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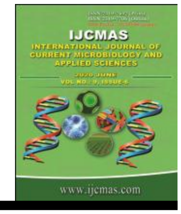

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Bridging Yield Gaps through Pheromone based Integrated Management of Tephritid Fruit Flies in Tomato, *Solanum lycopersicum* L.

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ABSTRACT

Fruit flies belonging to family Tephritidae have in the recent past caused serious economic losses in tomato crop in mid and low hills of Himachal Pradesh. The avoidable yield losses and fruit damage by fruit flies in tomato were 17.89 and 9.1 percent, respectively. *Bactrocera* (*Zeugodacus*) *scutellaris* was the most predominant species followed by *B.* (*Z.*) *tau* and *B.* (*Z.*) *cucurbitae* in Mandi district of Himachal Pradesh. In the on farm trials male annihilation using mixed lure traps+ bait application was found most effective treatment for fruit fly management recording highest net returns and BC ratio of Rs. 149480/ ha and 4.32, respectively. Pooled data of front line demonstrations for five crop seasons from 2014-2018 for area wide integrated management of fruit flies were found effective in reducing the fruit damage due to fruit flies by 19.98 percent and increased yield by 19.35 percent. The technology and extension gap of demonstrated technology was 106.98q/ha and 31.65q/ha, respectively which require further address by suitable research and extension techniques. Demonstrated technology not only convinced the farmers for using trapping as an integral component of fruit fly IPM but also resulted in reducing the pesticide load as evident by sale of more than 50000 fruit fly traps and reduction in pesticidal applications.

Introduction

Tomato is one of the most popular and widely grown vegetables in the world ranking second in importance to potato in many countries. It is rich in pro-vitamin A and vitamin C and contains an antioxidant lycopene. Tomato is cultivated in 0.789 mha with production of 19.745 mmt in the country (Anonymous, 2018), whereas in the state of Himachal Pradesh (NW Himalayas) it is cultivated in both summer and rainy seasons in about 12000 ha area with production of 485536 MT (Anonymous 2018a). Summer tomato is an important cash crop in the Balh valley and surrounding areas of district Mandi of Himachal Pradesh, India covering an area of 1000 ha with production of about 27000 MT.

The crop fetches handsome returns to the farmers of the region. In nature tomato plant is attacked by a number of insects and different non-insect-pests, that reduce its yield and also affect the market value of the produce. In general, the major pests of tomato include, gram pod borer, leaf miner, tobacco caterpillar, fruit flies, aphid and white fly. Most of these pests are polyphagous in nature and thereby have wide host range. In order to prevent the activity of major pests now-a-days several highly toxic broad-spectrum insecticides are used. As tomato fruits are plucked at close intervals, the maintenance of insecticidal film over plant due to frequent prophylactic application is not only uneconomical but also hazardous. Therefore, the uses of poisonous and hazardous toxicants are not very much desirable

Fruit flies (Diptera: Tephritidae) are recognized as one of the most important and serious pests of vegetable crops. In India, fruit flies are important pests of reproductive stages of a number of fruit and vegetable crops and cause huge economic losses (Verghese *et al.,* 2004; Dhillon *et al.,* 2005). Fruit flies cause huge economic losses to the tune of 35 – 80 percent in different areas of the state of Himachal Pradesh (Sood and Nath 1999; Prabhakar *et al.,* 2009). Their attack on the fruit not only reduces the yield but also affects or lowers the market value of the produce. *Bactrocera* (*Zeugodacus*) *cucurbitae* (Coquillett) and *B.* (*Z.*) *tau* (Walker) have been recorded as the major fruit fly species in the mid and low hills of Himachal Pradesh (Gupta *et al.,* 1992). However, in recent years, *Bactrocera* (*Z.*) *scutellaris* (Bezzi) a new fruit fly species has been reported to infest vegetable crops in the area (Sunandita and Gupta 2007; Prabhakar *et al.,* 2007).

Owing to high fecundity, polyphagous nature, wide host range, high adaptability, multivoltine nature, peculiar damaging potential, concealed egg, larva and pupal stages etc., fruit flies are the most difficult pest to manage. The hidden or concealed maggots inside the fruit or plant parts mostly escape the insecticides applied for its management. As the existing recommendation fail to target the adults, eggs and the developing maggots, besides high residual toxicity of pesticides, farmers consequently resort to frequent insecticidal applications; which leaves harmful residues on fruits and vegetables making them unsuitable for human consumption. Also the heavy loads of insecticides applied for their management pollutes our environment apart from many side effects.

