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Farmers driven validation of pest management in alphonso mango orchards of Southern Gujarat region of India using elements of cultural and mechanical methods

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Abstract
Under present studies, hoppers, thrips and fruit fly among the insects and anthracnose and powdery mildew among the diseases had caused both qualitative and quantitative losses in fruit yield during both the years. Activity of different species of hoppers (*Amritodus atkinsoni*, *I. clypaelis*, *I. niveosparsus*) and thrips (*Rhiphiphorothrips cruentatus Scirtothrips dorsalis*, *S. mangiferae*), persisted throughout the year on different parts of the mango tree while of fruit fly (*Bactrocera dorsalis*, *B. zonatus*, *B. correctus*) from March to July. Hopper population observed significant positive correlation with maximum temperature ('r' = 0.3716) and sun shine hours ('r' = 0.4364) and significant negative relationship with minimum temperature ('r'= -0.3964), morning relative humidity ('r' = -0.2762), evening relative humidity (r= -0.4825), average relative humidity (r= -0.4708), rainfall (r= -0.2957) and rainfall days (r= -0.4009). R value was however non- significant. Number of hoppers, thrips and per cent fruit damage by fruit fly and intensity of powdery mildew and Anthracnose was reduced as a result of implementation of different components of IPM technology as compared to farmer's practice where scheduled application of 15-20 sprays was made during both the years. Adoption of IPM module resulted in reduction in number of application of highly toxic pesticides (6) as compared to farmer's practice (11-12 sprays) thus cutting the cost of plant protection and more economic returns during both the years under studies.

Keywords: IPM, alphanso, correlation

Introduction
Despite the ongoing efforts, productivity in India for mango (7.2 t/ha) is far lower in comparison to highest productivity of 12.5 MT/ha observed in Brazil. It is largely due to persisting problems of pests and diseases. In spite of lower productivity, India stands first in production of mango in the world and is having world's more than 40 per cent mango production. However our share in international market is comparatively very less. India exports mango to more than 33 countries in the world. It was 5.97 per cent in volume and 3.96 per cent in value in the year 2000. In the year 2010-11, India's share was 4.36 per cent in terms of volume and 3.11 per cent in terms of value. Though recent data for export is not available, but it has further declined. The export prospects are known to hamper due to poor quality of harvested fruits as well as due to fruit fly infestation, a quarantine pest. This year the European Union has banned the export of alphonso mango from India mainly due to heavy infestation of fruit fly (http://www.dw.de/eus). Country witnesses the damage of not only fruit fly but also of other pests such as brown plant hopper, and thrips, powdery mildew and anthracnose ubiquitously all over India in different climatic regions. Most of the plant protection practices currently in use are the high input demands and require look, how different technologies can be deployed that are sustainable and can improve productivity and quality. To achieve the objectives of higher productivity and quality of harvested fruit, farmer's participatory integrated pest management research was attempted in southern Gujarat region of India by employing elements of cultural and mechanical methods of pest management in combination with bio and reduced risk pesticides against the pests of *alphonso* variety of mango which has great potential for export in International market.

It may form one possible alternate strategy to combat the noxious pests of mango so as to achieve not only sustainable and eco friendly pest management but also be economically viable ensuring good quality of fruits brightening the export potential as well.

Materials and Methods

Study site: It was located at mango orchard of ARS, Paria and at farmers' orchards in natural habitat of Valsad and Navsari districts of southern Gujarat, India. In the beginning two orchards of variety alphonso in year 2011-12 and later on 10 orchards of the same cultivar during 2012-13 were selected for implementation of the different components of IPM technology. Integrated pest management (IPM) package of practices were compared with farmers practice (non IPM) of entirely dependent upon the application of pesticides on schedule basis as well as no pest control. The study was conducted from October to July of the both the years. Surveillance studies on real time pest dynamics were conducted on alphonso variety of mango at experimental orchards of ARS, Paria, Valsad, Gujarat. In order to evaluate/ assess farmers' knowledge, perception and practices in mango pest management aspects, a survey was conducted in area where the implementation of IPM technology was practiced. Data pertaining to plant protection practices, farm production and other socio- economic variables for the year 2012-13 were documented with questionnaire through a random sample of 40 farmers comprising 20 IPM adopting farmers and 20 non-adopters of IPM of the mango growers of Valsad district of Southern region of Gujarat.

