INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
ISSN Print: 1560–8530; ISSN Online: 1814–9596
13–997/2014/16–3–521–528
http://www.fspublishers.org

Full Length Article

Impact of Sowing Times, Plant-to-Plant Distances, Sowing Methods and Sanitation on Infestation of Melon Fruit Fly (*Bactrocera cucurbitae*) and Yield Components of Bitter Gourd (*Momordica charantia*)

Muhammad Dildar Gogi, Muhammad Jalal Arif*, Muhammad Arshad, Muhammad Ahsan Khan, Muhammad Hamid Bashir, Khuram Zia and Zain-ul-Abdin
Department of Entomology, University of Agriculture Faisalabad, Pakistan
*For correspondence: jalalarif807@yahoo.com

Abstract

The present studies were conducted to evaluate the impacts of sowing times, plant-to-plant distances, sowing methods and field sanitation on infestation of *Bactrocera cucurbitae* and yield of *Momordica charantia*. Evaluated cultural practices exhibited a significant effect on infestation of *B. cucurbitae* and yield of *M. charantia*. Early sowing (15 February), plant-to-plant distance 45 cm, Hang Sowing Method (HSM) and sanitation measure were better cultural practices as these cultural practices exhibited lower fruit-infestation and yield-losses/plant but higher marketable-fruits/plant and marketable-yield/plant. Early sowing with a plant-to-plant distance of 45 cm demonstrated 2-3 times less fruit-infestation and yield-losses/plant, whereas approximately 1-2 times increase in marketable-fruits and marketable-yield per plant compared to other interactions between sowing times and plant-to-plant distances. HSM demonstrated approximately 1.3 times less fruit-infestation and yield-losses/plant, whereas 1.5 times more marketable-fruits and marketable-yield per plant compared to FSM. Similarly, sanitation measures exhibited 1.7 and 1.4 times reduction in the fruit-infestation and yield-loss/plant, respectively; but 2.4 and 3.2 times increase in marketable-fruits/plant and marketable-yield/plant, respectively over no sanitary measures. In conclusion, early sowing (15 February) with plant-to-plant distance of 45 cm, HSM and sanitation practice can be recommended for integration with other IPM practices against melon fruit fly in cucurbit cropping system.

Keywords: Melon fruit flies; Insect pest management; Cultural practices; Sanitation; Cucurbits

Introduction

Bitter gourd (*Momordica charantia* L.) is one of the most popular vegetable cultivated throughout Asia, especially in India, Pakistan, Sri Lanka, Bangladesh and China. Each and every part of this plant has nutritive and medicinal significance (Behera, 2004; Tahir and Haider, 2005; El-Batran *et al.*, 2006; Akram *et al.,* 2010). However, melon fruit fly [*Bactrocera cucurbitae* (Coquillett) (Diptera: Tephritidae)] is the major limiting factor in obtaining quality fruits and a high yield (Dhillon *et al.,* 2005a; Gogi *et al.*, 2009; Akram *et al.,* 2010).

Melon fruit fly causes heavy losses to bitter gourd (Lall and Singh, 1969; Gogi, *et al.*, 2009; Akram *et al.,* 2010). The maggots of melon fruit fly feed inside the fruit as well as on the fruit pulp (Dhillon *et al.,* 2005b) or, occasionally, on the flowers, taproots, stems, and leaf stalks (Narayanan, 1953; Weems and Heppner, 2001). The infested fruits and flowers do not develop properly and fall down or rot on the plant and result in a dramatic reduction in yield (Dhillon *et al.,* 2005a). The pseudo-punctures (punctures without eggs) and brown resinous deposits (formed due to the solidification of watery fluid oozing from the puncture) reduce the market value of the produce (Gogi *et al.*, 2009) Sterile females are reported to cause <1% damage by only pseudo-punctures, in cucumber, sponge-gourd and bitter gourd crops (Miyatake *et al.,* 1993). Young larvae leave the necrotic region and move to the healthy tissues, where they often introduce various pathogens and hasten the fruit-decomposition (Dhillon *et al.,* 2005b). Melon fruit fly has been reported to cause 90% fruit infestation in snake-gourd and 60 to 87% fruit infestation in pumpkin fruits in the Solomon Islands (Hollingsworth *et al.,* 1997). In the bitter gourd fruit, 41-95% melon fruit fly infestation has been recorded (Rabindranath and Pillai, 1986; Hollingsworth *et al.,* 1997). Singh *et al.* (2000) reported 31.27% damage on bitter gourd and 28.55% on watermelon in India. Gogi *et al.* (2009) showed that melon fruit fly showed 16-75% infestation on the bitter gourd fruits with 4.2-9.4 larvae/fruit in different genotypes of bitter gourd.

Conventional insecticides are being used for controlling fruit flies. Organophosphates, like, imidan (phosmet) (Yee *et al.,* 2007), triazophos (Reddy, 1997), malathion and azinphos-methyl (Neilson and Sanford, 1974; Mohammad and Aliniazee, 1989) and pyrethroids (Borah, 1997), have been used for many years to control different fruit flies. However, because of their relatively high mammalian toxicity (Yee *et al.,* 2007) and negative effects on the beneficial insects (Williams *et al.,* 2003), organophosphate insecticides, despite their effectiveness, are considered hazardous for use for end users and consumers (Yee *et al.,* 2007). With the concerted efforts of Environmental Protection Agency to reduce the use of harmful insecticides on agricultural crops, the trend has now been shifted towards an integrated pest management (IPM) for the control of tephritid fruit flies (Klungness *et al.,* 2005).