With growing awareness among scientists and pest management workers about the damage of fruit and economic losses due to fruit flies, now population monitoring, bait spray and male annihilation (mating disruption) are receiving importance for fruit flies management by the farmers and plant protection workers under field conditions in India. Further, fruit fly management options were earlier applied on individual farms by farmers leading to little success as we know that fruit flies don't respect the farm boundaries and can fly from one farm to other farm and even from non cultivated land and wild host plants. With the growing awareness among scientists, producers and consumers about fruit flies, their destruction potential and effect on regional and international trade, the approach to manage fruit flies has been changed in recent past from local area i.e. on farm integrated pest management practice by individual farmers to Area Wide Integrated Pest Management (AW-IPM) programme. In view of above facts, the present studies were conceptualized to determine avoidable losses, identification of prevalent fruit fly species, to access the effectiveness of a localized bottle trap (Palam Fruit Fly Trap) using a mixture of fruit fly para pheromones for attracting male adults combined with bait application under on farm trials and further dissemination through front line demonstrations for wide area pest management and as an integral component of IPM of fruit flies.

Materials and Methods

Study area

The present studies were conducted in district Mandi of Himachal Pradesh located in 31.5892° N latitude and 76.9182° E longitude. The study areas comprised of vegetable intensive Balh valley of district situated at an altitude of about 800 m amsl receiving average rainfall of about 1200 mm.

Extent of losses

To study the extent of losses/ avoidable losses caused by fruit flies in tomato, an experiment was conducted on farmer's field at three locations in the district during crop seasons of 2013 and 2014. The experimental plot was divided into two sets i.e. protected and unprotected with three replications. In protected plots, the crop was protected from fruit fly damage following regular application of gur (Jaggery) + malathion (5-6 applications) at weekly intervals, while no insecticidal application was made in case of unprotected plots. At each picking, percent fruit damage due to fruit flies and marketable yield were recorded in both protected and unprotected plots. The average data was used to work out percent avoidable fruit damage due to the pest as under:

$$\text{Available yield losses} = \frac{100 \times (\text{Marketbale yield in protected plot} - \text{Marketbale yield in unprotected plot})}{\text{Marketbale yield in protected plot}}$$

The efficiency of crop protection was also worked out as under:

$$\text{Efficiency of crop protection} = \frac{100 \times (\text{Actual yield} - \text{Yield without crop protection})}{\text{Attainable yield} - \text{Yield without crop protection}}$$

Species composition of fruit flies in tomato

Studies were conducted to ascertain the species composition of fruit flies in tomato fields in mid hills of Himachal Pradesh. The population of fruit flies infesting vegetables was monitored from March to September during crop seasons of 2013 and 2014 by using Palam fruit fly trap. The traps were installed at the rate of ten traps/acre in the fields planted with tomato. The data on fruit fly catch were recorded at weekly interval and the lure in the traps was replenished after each counting. The data recorded was pooled to draw inferences.

Efficacy of management modules on fruit fly damage and tomato yields

On farm trials (OFTs) for the management of fruit flies in cucurbits were conducted at six locations on tomato cv Avtar 7711 for two consecutive seasons during *kharif* 2013-2014 comprising four treatments viz. Palam fruit fly traps only @ 25/ hectare, Palam fruit fly traps @ 25/ hectare + BAT (5 g jaggery+ 2 ml malathion / liter of water thrice at 15 days interval), BAT (5 g jaggery+ 2 ml malathion / liter of water 5-6 times at 10 days interval) and Farmers practice (repeated use of insecticides).

The crops were transplanted in the month of March each season and raised as per the standard package of practices except insect management (Anonymous, 2018a). Farmers were provided with critical inputs except for control treatment and fruit damage and yield data was recorded in all the treatments. At the end of the season cumulative percent fruit damage was worked out and arcsine transformation was employed. The transformed percent fruit damage and yield data was analyzed in RBD to draw inferences (Gomez and Gomez 1984) and to work out the economics of the treatments.

Front line demonstrations

Based on the results of OFTs, the best technology i.e. Palam fruit fly traps @ 25 traps/ ha + BAT (5 g gur+ 2 ml malathion/liter of water thrice at 15 days interval) was demonstrated along with Farmers Practice through FLDs in different parts of the district for four consecutive years during *kharif* 2014 to *kharif* 2018. The farmers were educated regularly about the use of traps and other precautions. The lures were replaced after 6 weeks at each location. Yield data and percent fruit damage due to fruit flies for the improved practice as well as farmers' practice were recorded and analyzed to draw the inferences. Fisher's Least Significant Difference (LSD) test was employed in order to analyze the difference in fruit fly incidence and yield mean between the Demonstration plot and Farmer's plot by using following formula (Yadav *et al.*, 2018).

$$LSD_{0.05} = t\sqrt{MSW\left(\frac{1}{N1}+\frac{1}{N2}\right)}$$

Where;
t = Critical value from t distribution table,
MSW = Mean square within, obtained from the results of ANOVA test,
N_1 = Number of observation of first group,
N_2 = Number of observation of second group,