Integrated Pest management Practices

Integrated pest management package included (1) Sanitation (Pruning of intermingled and overcrowded and disease infected branches for management of leaf webber and anthracnose and leaving central opening for management of hoppers during month of October- November, pasting of copper oxy chloride to prevent occurrence of dieback. Removal of powdery mildew infected branches and destroying of fruit fly infested fallen fruits using plastic bags and destroying them by burying them 30-40 cm below the ground during month of April and later. (2) Cultural practices (Deep ploughing of orchards during month of October to expose the pupae of fruit fly and inflorescence midge, raking of soil around the tree and mixing *Metarrzhium anisoplae* @ 10^8 spores/g of formulation reduce the abundance of soil born pests such as fruit fly pupae, inflorescence midge and mealy bug and heavy irrigation in month of October (3) Mechanical control (Trapping fruit fly males by methyl eugenol from March to June. Traps are suspended at a height of 5' in mango trees tied firmly on a branch of the tree. The openings are well hung in order to facilitate the access of flies into traps. The methyl eugenol dispensers are renewed every month. In one hectare, 10 traps have been laid out covering all direction as well as centre of the orchards. Hot water treatment to harvested fruits at 48 °C for 5 minutes (4)

Pesticides: *Beauveria bassiana* ($1x10^8$ spores/ml) @ 2 g/l of water foliar spray on bark of the trees against resting hoppers, ETL based application of lambdacyhalothrin (0.3 ml/l) and carbendazim (0.5 g/l) in flowering or bud initiation trees in month of December, application of Indoxacarb (3 ml/10 l) + Sulphur @ 3 g/l of water in flowering trees in month of January and, application of Imidacloprid (3 ml/ 10 l) + Hexaconazole (0.5 ml/l) or Propiconazole (0.5 ml/l) in month of February, Application of profenofos (1 ml/l) + tridemephon (1 ml/l) or thiamethoxam 3 ml/10l) + tridemephon (1 ml/l) and application of azadirachtin 3000 ppm (3 ml/l), in month of March Application of Profenofos + cypermethrin (ready made mix 1 ml/l)) + carbendazim (0.5 g/l) in the month of April for management of leaf webber, hoppers, thrips, blossom midges, fruit fly, powdery mildew and anthracnose. A set of farmers participatory exercises/trainings were adapted on different aspects such as on identification of pests vis a vis learning to differentiate the damage due to insects, diseases, scouting of pest damage/monitoring time of application and choice of pesticides, handling of methyl eugenol traps for mass trapping of fruit fly adults and hot water treatments of harvested fruits at 48 ^{O}C for 5 minutes to kill he eggs of fruit fly and reducing its infestation and conservation of natural enemies for the implementation of the IPM technology.

Non IPM: In non IPM orchards, 12-16 applications of synthetic pesticides were applied beginning from January up to July at regular intervals in indiscriminate manner. No methyl eugenol traps were installed.

Maintenance of orchard: Recommended horticultural practices were given in both IPM and non IPM orchards. All the trees were planted in 10 x 10 m. Spray of pesticide volume of water kind of sprayer etc i.e application of pesticides nozzle etc.