The IPM includes a combination of chemical, biological and cultural control tactics (Sarfraz *et al*., 2005; Gogi *et al*., 2006) with insecticides still to continue as important components of such strategies. The fruits of cucurbits and bitter gourd, of which the melon fly is a serious pest, are picked up at short intervals for marketing and self-consumption. Therefore, it is difficult to rely on insecticides to control this pest because a time bar application of insecticides to control melon fruit flies is considered undesirable for the human health (Dhillon *et al.,* 2005a). Similarly, the maggots damage the fruits internally. This behavior again makes it difficult to control this pest with insecticides (Dhillon *et al.,* 2005b; Klungness *et al.,* 2005). Therefore, it is imperative to explore alternative methods of control, such as the development and identification of resistant genotypes, adult food-baits, oviposition-baits, plant extracts, cultural practices etc., and use them as integral part in IPM.

Cultural controls can be powerful approaches for reducing infestation by tephritid fruit flies (Teixeira and Isaacs, 2007). Adopting cultural practices alone can effectively reduce the infestation of melon fruit fly (Jan *et al.,* 2012). From sowing to harvesting, different types of cultural practices are adopted by the farmers as a part of production technology of crops, which directly or indirectly, helps reduce the insect pest damage to the crops including vegetables (Dhaliwal and Arora, 2003; Dhillon *et al.,* 2005b; Panhwar, 2005; Jan *et al.,* 2012). In some countries, farmers are very careful to till their crop after final harvest but this practice does not result in the mortality of all the larvae or pupae (Pandey, 2004). It is, therefore, imperative to organized sound efforts for encouraging the removal of infested fruits from the cropping system, especially in those countries, where fruit flies are well established (Klungness *et al.,* 2005).

From the above account we hypothesize that adopting cultural practices may help reduce the infestation of melon fruit fly on bitter gourd. The present studies were carried out to evaluate impacts of some cultural practices like time of sowing, plant-to-plant distances, sowing methods and field sanitation on the fruit infestation by melon fruit fly yield losses, number of marketable fruits and marketable yield of bitter gourd.

Materials and Methods

Experimental Details and Treatments

Screening of sowing times and plant to plant distance: A conventional bitter gourd cultivar, green long, was sown at the campus research area of University of Agriculture, Faisalabad, during 2005, following two factor factorial experiments under a randomized complete block design, with three repeats. Two factors were three sowing times i.e., 15 March (optimum), 15 February (early) and 15 April (late) and plant-to-plant distances i.e., 30, 45, 60 and 75 cm.

Screening of sowing methods and sanitary measures: Bitter gourd cultivar, green long, was sown, at Harappa, during 2006, following two factor factorial experiments, under a randomized complete block design, with three repeats. The two factors i.e., sowing methods and sanitary measures consisted of further different levels. Sowing methods consisted of two levels i.e., two sowing methods, viz., flat sowing method (FSM) and hang sowing method (HSM); whereas the sanitary measures also had two levels i.e., sanitation and without sanitation measures. The sowing of the bitter gourd cultivar was completed up to 20 April, according to the experimental design, with a bed dimension of 6×2 m and a plant to plant distance of 45 cm. At 4-5 leaf stage, the plants were hung on the wire-net, netted and spread on the seed bed, with the help of bamboo sticks in HSM, whereas, plants were let spread on the ground in FSM.

Agronomic practices and harvesting: In both the experiments, recommended agronomic practices were carried out as and when required, but no plant protection measure was taken. Five pickings were done in total and after each picking the fruits were separated into marketable (uninfested) and unmarketable (infested) lots and weighed. The infested fruits were counted and fruit infestation and yield loss were calculated.

Statistical Analysis

The data were analyzed by a factorial ANOVA, through Multivariate General Linear Model (MGLM) Technique (Tabachnick and Fidell, 2001), using a Statistica program to determine the differences in above mentioned parameters. The means of significant parameters were compared by using Tukey's Honestly Significant Difference (HSD) tests for paired comparisons after an analysis of variance (ANOVA) at probability level of 5%.

Results

Sowing Times and Plant-to-Plant Distance

The sowing times and plant-to-plant distances had significant ($P<0.01$) effects on percentage fruit-infestation, marketable-fruits/plant, yield-loss/plant and marketable-yield/plant. However, the interactions between sowing times and plant-to-plant distance, revealed highly significant effects on the percentage fruit-infestation, but non-significant effects on the marketable-fruits/plant, yield-loss/plant and marketable-yield/plant (Table 1). Among four plant to plant distances, a plant to plant distance of 45 cm was better although a plant to plant distance of 75 cm had lower fruit infestation (20.8%) and yield loss/plant (121.3 g) and marketable yield/plant (461.5 g). A 30 cm plant-to-plant revealed 30% fruit infestation, 141.7 g yield loss/plant, 4.3 marketable fruits/plant and 311.5 g marketable yield/plant, showing it to be the least effective in reducing fruit and yield loss (Fig. 1).