The yield increase in demonstrations over farmers' practice was calculated using the following formula (Choudhary *et al.*, 2009; Yadav *et al.*, 2017 and 2018):

$$\textbf{Yield increase over farmer's practice (YIOFP, \%)} = \frac{\text{Demonstration Plot Yield (DPY)} - \text{Farmer's Plot Yield (FPY)}}{\text{Farmer's Plot Yield (FPY)}} \times 100$$

The technology gap, extension gap and technology index were estimated using the following formulae Samui *et al.*, 2000; Dwivedi *et al.*, 2014; Yadav *et al.*, 2018):

$$\textbf{Technology gap (q ha}^{-1}\textbf{)} = \text{Potential Yield (PY)} - \text{Demonstration Plot Yield (DPY)}$$

$$\textbf{Extension gap (q ha}^{-1}\textbf{)} = \text{Demonstration Plot Yield (DPY)} - \text{Farmer's Plot Yield (FPY)}$$

$$\textbf{Technology Index (TI \%)} = \frac{\text{Potential Yield (PY)} - \text{Demonstration Plot Yield (DPY)}}{\text{Potential Yield (PY)}} \times 100$$

Economic analysis of CFLD's

Cost of cultivation in demonstration plot included cost of inputs i.e. seed, fertilizers, bio fertilizers, herbicide *etc.* except fruit fly management were invested by the farmers. Under farmer's practice, it also included cost of inputs purchased for fruit fly management by the farmers. The gross and net returns were worked out accordingly by taking cost of cultivation and price of produce (Choudhary *et al.*, 2009; Yadav *et al.*, 2017 and 2018).

Impact assessment

The impact of technology was assessed in terms of usefulness of tarps, reduction in number of insecticidal application etc. during 2018 and 2019.

Results and Discussion

Extent of losses

The pooled data of two seasons presented in Table 1 revealed that fruit damage (%) due to fruit flies was 8.5 percent in protected plot compared to 17.6 percent in unprotected plots. The marketable yield consequently was higher (207.4 q/ha) in protected plot compared to 170.3 q/ha in unprotected plot. The avoidable fruit damage and yield losses in the former treatment were 9.1 and 17.89 percent respectively.

The efficiency of crop protection worked out (28.60 %) was though on lower side, but satisfactory in view of farm holdings and wide agro climatic situations. Fruit flies have earlier been recorded as major hindering factor in tomato cultivation in Himachal Pradesh by Gupta *et al.,* (1992) and Sood *et al.,* (2010).

Bactrocera (*Zeugodacus*) *scutellaris (Bezzi), B.* (*Z.*) *tau* (Walker) *and B.* (*Z.*) *cucurbitae* (Coquillett) were the predominant fruit fly species infesting tomato at majority locations surveyed in Mandi. Of the total fruit flies trapped, *B. scutellaris* comprised of 39.01 percent, followed by *Z. tau* (32.98 %) and *Z. cucurbitae* (12.83 %) (Figure 1). *Z. tau* and *Z. cucurbitae* was earlier considered to be the major fruit fly species infesting vegetable crops in Himachal Pradesh, however during the course of present survey, *Z. scutellaris* (Bezzi) and *Z. tau* both were recorded as the predominant species in traps in tomato ecosystem in Himachal Pradesh. *Bactrocera* (*Zeugodacus*) *cucurbitae* and *B.* (*Z.*) *tau* were reported infesting vegetables in Himachal Pradesh (Kapoor *et al.,* 1980; Gupta *et al.,* 1992). However, Sood and Nath (1999) and Prabhakar *et al.,* (2009) reported *Z. tau* as a major fruit fly species infesting vegetables while Singh *et al.,* (2013) reported *Z. scutellaris* as the predominant species trapped in cue lure in vegetables in the State. *Z. tau* has also been reported from north-eastern region of India (Borah and Dutta 1996), China (Yang *et al.,* 1994) and Bangladesh (Huque 2006).

The reports of different workers on infestation of vegetables by fruit flies in the Himachal Pradesh substantially support the present findings, that tomato is not damaged by a single fruit fly species but by a complex of species viz. *Z. tau, Z. cucurbitae and Z. scutellaris* (Prabhakar *et al.,* 2007; Sunandita and Gupta 2007; Prabhakar *et al.,* 2009).

Efficacy of management modules on fruit fly damage and tomato yields

On farm trials involving four treatments conducted at six locations for two seasons in the district revealed that when fruit fly traps were installed alone for the management of fruit flies in tomato fields, the impact on fruit damage and yield was not visible as the traps were though attracting male fruit flies, but the females continued to damage the crop (Table 2). Likewise BAT application (5 g gur+ 2 ml malathion / liter of water thrice at 10 days interval) alone also was not sufficient enough to lower the fruit fly damage and enhance yields.

However when BAT application was incorporated along with the trapping, the impact was quite visible as the damage reduced significantly to 10.07 percent compared to either trapping (19.43 %) or BAT application (14.82 %).

