes	14.81%	90%
No	85.19%	10%

Source: Field survey, 2022.

of these organisms. Respondents were categorized based on their knowledge extent, with proportions in Solukhumbu and Sindhuli identified as essential (16.67% and 53.33%), intermediate (9.26% and 33.33%), and high (5.56% and 10%), respectively. According to Yadav *et al.* (2022a), the information on damage symptoms aids in identification of pest. Therefore, the identification of drop fruit symptoms was reported by 31.48% and 33.33% of respondents in Solukhumbu and Sindhuli, respectively, while higher levels of awareness were seen for symptoms preceding fruit drop in Sindhuli (50% compared to 14.81% in Solukhumbu). Notably, 48.15% of respondents in Solukhumbu were unaware of damage symptoms, contrasting with only 6.67% in Sindhuli. The information on lifecycle and behavior of the pest plays a vital role in the management of pests; the higher the information about lifecycle and behavior higher will change of management (Yadav *et al.*, 2022b). In Solukhumbu, a mere 14.82% of respondents understood fly lifecycle and behavior, with none possessing extensive information. In contrast, 66.7% of Sindhuli farmers were knowledgeable, with varying levels of understanding categorized as basic, intermediate, and high (43.33%, 16.67%, and 6.7%, respectively). In Solukhumbu, 59.26% of respondents sought additional management information despite implementing field sanitation practices. Conversely, in Sindhuli, most respondents were knowledgeable about management techniques, with only 6.67% lacking ideas. This was supported by research of Pashi *et al.* (2021). Management knowledge levels were ranked as basic, intermediate, and high (25.93%, 9.26%, and 5.56% in Solukhumbu; 26.67%, 53.33%, and 13.33% in Sindhuli, respectively). The above-obtained result is similar to that of Adhikari *et al.* (2022c), which shows that the population of the citrus fruit fly has increased in the past 20 years in both Sindhuli and Solukhumbu.

Management practices adopted by farmers to control citrus fruit fly

In Solukhumbu, approximately 40.74% of farmers unknowingly implemented management practices, with 42.59% employing only field sanitation, 11.11% combining field sanitation with pheromone traps, and 5.56% utilizing field sanitation and botanical options alongside protein bait (Table 4). The results are consistent with the findings reported by Yadav *et al.* (2022c), indicating that sustainable approaches, particularly focusing on botanical aspects, significantly aid in mitigating pest infestations. Conversely, all respondents in Sindhuli adopted the Area-Wide Control Program (AWCP) incorporating protein bait and field sanitation, representing an advanced and effective management method. The AWCP, recognized for its environmental friendliness, economic viability, and sustainability, significantly reduced infestation in Sindhuli from around 75% to 4% (Table 4). While only 14.81% of respondents in Solukhumbu were familiar with AWCP, a substantial 90% in Sindhuli had knowledge of this method. In both regions, perceptions were categorized based on ease, effectiveness, cost, and preference.

Table 5. Farmer's perception of management practices in Solukhumbu and Sindhuli.

Management practices	Solukhumbu	Sindhuli
	Easiest	**Easiest**
Field sanitation	22.2%	33.3%
Protein bait	22.2%	60.0%
Chemicals	5.6%	
Unknown	50.0%	6.7%
	Effective	**Effective**
Protein bait	22.2%	
AWCP with protein bait	13.0%	93.3%
Chemicals	13.0%	
Unknown	51.9%	6.7%
	Cheapest	**Cheapest**
Field sanitation	53.7%	80.0%
Unknown	46.3%	20.0%
	Expensive	**Expensive**
Protein bait	35.1%	86.7%
Chemicals	1.86%	
Unknown	55.6%	13.3%

Source: Field survey, 2022.

Table 6. Protein bait spray time in Sindhuli.

Spray time	Percentage
Third week of April	6.67%
Last week of April	53.33%
First week of May	40.00%

Source: Field survey, 2022.

In Solukhumbu, 22.22% of respondents found field sanitation and protein bait to be the most accessible methods, while 5.6% mentioned chemicals as a permanent solution, though often referring to components within protein bait. This finding aligns with the findings of Karki *et al.* (2023) and Katel *et al.* (2023) who reported that any crop pests can be effectively controlled or managed with the application of chemical pesticides. Conversely, in Sindhuli, 60.03% viewed using protein bait as the easiest method. Further, Additionally, 93.3% of respondents in Sindhuli perceived AWCP as the only practical option for effective management (Table 5). Regarding cost, field sanitation was deemed the cheapest management practice in both regions. However, 93.75% of respondents in Solukhumbu considered protein bait expensive, contrasting with 86.7% in Sindhuli (Table 5). Yadav *et al.* (2023b) reported that there is a growing inclination among farmers towards integrated pest management approaches for pest control in their crops. The timing of protein bait spray is critical for effective control of Chinese citrus fruit flies, typically applied 25 days after adult emergence (Table 6). Further, Yadav *et al.* (2023c) proposed that the micro-organism fungi, Beauveria bassiana can control the flies naturally. In an area-wide management program, as demonstrated by Adhikari *et al.* (2021), Sharma and Dahal (2020), Adhikari *et al.* (2020) and Xia *et al.* (2018), the primary sanitary measure might involve promptly collecting fallen fruits and then treating the produce accordingly to fulfill phytosanitary requirements.

Conclusion

The study highlights the significant impact of the Chinese citrus fruit fly as a major pest in citrus orchards. Our findings underscore the heightened motivation and expectations among citrus farmers in Sindhuli compared to those in Solukhumbu. The Area-wide Management Program (AWCP) utilizing protein bait emerges as the most effective method for controlling the Chinese citrus fruit fly, emphasizing the importance of governmental agricultural bodies like PMAMP and AKC in supporting such initiatives. The study further emphasizes the critical role of proper dissemination of information and technologies for effectively managing citrus fruit flies. Despite initial misconceptions about the costliness of protein bait, our analysis reveals its affordability at Rs. 195 per fruiting tree per year, dispelling concerns among respondents. Furthermore, our research sheds light on the variability in the timing of protein bait application due to fluctuating climatic conditions, highlighting the necessity of pupa culture for accurately predicting emergence dates. Conclusively, the use of sweet orange as a trap crop within mandarin orchards, offering a promising strategy for pest management.

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Authors contribution

Conceptualization, S.L.; methodology, S.L.; software, S.L. and B.Y.; validation, S.L. and B.Y.; formal analysis, S.L. and B.Y.; investigation, S.L., R.K. and B.Y.; resources, S.L.; data curation, S.L.; writing—original draft preparation, S.L.; writing—review and editing, S.L., R.K., C.S. and A.S.; visualization, S.L. and B.Y.; supervision, S.L. and B.Y.; project administration, S.L.; funding acquisition, B.Y. All authors have read and agreed to the published version of the manuscript.

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