Fruit infestation and yield loss/plant were significantly (P<0.01) lower at early sowing (15 February), intermediate, at optimum sowing time (15 March) and significantly higher at the late sowing time (15 April), whereas marketable fruits/plant and marketable yield/plant were significantly higher at early sowing (15 February), intermediate at optimum sowing time (15 March) and lower at the late sowing time (15 April). At early sowing date, plant to plant distances of 75, 60 and 45 cm showed similar fruit infestation, marketable fruits/plant, yield loss/plant and marketable yield/plant (Fig. 2). Contrarily, in late sown field 75, 60 and 45 cm plant-to-plant distances showed 2-3 times more infestation, 1-2 times less marketable fruits/plant, 2-3 times more yield loss/plant and 1-2 times less marketable yield/plant as compared to early sowing. However, early sowing at a plant-to-plant distance of 45 cm was comparatively better as evident from more marketable yield/plant (Fig. 3).

Sowing Methods and Sanitary Measures

Analysis of variance revealed that sowing methods (FSM and HSM), sanitation measures and their interactions had significant effects on the percentage fruit infestation, marketable fruits/plant, yield loss/plant and marketable yield/plant (Table 2). Of both methods, HSM with 1.3 times less fruit infestation (47.1%), 1.5 times more marketable fruits/plant (4.29), 1.2 times less yield loss/plant (181.6 g) and 1.6 times more marketable yield/plant (282.0 g), compared to FSM, proved better sowing method (Fig. 4). Similarly, sanitation measures resulted in 1.7 times reduction in the fruit infestation (39.4%), 1.4 times reduction in the yield loss/plant (168.0 g), 2.4 times increase in the marketable fruits/plant (5.08) and 3.2 times increase in the marketable yield/plant (353.9 g) compared to the control (no sanitary measures applied) (Fig. 5). HSM with sanitation measures yielded lower fruit infestation (29.8%) and yield loss/plant (137.9 g); whereas, higher marketable fruits/plant (6.2 fruits) and marketable yield/plant (439.4 g). However, other combinations between sowing methods and sanitary measures proved less effective (Fig. 6). HSM in combination with sanitation measures proved better combination and could be used in IPM models.

Discussion

Among tested sowing times, based upon changes in the fruit characters, early sowing (15 February) was relatively better sowing time to mitigate the melon fruit fly infestation and get quality produce of bitter gourd. This may be attributed to the seasonal cycle of melon fruit fly. Melon fruit fly remains inactive from November to February and present in form of “Leks”, among litters or in the form of pupae, in the soil. In the month of March, when temperature increases, the hibernating population starts to emerge and shows little activity, while its peak activity starts in the month of April/May-July (Singh *et al*., 2007). During winter months, its preoviposition period is also prolonged and it infests only in the fruit of soft rind (Atwal, 1986). This seasonal effect on the biology and behavior of melon fruit fly helps in reducing the fruit infestation and increasing the marketable yield when early sowing of most of the cucurbits is adopted as a cultural practice (Borah, 1996; Joshi *et al.,* 1995; Pandit *et al.,* 2010).

Table 1: ANOVA parameters for main effect of different sowing times, plant-to-plant distances and associated interactions on the percent fruit-infestation, marketable-fruits/plant, yield-loss/plant and marketable-yield/plant (total *df* = 35)

Source of Variation	*df* (V^a/E^b)	Fruit-infestation (%) F	Fruit-infestation (%) P	Marketable-fruits/plant F	Marketable-fruits/plant P	Yield-loss/plant F	Yield-loss/plant P	Marketable-yield/plant F	Marketable-yield/plant P
Sowing times	2/22	961.40**	<0.001	109.7**	<0.001	982.99**	<0.001	109.66**	<0.001
Plant-to-plant distances	3/22	103.19**	<0.001	71.5**	<0.001	10.27**	<0.001	94.32**	<0.001
Sowing times × plant-to-plant distances	6/22	12.61**	<0.001	1.25ns	0.321	2.43ns	0.06	1.27ns	0.331

**Highly significant; ns Non-significant, at probability level of 5%, a degree of freedom of Variable, b degree of freedom of Error

Table 2: ANOVA parameters for main effect of different sowing methods, sanitary measures and associated interactions on the percent fruit-infestation, marketable-fruits/plant, yield-loss/plant and marketable-yield/plant (total *df* = 11)

Source of Variation	*d.f.* (V^a/E^b)	Fruit-infestation F	Fruit-infestation P	Marketable-fruits/plant F	Marketable-fruits/plant P	Yield-loss/plant F	Yield-loss/plant P	Marketable-yield/plant F	Marketable-yield/plant P
Sowing methods	1/6	245.97**	<0.001	183.83**	<0.001	119.91**	<0.001	193.354**	<0.001
Sanitary measures	1/6	1182.21**	<0.001	825.14**	<0.001	359.63**	<0.001	1152.96**	<0.001
Sowing methods × sanitary measures	1/6	54.73**	<0.001	68.31**	<0.001	45.86**	<0.001	98.392**	<0.001