The farmers practice of repeated insecticide use though recorded statistically on par reduction of fruit damage (10.50 %) with Traps 25/ ha+ BAT (5 g gur+ 2 ml malathion/ liter of water thrice at 15 days interval) treatment, but was not environmentally and economically benign. The marketable yield in case of farmers practice was highest (196.02 q/ha) but was statistically on par with treatment comprising Traps @ 25/ ha+ BAT (194.48q/) compared to either BAT (144.78 q/ha) and trapping alone (130.18 q/ha). The net returns and cost benefit ratio were also maximum in treatment comprising Traps 25/ ha+ BAT (5 g gur+ 2 ml malathion/ liter of water thrice at 15 days interval) followed by farmers practice of repeated use of insecticides, BAT and trapping only. In spite of less direct impact on reduction of fruit damage, the trapping could play a vital role in fruit fly management when adopted on a mass scale for area wide management of the pest.

The impact of trapping could be more visible in subsequent years of trapping. In on farm trials, trapping + bait application was the most effective and economic treatment compared to either trapping and bait application alone, which could be attributed to the fact that the traps were installed in selective fields; hence the overall impact could not be transformed into lowering the fruit damage and yield enhancements as traps only attract male adults leaving the already fertilized females free to lay eggs/ damage fruits. Lure and kill approach based on food attractants or parapheromones mixed with killing agent for the management of fruit flies has been an integral component of fruit fly Integrated Pest Management (IPM) since the beginning of century (Canale *et al.,* 2013).

But, the vegetable farmers in the hilly state of Himachal Pradesh were dependent on available chemicals resulting in environmental degradation and high input costs, hence inclusion of trapping along with BAT as a component of fruit fly management will not only ensure the protection of the crop but also reduce frequent insecticide applications, which pose serious environmental and health hazards.

Effect of IPM modules on fruit fly incidence and tomato productivity under front line demonstrations

Front line demonstrations (FLDs) on fruit fly management in tomato conducted for five consecutive seasons from *kharif* 2014- *kharif* 2018 revealed that the fruit fly incidence (percent fruit damage) in demonstration plots decreased to almost half compared to farmers practice during all the seasons (Table 3).

The average of 62 demonstrations revealed that fruit damage in demonstration plots was 8.26 percent which was 19.98 percent less than the fruit damage recorded in Farmers practice (10.33 %). Similar trend of observations with regard to marketable yield were evident from the data presented in Table 4 which varied from 187.10 to 198.2 q/ha during the five years of demonstrations and was statistically higher than the farmers practice during all the seasons. The average yield for five seasons was significantly higher (192.83 q/ha) compared to farmers practice (161.61 q/ha) and 19.35 percent higher than the farmer’s practice proving the superiority of the demonstrated technology.

The less fruit damage and higher marketable yield in demonstration plots proved superiority of the demonstrated technology under front line demonstrations. This may be attributed to the fact that in the demonstration plots apart from providing critical inputs for effective management of this pest, the farmers were also educated about identification of the pest which could be the major factor for enhancing the yields in demonstration plots. The present findings are in accordance with previous studies of Kumari *et al.,* (2007), Choudhary *et al.,* (2009 and 2013), Kumbhare *et al.,* (2014), Kumar *et al.,* (2015) and Yadav *et al.,* (2018) who also reported yield enhancement and better monetary returns through adoption of improved farm technology under FLDs.

Economic analysis

The season wise economic analysis of demonstrated technology under FLDs in comparison to farmer's practice presented in Table 4 revealed that the highest net returns of Rs. 153200 per ha was observed during 2017 crop season. The average net returns of Rs. 147835/ha obtained under the demonstrated technology in pooled data of all seasons was much higher than the farmer's practice (Rs. 113614/ha) which may be attributed to improved technologies. Consequently the benefit cost ratio in the demonstrated plots was also higher (4.29) compared to farmers practice (3.37).

Technology and extension gap

The data presented in the Figure 2 revealed that technological gap ranged from 101.80 to 112.90 q ha^{-1} under the demonstrated technologies during the periods under study. The highest technological gap was observed during *kharif* 2018 (112.90 q ha^{-1}) followed by *kharif* 2016 (110.50 q ha^{-1}), *kharif* 2015 (108.06q ha^{-1}), *kharif* 2014 (102.57 q ha^{-1}) while the lowest during *kharif* 2017 (101.80 q ha^{-1}). The overall technological gap based on pooled data for five seasons FLDs programme was 106.98 q ha^{-1}. The results presented in the Figure 2 further revealed that extension gap ranged between 23.40 q ha^{-1} to 36.80 q ha^{-1} and it was highest during *kharif* 2017, followed by *kharif* 2015, *kharif* 2014, *kharif* 2018 and *kharif* 2016 respectively. On an average extension gap under five consecutive years of FLD programme was 31.65 q ha^{-1}. Yearly variations in the technology and extension gap could be attributed to various biophysical factors like dissimilarity in the soil fertility status, unfavorable micro climatic conditions and specific crop management problems (Yadav *et al.,* 2017; Yadav *et al.,* 2018). Therefore, location specific crop management is suggested to bridge the gap between potential yield and demonstration yields. Earlier, various workers also reported almost similar findings in demonstrations technologies (Choudhary 2013; Kumar *et al.,* 2015; Yadav *et al.,* 2018).