Observations on Pests and beneficial insects: Five trees one each in all the four direction and fifth in the centre was marked randomly in the orchard of variety Alphonso. Observations on population of insects and incidence of the diseases were recorded on five trees per orchard in size of one acre at weekly interval in both IPM and farmers practice orchards as well as at experimental orchard at ARS, Paria.. Number of nymphs and adults of hoppers (*Idioscopus clypealis, I. niveosparsus* and *Amritodus atkinsoni*) in a single panicle/inflorescence from each direction of selected tree was visually counted during the season. During off season, standard sweep nets (@ 4 sweeps /tree) were used to sample the hoppers resting on tree trunks after disturbance using net. For, flower thrips (*Scirtothrips dorsalis*) and foliage thrip (*Rhiphiphorothrips cruentatus*), a tender shoot from each direction of the selected tree was tapped once onto a white paper, and the number of fallen nymphs and adults of thrips were counted. Recording of anthracnose *Glomerella cingulata* (*Colletotrichum gloeosporioides*) on twigs was based on number of leaves twigs infected and total number of leaved and the per cent infection was worked out. The number of inflorescence affected due to powdery mildew of mango *Oidium mangiferae* out of 10 inflorescences examined in each direction was counted.

Observations on natural enemies: During flowering season, the number of grubs, pupae and adults of chrysopids, lady bird beetle and nymphs and adults of spiders per panicle/ inflorescence, maggots and pupae of hover fly in each direction of the selected tree were also recorded. During off season, the number of grubs, pupae and adults of chrysopids per shoot in each direction of the selected tree were counted and recorded.

Results and Discussion

Real time pest dynamics: Twenty Eight species of fourteen

types of insect were recorded on mango alphonso trees on different stages of mango tree at ARS, Paria during both the years under studies (Table 1). Besides, spiders *Marpissa sp. Lyssomanes sikkimiensis, Plexippus paykulli* at the flowering stage, coccinellids (*Coccinella septum punctata, C. transversalis, Menochilus sexmaculatus*) and green lacewing (*Chrysoperla* sp) among the natural enemies were also recorded which predated upon different of insects listed in table1.

Under present studies, hoppers, thrips and fruit fly among the insects and anthracnose and powdery mildew among the diseases had caused both qualitative and quantitative losses in fruit yield during both the years. Activity of different species of hoppers (*Amritodus atkinsoni, I. clypaelis, I. Niveosparsus*) and thrips (*Rhiphiphorothrips cruentatus Scirtothrips dorsalis, S. Mangiferae*), persisted throughout the year on different parts of the mango tree while of fruit fly (*Bactrocera dorsalis, B. zonatus, B.. correctus*) from March to July. Maximum activity of all the pest was noticed from flowering to fruiting stage of the tree growth between SMW 8 and 30. Peak activity of the hoppers is noticed from 8th SMW to 14th SMW. Earlier studies revealed that the hopper populations were higher during flowering stage and had a peak during the second fortnight of March, coinciding with the marble stage of the crop (Sushil Kumar *et al*.,2005) [14]. Maximum activity of thrips was restricted between 3rd SMW and 25th SMW Highest PDI (1-10 scale) of Powdery mildew was recorded during first fortnight of April, whereas Anthracnose peaked on fruits during 34th standard week. The fruit rot was mainly observed during fruiting season (April- July) in the form of reddish brown lesions or spots on fruit epidermis. The damage peaked during first fortnight of July. Fruit fly adult monitoring data revealed that male of three species could be trapped from the month of March and continued till end of July. Higher number of male adults were observed in month of.....