**Highly significant, at probability level of 5%, a degree of freedom of Variable, b degree of freedom of Error

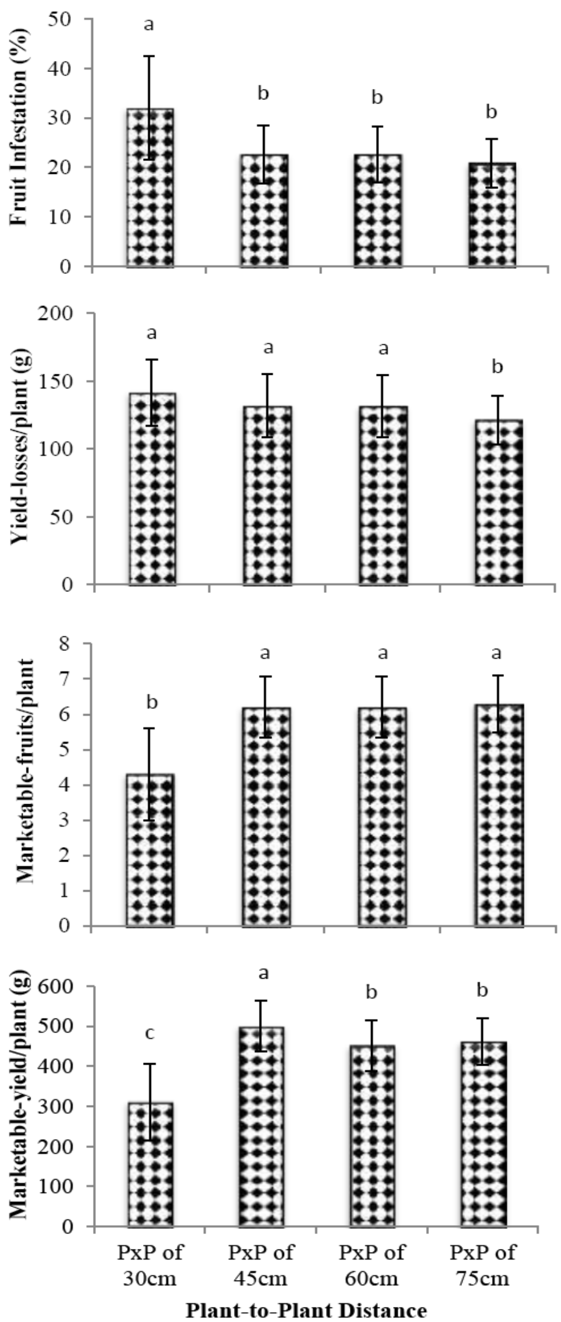

Fig. 1: Fruit infestation (%), marketable fruits/plant, yield losses/plant (g) and marketable yield/plant (g) demonstrated by melon fruit fly in bitter gourd crop sown at different plant-to-plant distances (Means of bars sharing similar letters are not significantly different at p = 0.05; Error bars indicate the ±SE)

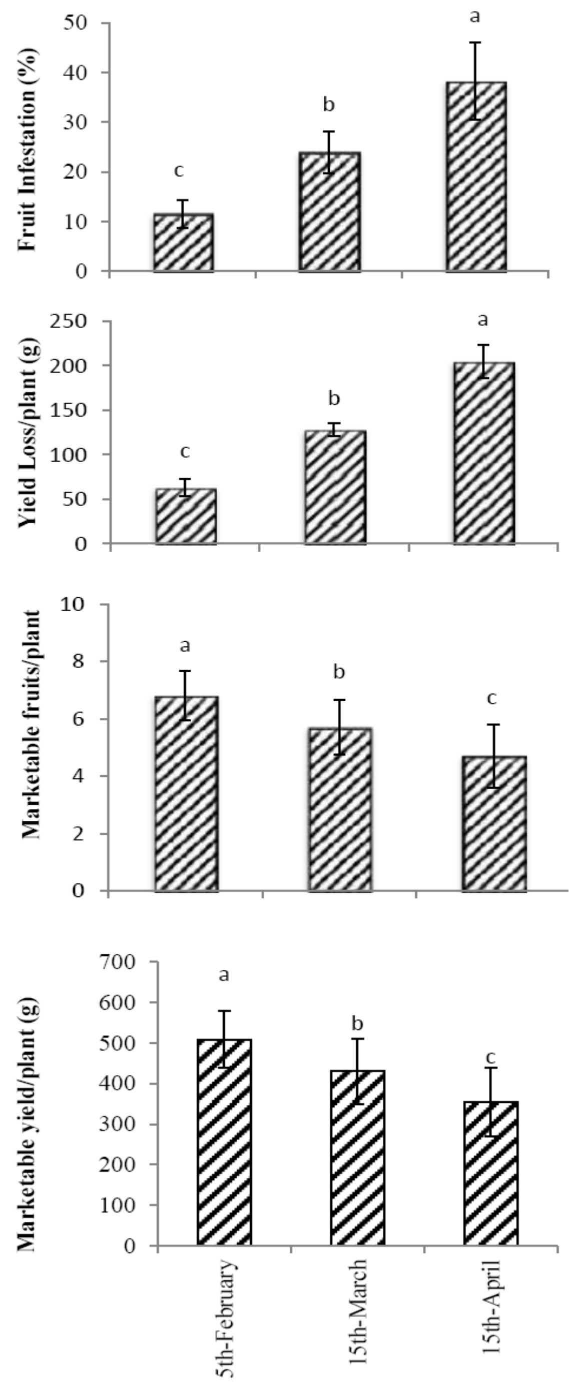

Fig. 2: Fruit infestation (%), marketable fruits/plant, yield losses/plant (g) and marketable yield/plant (g) demonstrated by melon fruit fly in bitter gourd crop sown at different sowing times (Means of bars sharing similar letters are not significantly different at p = 0.05; Error bars indicate the ±SE)