The extension gaps are the indicators of lack of awareness for the adoption of improved farm technologies by the farmers (Yadav *et al.,* 2015; Yadav *et al.,* 2017; Yadav *et al.,* 2018) and an effective agricultural extension can bridge the gap between research findings and farmers fields (Evenson 1997; Oladele 2004). Hence, there is a strong need to educate the farmers through various extension means i.e. CFLDs, capacity buildings and providing quality seed along with essential critical inputs to minimize these gaps.

Technology index

Technology index indicates about the feasibility of the technology under existing agro climatic conditions (Kumari *et al.,* 2007; Choudhary *et al.,* 2013; Kumar *et al.,* 2015; Yadav *et al.,* 2017; Yadav *et al.,* 2018). Lower the value of technology index refers to higher feasibility of improved technology and vice-versa. The data given in the Figure 3 revealed that least technology index (33.93 %) was observed during *kharif* 2017 followed by *kharif* 2014 (34.19 %), *kharif* 2015 (36.02 %), *kharif* 2016 (36.83 %) and *kharif* 2018(37.63 %) which may be due to slight variations contributing factors and micro climatic conditions of study area.

Table.1 Avoidable losses due to fruit flies in tomato

Percent fruit damage		Marketable yield (q/ha)		Avoidable Fruit damage (%)	Avoidable Yield Losses (%)	Efficiency of crop protection
Protected*	Unprotected	Protected*	Unprotected			
8.5	17.6	207.4	170.3	9.1	17.89	28.60

* Protected: Palam Trap + five to six applications of jiggery 5g + Malathion 2ml/ L of water

Table.2 Effect of fruit fly traps on fruit damage and tomato yield in Sundernagar (Mandi)

Treatments	% fruit damage*	Yield (q/ha)*	Gross Returns** (Rs.)	Net Returns (Rs.)***	Benefit cost ratio
T_1: Traps only @ 25/ hectare	19.43 (29.13)	130.18	130180	88180	**3.10**
T_2:Traps 25/ ha+ BAT (5 g gur+ 2 ml malathion/ liter of water thrice at 15 days interval)	10.07 (20.65)	194.48	194480	149480	**4.32**
T_3:BAT (5 g gur+ 2 ml malathion/ liter of water at 10 days interval)	14.82 (25.15)	144.78	144780	101780	**3.37**
T_4: Farmer's practice repeated use of insecticides (5-6 applications)	10.50 (21.08)	196.02	196020	148020	**4.08**
SE (mean)	1.11	9.02			
CD ().05)	(2.37)	19.23			
CV	**15.05**	**17.62**			

*Pooled data of three years average of ten locations, figures in the parenthesis are arcsine transformation values
** Trap cost @ Rs. 80 per trap and installed twice in the season; *** Produce cost- Rs. 1000 per q

Table.3 Fruit fly incidence in demonstration plot viz a viz farmer's plot under FLDs in Mandi district of Himachal Pradesh

Year	No. of demonstrations	Fruit fly incidence (%)		LSD $_{0.05}$	Reduction in fruit damage over FP (%)
		DP*	FP**		
2014	14	8.25	10.11	1.39	18.43
2015	18	8.71	10.28	0.99	15.28
2016	10	8.56	10.66	1.18	19.70
2017	10	7.94	10.49	0.89	24.31
2018	10	7.86	10.10	0.75	22.18
Pooled data	62	8.26	10.33	0.48	19.98

* DP: Demonstration plot; **FPY: Farmers plot

Table.4 Yield and economics of integrated fruit fly management in tomato under FLDs in Mandi district of Himachal Pradesh

Year	Marketable fruit yield (q ha^{-1})		$LSD_{0.05}$	YIOFP (%)	Net returns (Rs/ ha^{-1})		BC ratio	
	DPY*	FPY**			DPY*	FPY**	DPY*	FPY**
2014	197.43	165.05	10.31	19.60	152429	117071	4.39	3.44
2015	191.94	158.00	5.99	21.48	146944	110000	4.27	3.29
2016	189.50	166.10	9.02	14.09	144500	118100	4.21	3.46
2017	198.20	161.40	11.86	22.80	153200	113400	4.40	3.36
2018	187.10	157.50	11.21	18.79	142100	109500	4.16	3.28
Pooled data	192.83	161.61	4.09	19.35	147835	113614	4.29	3.37