Table 1: Insect associated with mango on alphonso cultivar of mango in Southern Gujarat region of India

Pest	Period of active occurrence	Plant part infested
Amritodus atikinson Idioscopus clypealis *I. .niveosparsus*	December-April	Leaf/twigs/Panicle flowering and fruiting stage, on tree trunks during off season
Rhiphiphorothrips cruentatus *Scirtothrips dorsalis,* *S. mangiferae*	Throughout the year January to April	Foliage Panicle stage, flowers and fruits
Drosicha mangiferae	April to May	Twigs and fruits
Chlumetia transversa	October to April	New and old leaves and shoot
Erosomyia indica *Dasyneura amaranjarae*	December to March	Panicle, flowering, shoots and buds
Protocontarinia mattejana	October to April	Leaves
Euthalia garuda garuda	September- November	Leaves
Deoraus marginatus	August- October	Leaves
Myllocerus discolor	September- November	Leaves
Acrocercops syngramma	September- November	Leaves
Indarbela quadrinotata	December-April	Tree trunk
Batrocera rufomaculata	December-April	Tree trunk
Chloropulvinaria polygonata	December-April	Leaves
Aspidiotus destructor	March-June	Leaves
Orthaga spp	December - June	Leaves- twigs
Oligonychus mangiferae	December- April	Bud stage and new flushes
Bactrocera dorsalis *B. zonatus* *B..correctus*	May- July March- July May- July	Fruit stage
Oecophylla smaragdina	February –May	Twigs and fruits

Impact of abiotic factors on the Pest incidence: Hopper population observed significant positive correlation with maximum temperature ('r' = 0.3716) and sun shine hours ('r' = 0.4364) and significant negative relationship with minimum temperature ('r'= -0.3964), morning relative humidity ('r' = -0.2762), evening relative humidity (r= -0.4825), average relative humidity (r= -0.4708), rainfall (r= -0.2957) and rainfall days (r= -0.4009). R value was however non-significant. The findings are in conformity with earlier observations on *A. atkinsoni* Lethierry that showed that the maximum temperature and sunshine hours caused the build up of the pest population, while relative humidity, rainfall and rainy days had adversely affected the pest population. Multiple correlation coefficient between the pest and the abiotic factors was significant, explaining 78.79% variation in the population by all these factors. The mango hoppers correlated negatively and significantly with morning relative humidity (r=-0.549, -0.581) and evening relative humidity (r=-0.658, -0.688) in two cultivars *viz*., Baneshan and Dashehari, respectively and non-significantly with temperature and rainfall (Kumari *et al*., 2009) [8].

Thrips population had significant positive correlation with maximum temperature ('r' = 0.4512) and sun shine ('r' = 0.5292) and significant negative correlation with morning relative humidity ('r' = -0.4539), evening relative humidity (r= -0.4527), average relative humidity (r= -4848), rainfall ('r' = -0.2948) and rainfall days (r= -0.5007). R value was significant at 5 per cent level exhibiting 28.52 per cent variation in thrips population due to fluctuation in abiotic factors. Fruit fly please specify which species was trapped is a major insect-pest may be trapped throughout the year using methyl eugenol, however, damage to the mango crop is observed mainly during fruiting season of the crop i.e. May - July, more predominant in late maturing varieties coinciding with early rains or high humidity. Studies on population dynamics revealed that the hopper populations were comparatively higher during flowering stage and had a peak during the second fortnight of March, coinciding with the marble stage of the crop. The maximum temperature and sunshine hours caused the build up of the pest population,

while relative humidity, rainfall and rainy days had adversely affected the pest population. Multiple correlation coefficient between the pest and the abiotic factors was significant, explaining 78.79% variation in the population by all these factors.

Pest incidence in alphonso cultivar of mango under IPM and non IPM practices

IPM based practices were compared with non IPM farmers practice orchards. Implementation of IPM module on alphanso cultivar of mango resulted better management of the pests. Number of hoppers, thrips and per cent fruit damage by fruit fly and intensity of powdery mildew and Anthracnose was reduced as a result of implementation of different components of IPM technology as compared to farmer's practice where scheduled application of 15-20 sprays was made during both the years. Values on pest incidence were also greatly lower over no pest control orchards (Table 2). A strong trend was visible in population build-up and infestation of fruits as the season progresses from the month of March to July with a peak in month of May in non IPM orchards. A large number of adult fruit flies catch in methyl eugenol traps in IPM orchards helped in reduction in its infestation, which has been reported as effective method of management of fruit fly (Verghese 2004, Singh *et al*., 2008) [2, 16]. The data on the fruit infestation due to fruit fly in IPM and non IPM orchards provide significant information on the use of this nonhazardous method of fruit fly control.