The results of screening trials, for different cultural practices, revealed that plant to plant distance of 45 cm, manifested minimum fruit infestation, maximum marketable fruits/plant, minimum yield loss/plant and maximum marketable yield/plant, although, a plant to plant distance of 75 cm showed lower fruit and economic yields. Lower fruit infestation and yield loss/plant in plots at 45 cm is attributed to the behavior of melon fruit fly, proper ventilation of the creepings and exposure of more fruit to sun rays due to more spacing among bitter gourd creepings.

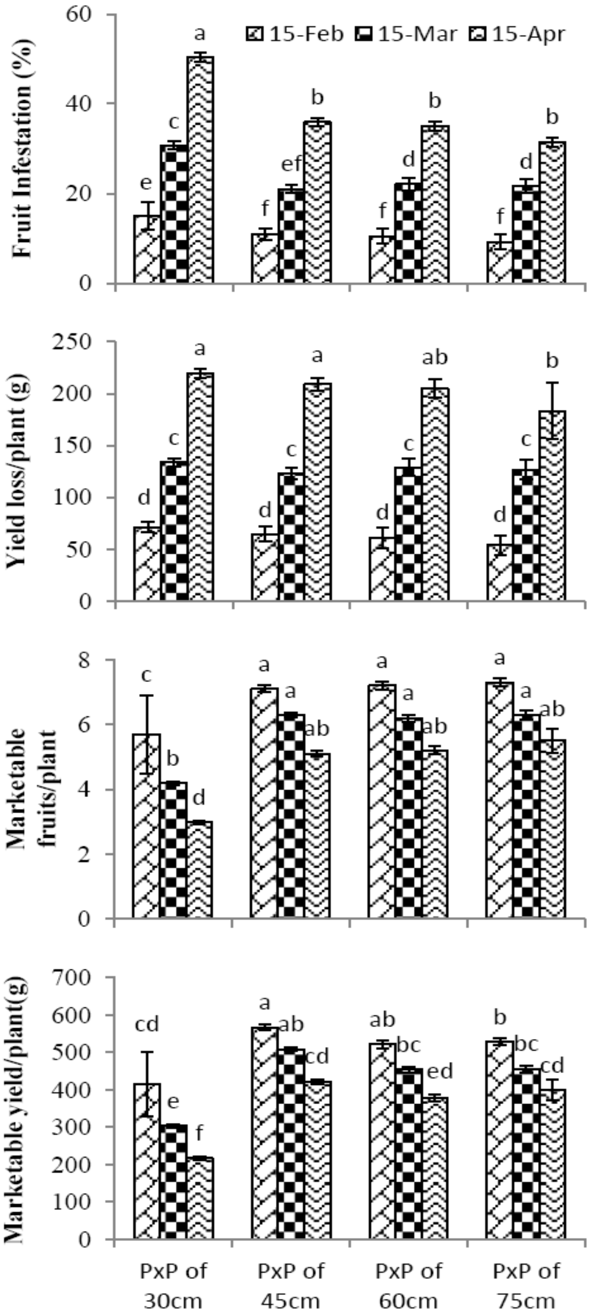

Fig. 3: Fruit infestation (%), marketable fruits/plant, yield losses/plant (g) and marketable yield/plant (g) demonstrated by melon fruit fly in bitter gourd crop at different interactions between plant-to-plant distances and sowing times (Means of bars sharing similar letters are not significantly different at p = 0.05; Error bars indicate ±SE)