* DPY: Demonstration plot yield; **FPY: Farmers plot yield, YIOFP: Yield increase over farmers practice

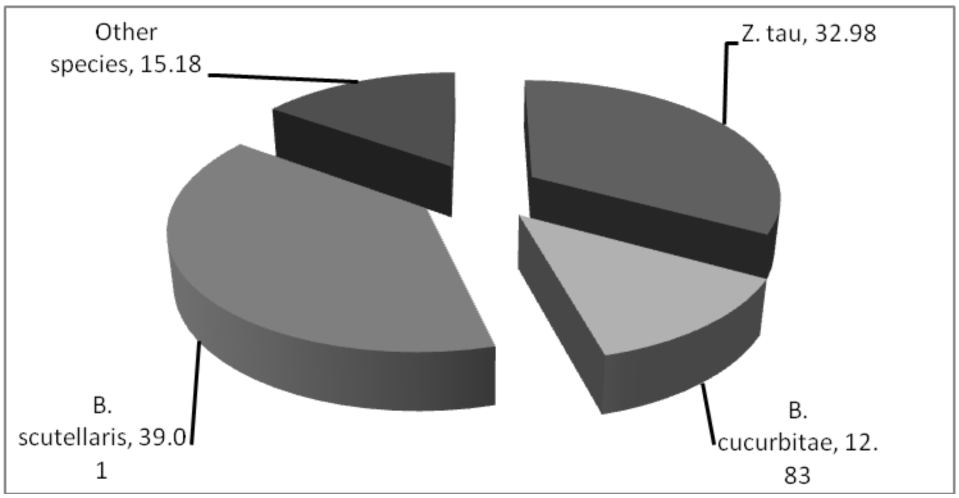

Fig.1 Species composition of fruit flies at Sundernagar (Mandi)

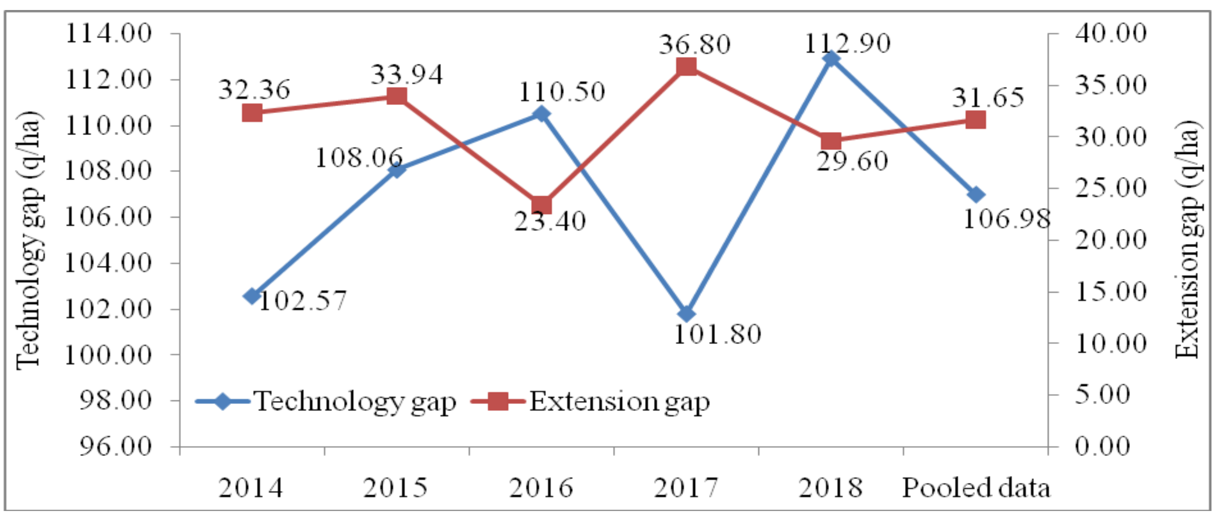

Fig.2 Yield gaps under demonstrated technologies in tomato in Mandi district of Himachal Pradesh