Economic analysis

Adoption of IPM module resulted in reduction in number of application of highly toxic pesticides (6) as compared to farmer's practice (11-12 sprays) thus cutting the cost of plant protection and more economic returns during both the years under studies (table 3). Mango fruit yield was higher in IPM orchards during 2011-12 and 2012-13 (7845 kg/ha and 13680 Kg/ha) than non IPM practices (5435 kg/ha and 8610 Kg/ha) as well as over no pest control (4040 kg/ha and 2656 kg/ha), respectively. Total cost of cultivation in IPM plots was Rs 33377/ha and Rs 33404 per hectare during year 2010-11 and 2012-13, respectively while the corresponding figures in non IPM orchards were Rs.47231 and Rs.48068/ha which were very high indicating reduction in cost of plant protection that was primarily observed as a results of implementation of IPM technology. Cost of plant protection in IPM orchards was Rs. 12222/ha and Rs 11412/ ha during 2010-11 and 2012-13 while in non IPM orchards it was Rs 21996/ ha during both the years. Gross income in IPM orchards was Rs 3,76,200/ ha, and Rs.163800/ha while it was 109800/ha and Rs 2,36,775 /ha in non IPM orchard during 2011-12 and 2012-13, respectively. Net economic return (Rs/ha) earned due to implementation of IPM technology during year 2010-11 and 2012-13 was Rs.130423/ha and Rs. 342796 which were considerably higher over farmers practice (Rs. 62569/ha and Rs. 188707/ha) and no pest control (Rs. Rs.45043 and Rs. Rs. 47246/ha).

One of the goals of the IPM is to reduce the vulnerability in net return, lower the SD lower is the risk involved in IPM technology. In the present results net profit (Rs/ha) was higher than non IPM practice and no pest control.

Table 2: Mean incidence of different pests recorded on aplhonso variety of mango in Southern region of Gujarat during years 2011-12 & 2012-13 under different practices of cultivation

Parameters	2011-12			2012-13		
	IPM	Non IPM	No Pest control	IPM	Non IPM	No pest control
Hoppers/twig or panicle	3.60	5.14	11.17	3.35	6.82	14.95
Thrips/twig or panicle	3.00	6.16	32.70	3.20	6.15	25.80
Fruit Fly (% fruit damage)	3.43	6.20	14.60	4.00	6.80	13.70
Powdery mildew (% disease intensity)	4.86	6.67	13.30	4.60	6.70	13.20
Anthracnose (% disease intensity)	6.90	12.23	32.36	6.57	12.30	32.60

Table 3: Mean mango fruit yield and economics of cultivation in alphonso varieties of mango during years 2011 & 2012-13

Parameters	2011-12			2012-13		
	IPM	FP	No Pest control	IPM	FP	No pest control
Total cost of cultivation Rs/ha (all inputs)	33377	47231	35757	33404	48068	25794
Gross Income (Rs/ha)*	163800	109800	80800	3,76,200	2,36,775	73040
Net return Rs/ha	130423	62569	45043	342796	188707	47246
Mean Yield (Kg/ ha)	8190	5490	4040	13680	8610	2656
Cost of plant protection (Rs/ha)	12222	21996	-	11412	21996	-
Fruit bearing (No. of fruits/ tree)	327	219	142	547	344	177
No. of sprays of pesticide	6	12	2	6	12	2

Market price: Kesar: Rs 350/20 Kg Alphonso: Rs 550/20 Kg

Thus adoption of IPM practices result higher economic returns over non IPM practices and no pest control. Benefits provided by IPM were due to many factors but higher fruit yield by 30-35%, reduction in number of sprays by 50 per cent and resultant lowering of the cost of plant protection over non IPM were the most important reasons for higher economic returns. The analysis of data for risk (Standard deviation) and probability on net return indicated that SD and probability for IPM is lower by one third and one half over non IPM and no pest control, respectively.