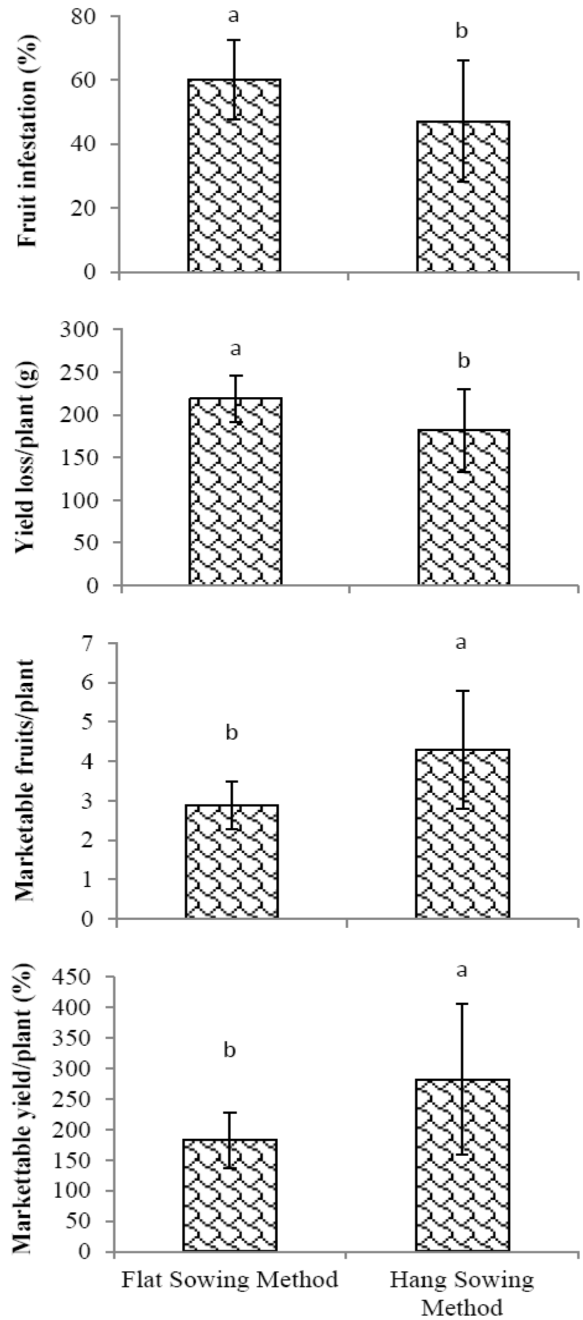

Fig. 4: Fruit infestation (%), marketable fruits/plant, yield losses/plant (g) and marketable yield/plant (g) demonstrated by melon fruit fly in bitter gourd crop sown by different sowing methods (Means of bars sharing similar letters are not significantly different at p = 0.05; Error bars indicate the ±SE)

The fruits exposed to the sun rays were least infested as compared to those hidden under the creepings. This showed that the melon fruit flies prefer to oviposit in those fruits, which are not exposed to the sun rays. In spite of more fruit infestation and yield loss/plant at plant-to-plant distance of 45 cm, more marketable yield in these plots may be attributed to more plant population due to a less plant-to-plant distance. In the early sown plots at all plant to plant distances a similar fruit infestation, marketable fruits/plant, yield

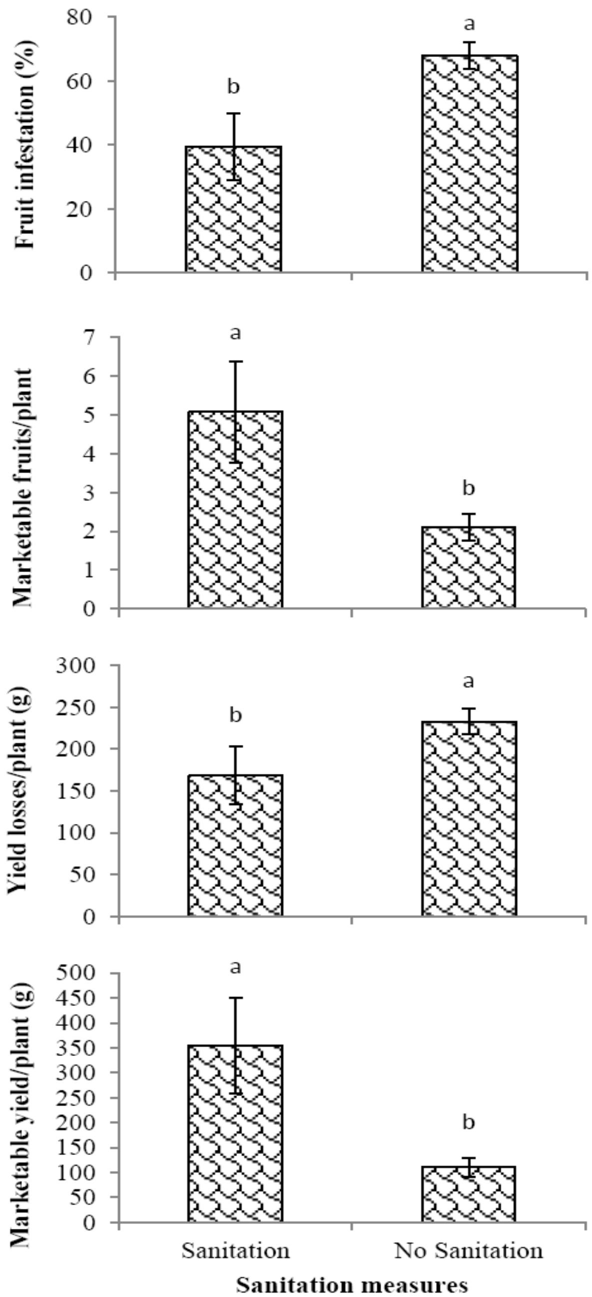

Fig. 5: Fruit infestation (%), marketable fruits/plant, yield losses/plant (g) and marketable yield/plant (g) demonstrated by melon fruit fly in bitter gourd crop experienced sanitation or no-sanitation measure (Means of bars sharing similar letters are not significantly different at p = 0.05; Error bars indicate the ±SE)