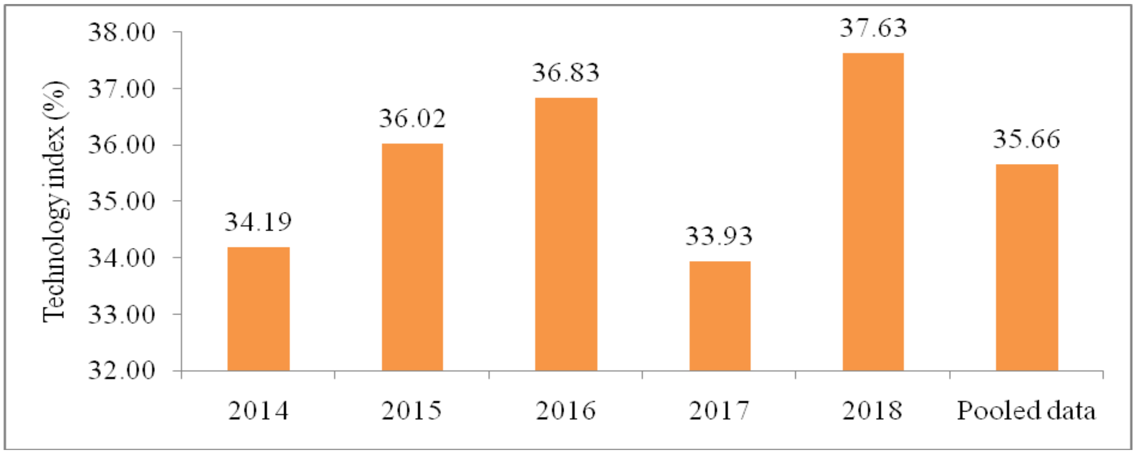

Fig.3 Technology index for integrated fruit fly management in tomato in Mandi district of Himachal Pradesh

Overall, the technology index of 35.66 percent observed in pooled data of five years though showed the satisfactory performance of technological interventions in the region. The observations regarding technology index though showed satisfactory performance of technological interventions but also figured out scope for further adoption of this technology in the region.

Impact of technology

The technology has reduced the fruit fly damage and enhanced the effectiveness of either trapping or bait application alone, owing to which trapping has become an important component of fruit fly management in the state. Being a farmer friendly technology, farmers groups were trained in preparation of bottle traps by recycling/ using the empty plastic bottles available in each household and the required only impregnated septa/ lure from the KVK/ university. More than fifty thousand traps have been supplied to the farmers for area wide management of pest; consequently making fruit fly trapping a popular tool amongst the farmers for wide area fruit fly eradication. Apart from direct benefit of in terms of higher yield (20-30 %) following trapping; installation of traps also reduced average number of insecticidal applications from 7-8 to 4-5 in cucurbits not only reducing labour costs but also saving time and money. Overall, the technology has been adopted in approximately 500 ha vegetable growing area in the state, resulting in enhanced yields and less pesticide usage apart minimizing environmental hazards. Trapping using para pheromones and insecticidal baits till date is the most relevant mean of fruit fly management and an integral component of its IPM, however in hilly states like Himachal Pradesh where majority farmers are small/ marginal cultivating fruits/ vegetables in the same fields/ adjoining fields mixed lure based traps is not only most effective but also economically viable option. Further emphasis of state government on natural farming has necessitated environmentally benign pest management alternatives. Fruit fly trapping is hence a viable alternate for fruit fly management in cucurbits. Large scale demonstrations is therefore need of the hour to popularize such technologies for wider area management of dreaded pests like fruit flies not only to enhance yields but also to minimize environmental pollution by reducing pesticide applications. Mass trapping of fruit flies (MAT) combined with bait application though found very effective but need wider area adoption to eradicate this pest.

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References

Anonnymous, 2018. http://agricoop.nic.in/ sites/default/files/ 2018-19 %20%281st% 20Adv. Est_.%29_updt. pdf.

Anonnymous, 2018a. Package of Practices for vegetable crops in Himachal Pradesh. Dir. Ext. Edu. CSK HPKV Palampur. p. 203

Borah, S.R. and Dutta, S.K. 1996. Comparative biology of *Dacus tau* (Walker) on cucurbitaceous vegetables. J. Agri Sci Soc. NE India. 9(2): 159-165.

Canale, A., Benelli, G., Conti, B., Lenzi, G., Flamini, G., Francini, A., and Cioni, P.L. 2013. Ingestion toxicity of three Lamiaceae essential oils incorporated in protein baits against the olive fruit fly, *Bactrocera oleae* (Rossi) (Diptera Tephritidae). Nat. Prod. Res. 27 (22): 2091–2099.

Choudhary, A.K. 2013. Technological and extension yield gaps in pulse crops in Mandi district of Himachal Pradesh, India. Ind. J. Soil Cons. 41(1): 88–97.

Choudhary, A.K., Yadav, D.S. and Singh, A. 2009. Technological and extension yield gaps in oilseeds in Mandi district of Himachal Pradesh. Ind. J. Soil Cons. 37(3): 224-229.

Dhillon, M.K., Singhm R., Naresh, J.S. and Sharma, H.C. 2005. The melon fruit fly, *Bactrocera cucurbitae*: a review of its biology and management. J. Insect Sci. 5(1): 1-16.

Dwivedi, A.P., Mishra, A., Singh, S.K. and Singh, M. 2014. Yield gap analysis through front line demonstration in different agro-climatic zones of M.P. and Chhatisgarh. J. Food Leg**.** 27(1): 60-63.

Evenson, R.E. 1997. The economic contributions of agricultural extension to agricultural and rural development. In: Improving agricultural extension: A Reference Manual. Swanson BE, Bentz RP, Sofranko AJ (eds.). Food and Agriculture Organization (FAO), Rome, pp 27–36.