Present study suggested lower vulnerability and higher probability in net return over non IPM and no pest control while adopting IPM technology. It indicated low risk in spending for plant protection in IPM as compared to non IPM. Therefore IPM programme may not be viewed more risky as compared to non IPM programme. Simple method of ploughing/hoeing by exposing the fruit fly pupae to natural enemies, destruction of fallen infested fruits, hot water treatment of fruits at temperature regimen 48 ºC for 5 minutes to disinfest fruits from fruit fly and trapping of adults through

methyl eugenol traps were reported to be more effective in management of fruit fly (Verghese, 2011 Muhammad Ishaq *et al*.,2004, Ndiaye *et al*., 2008, Singh *et al*., 2008, Abdul and Khalid, 2005) [17, 9, 10, 15, 1]. Efficiency in management of fruit flies was further augmented through application of parasitic fungi *M. anisoplae* in soil which has been reported to be effective in reducing pupal survival in soil was also implemented in the present studies. Need based/Action threshold level application of the effective pesticides were given from month of January to April that forms one of the important component of IPM technology implemented in the present studies. The spray of spinosad 0.004%, at panicle emergence followed by second spray of thiamethoxam 0.008% after and need based of neemazal 1000 ppm when fruits were at pea size was found to be most effective in reducing hopper and other pests (Ray *et al*., 2014) [12]. Other pesticides that were found effective were Profenophos 50% EC (88.51% suppression) and Buprofezin 25% SC (Ghosh., 2013) [6]. Hexaconazole, sulphur or tridemephon or propiconazole were found highly effective for management of powdery mildew (Sharma *et al*.,2012, Chavan *et al*., 2009) [4, 7]. However non IPM growers are stimulated to use synthetic pesticides as the only means of pest control. Analysis of the survey data revealed that Non IPM farmers undertake on an average 16 application of chemical pesticides to mitigate losses due to the pests.

Implementation of IPM technology had created awareness among the IPM mango growers about the presence of natural enemies like coccinellid beetle, predating hoppers and thrips, enhancing the ability of pest recognition i.e to differentiate the damage from insects and diseases, appreciating the management of fruit flies through trapping of adults by methyl eugenol lures, augmentation of mortality factors against pupae of fruit flies such as *M. anisoplae* in soil, application of *Verticillium lecani* in month of October on resting adults of hoppers on tree trunks, right choice and proper time of application of pesticides for reducing pest load such as anthracnose, powdery mildew, thrips and hoppers. It had resulted reduced number of application of pesticides by virtue of adoption of other methods of pest control such as cultural and mechanical method of pest control

Table 4: Expected mean net returns and risk (Rs/ha) for various management practices adapted in alphonso cultivar of mango

Pest management strategy	Average net return (Rs/ha)	Risk Standard Deviation
Integrated pest management	342794	15722
Farmers practice	187708	22800
No pest control	47246	29688

Conclusion

Implementation of IPM technology had created awareness among the IPM mango growers about the presence of natural enemies like coccinellid beetle, predating hoppers and thrips, enhancing the ability of pest recognition i.e to differentiate the damage from insects and diseases, appreciating the management of fruit flies through trapping of adults by methyl eugenol lures, augmentation of mortality factors against pupae of fruit flies such as *M. anisoplae* in soil, application of *Verticillium lecani* in month of October on resting adults of hoppers on tree trunks, right choice and proper time of application of pesticides for reducing pest load such as anthracnose, powdery mildew , thrips and hoppers. It had resulted reduced number of application of pesticides by virtue of adoption of other methods of pest control such as cultural and mechanical method of pest control.

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