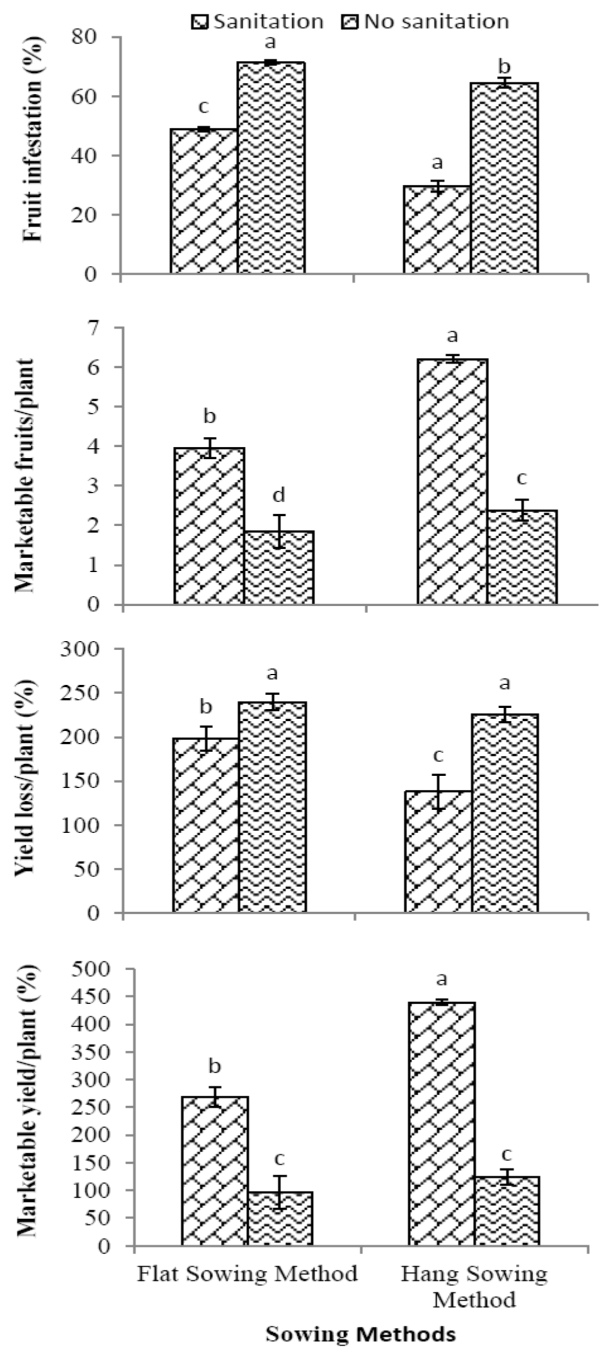

Fig. 6: Fruit infestation (%), marketable fruits/plant, yield losses/plant (g) and marketable yield/plant (g) demonstrated by melon fruit fly in bitter gourd crop under different interactions between sanitation measures and sowing methods (Means of bars sharing similar letters are not significantly different at p = 0.05; Error bars indicate the ±SE)

loss/plant and marketable yield/plant were noticed. However, at early sowing, at a plant to plant distance of 45 cm was comparatively better as this resulted in more marketable yield/plant (567.2 g). These results cannot be compared or contradicted, as no information is available thus far.

Of the sowing methods and sanitation measures, HSM with 1.3 times less fruit infestation, 1.5 times more marketable fruits/plant, 1.2 times less yield loss/plant and 1.6 times more marketable yield/plant was better as compared to FSM. Less infestation and yield loss in the HSM was due to the fact that there was proper ventilation and more fruits were directly exposed to sun; hence these fruits are not preferred for oviposition. Similarly, more marketable fruits and yield per plant in the HSM is attributed to the fact that in this method least number of fruits come in contact with the soil; hence deterioration of fruits due to scavenger like *Drosophilla melanogaster* (Dhillon *et al.*, 2005b) or other factors is avoided, which results in more marketable yield. However, results, regarding the effect of sowing methods on fruit infestation and marketable yield characters could not be compared or contradicted.

Many advanced technologies have been adopted to control fruit flies including melon fruit fly (Tan, 2000). However, management of life stages of flies, especially, post-oviposition to adult eclosion, have been totally overlooked in these control programs (Klungness *et al.*, 2005). These life stages of fruit flies can be managed through tilling and destruction of infested fruits during picking (Pandey, 2004; Klungness *et al.*, 2005). The present study showed that adoption of sanitation measures resulted in 1.7 times reduction in the fruit infestation and concomitant reduction in the yield loss. More yield obtained by adopting sanitation measure appears to be due to the reason that maggots of fruit flies, feeding inside the fruits, are killed, reproduction cycle is broken and the development of overlapping generations in the area is reduced/suppressed, effectively (Klungness *et al.*, 2005; Panhwar, 2005; Akram *et al.*, 2010). Different quarantine agencies and fruit flies control programs like California Department of Food and Agriculture, Secretariat of the Pacific, Taiwan's national fruit fly control program etc., encouraged the removal of infested fruits from the environment and fruit stripping and disposal as an important sanitation practice of fruit flies eradication program especially when the presence of a quarantine fruit fly is detected (Klungness *et al.*, 2005; Panhwar, 2005). Overall, the HSM with sanitation measures yielded significantly lower fruit infestation and yield loss/plant and proved to be a better combination and could be used in IPM models.