Gomez, K.A. and Gomez, A.A. 1984. Statistical Procedures for Agricultural Research. John Wiley and Sons, New York, 690p.

Gupta, D., Verma, A.K. and Gupta, P.R. 1992. Population fluctuations of the maggots of fruit flies (*Dacus cucurbitae* Coquillette and *D. tau* Walker) infesting cucurbitaceous crops. Adv. Plant Sci. 5: 518-523.

Huque, R. 2006. Comparative studies on the susceptibility of various vegetables to *Bactrocera tau* (Diptera: Tephritidae). Pakistan J. Biol. Sci. 9(1): 93-95.

Kapoor, V.C., Hardy, D.E., Agarwal, M.L. and Grewal, J.S. 1980. *Fruit Fly (Diptera: Tephritidae) Systematics of Indian Subcontinent.* Export Indian Publishers, Jalandhar. p 113

Kumar, S., Choubey, A.K. and Singh, R. 2015. Analysis of yield gaps in black gram (*Vigna mungo*) in district of Himachal Pradesh. Him. J. Agril. Res. 41(1):49-54.

Kumari, V., Kumar, A., Kumar, A. and Bhateria, S. 2007. Demonstration- an effective tool for increasing the productivity of rapeseed–mustard in Kangra district of Himachal Pradesh. Him. J. Agril. Res. 33(2): 257-261.

Kumbhare, N.V., Dubey, S.K., Nain, M.S. and Bahal, R. 2014. Micro analysis of yield gap and profitability in pulses and cereals. Legume Research -An

International Journal. 37 (5):532-536.

Oladele, O.I. 2004. Africa in search of extension system: experience from Nigeria. J. Food Agric. Environ. 2(1): 276–280.

Prabhakar, C.S., Sood, P., Mehta, P.K. and Choudhary, A. 2007. Fruit fly, *Bactrocera scutellaris* (Bezzi): a potential threat to cucurbit cultivation under low and mid hills of Himachal Pradesh. Pest Man. Econ. Zoo. 15(2): 181-185.

Prabhakar, C.S., Sood, P., Mehta, P.K. and Choudhary, A. 2009. Distribution and developmental biology of fruit flies infesting cucurbits in north-western Himalaya. J. Insect Sci. *22(3):* 300-308.

Samui, S.K., Maitra, S., Roy, D.K., Mondal, A.K. and Saha, D. 2000. Evaluation on frontline demonstration on groundnut. J. Ind. Soc. Coastal Agric. Res. 18(2): 180-183.

Singh, M., Gupta, D. and Sharma, D. 2013. *Bactrocera scutellaris* (Bezzi) - a dominant fruit fly species in vegetable fields in mid hills of Himachal Pradesh. Insect Environ. 19(3): 137-139.

Sood, P. and Nath, A. 1999. Fruit flies associated with cucurbits in Himachal Pradesh. J. Hill Res. 12(1): 52-54.

Sood, P., Prabhakar, C.S. and Mehta, P.K. 2010. Eco-friendly management of fruit flies through their gut bacteria. J. Insect Sci. 23(3): 275-283.

Sunandita and Gupta, D. 2007. A note on host range of fruit fly species infesting summer vegetable crops in mid hills of Himachal Pradesh. J. Insect Sci. 20(1): 106-107.

Verghese, A., Madhura, H.S., Jayanthi, P.D.K. and Stonehouse, J.M. 2004. Fruit flies of economic significance in India with special reference to *Bactrocera dorsalis* Hendel. In: Proceedings of the Sixth International Symposium on Fruit Flies of Economic Importance, Stellenbosch, South Africa, 6-10 May 2002 (BN Barnes, ed.). pp. 317-324

Yadav, D.S., Choudhary, A.K., Sood, P., Thakur, S.K., Rahi, S. and Arya, K. 2015. Scaling-up of maize productivity, profitability and adoption through frontline demonstration technology-transfer programme using promising maize hybrids in Himachal Pradesh. Annals Agric. Res. New Series. 36(3): 331-338.

Yadav, D.S., Sood, P. and Sharma, L.K. 2018. Scaling-up of paddy cv. HPR 2612 (Palam Basmati 1) under irrigated transplanted conditions of Himachal Pradesh. J. Hill Agric. 9(3): 335-339.

Yadav, D.S., Sood, P., Sharma, L.K., Kumar, S. and Sharma, K. 2017. Yield gap analysis in Pusa Basmati 1509 in district Mandi of Himachal Pradesh. J. Hill Agric. 8(3): 334-338.

Yang, P.J., Carey, J.R. and Dowell, R.V. 1994. Host specific demographic studies of wild *Bactrocera tau* (Walker) (Diptera: Tephritidae). Pan-Pacific Ent. 70(3): 253-258.

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