In conclusion, in cucurbit cropping systems, cultural practices like sowing methods, plant-to-plant distance, sanitation, sowing time etc. are either completely neglected or given least significance by the growers putting more reliance on the chemical control. The farmers should exercise cultural practices in integration with other IPM practices, avoid flat-sowing-method, elude delay in sowing and implement sanitation. They should prefer early sowing of bitter gourd under hang-sowing-method with 45 cm plat-to-plant distance and exercise sanitation in the field to get quality produce of bitter gourd and other cucurbits.

Acknowledgements

We express gratitude to Higher Education Commission of Pakistan for providing funds to conduct this piece of research work as a part of a Ph.D. project under indigenous Ph.D. program.

References

Akram, M.W., M.M. Rahman and R. Ali, 2010. Evaluation of some management practices for the suppression of cucurbit fruit fly in bitter gourd. *J. Bangl. Agric. University,* 8: 23–28

Atwal, A.S., 1986. *Agricultural Pests of India and South-East Asia*. Kalyani Publishers, New Delhi, India

Behera, T.K., 2004. Heterosis in bitter gourd. *J. New Seeds*, 6: 217–222

Borah, R.K., 1996. Influence of sowing seasons and varieties on the infestation of fruitfly *Bactrocera cucurbitae* (*Dacus cucurbitae*) in cucumber in the hill zone of Assam. *Ind. J. Entomol*., 58: 382–383

Borah, R.K., 1997. Effect of insect incidence in cucumber (*Cucumis sativus*) in hill-zone of Assam. *Ind. J. Agric. Sci.*, 67: 332–333

Dhaliwal, G.S. and R. Arora, 2003. *Principles of Insect Pest Management*, 2nd edition, p: 70. Kalyani Publishers, Ludhiana, India

Dhillon, M.K., J.S., Naresh, R. Singh and N.K. Sharma, 2005a. Influence of physico-chemical traits of bitter gourd, *Momordica charantia* L. on larval density and resistance to melon fruit fly, *Bactrocera cucurbitae* (Coquillett). *J. Appl. Entomol*., 129: 393–399

Dhillon, M.K., R. Singh, J.S. Naresh and H.C. Sharma, 2005b. The melon fruit fly, *Bactrocera cucurbitae*: A review of its biology and management. *J. Insect Sci.*, 5: 1–16

El-Batran, S.A.E.S., S.E. El-Gengaihi and O.A. El-Shabrawya, 2006. Some toxicological studies of *Momordica charantia* L. on albino rats in normal and alloxan diabetic rats. *J. Ethnopharmacol.*, 108: 236–242

Gogi, M.D., M. Ashfaq, M.J. Arif and M.A. Khan, 2009. Screening of bitter gourd (*Momordica charantia*) germplasm for sources of resistance against melon fruit fly (*Bactrocera cucurbitae*) in Pakistan. *Int. J. Agric. Biol*., 11: 746–750

Gogi, M.D., R.M. Sarfraz, L.M. Dosdall, M.J. Arif, A.B. Keddie and M. Ashfaq, 2006. Effectiveness of two insect growth regulators against *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae) and *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) and their impact on population densities of arthropod predators in cotton in Pakistan. *Pest Manage. Sci.*, 62: 982–990

Hollingsworth, R., M. Vagalo and F. Tsatsia, 1997. Biology of melon fly, with special reference to the Solomon Islands. *In*: Allwood, A.J. and R.A.I. Drew (eds.), *Management of Fruit Flies in the Pacific. Proc. Aust. Country Industr. Agric. Res.*, 76: 140–144

Jan, A.S., S. Ahmad, M.U.D. Siraj and M. Ajmal, 2012. Management of melon fruit fly, *Myiopardalis pardalina* Bigot (Diptera: Tephritidae) in Kunduz, Afghanistan. *Int. Conf. Agric., Envir. Biol. Sci. (ICAEBS'2012)*, pp: 1–5. May 26-27, 2012, Phuket

Joshi, V.R., D.B. Pawar and K.E. Lawande, 1995. Effects of different training systems and planting seasons on incidence of fruit flies in bitter gourd. *J. Maharashtra Agric. University*, 20: 190–291

Klungness, L.M., E.B. Jang, R.F.L. Mau, R.I. Vargas, J.S. Sugano and E. Fujitani, 2005. New sanitation techniques for controlling tephritid fruit flies (Diptera: Tephritidae) in Hawaii. *J. Appl. Sci. Environ. Manage.*, 9: 5–14

Lall, B.S. and B.N. Singh, 1969. Studies on the biology and control of melon fly, *Dacus cucurbitae* (Coq.) (Diptera: Tephritidae). *Labdev J. Sci. Technol*., 7: 148–153

Miyatake, T., T. Irabu and R. Higa, 1993. Oviposition punctures in cucurbit fruits and their economic damage caused by the sterile female melon fly, *Bactrocera cucurbitae* Coquillett. *Proc. Assoc. Plant Prot. Kyushu*, 39: 102–105

Mohammad, A.B. and M.T. Aliniazee, 1989. Malathion bait sprays for control of apple maggot Diptera: Tephritidae). *J. Econ. Entomol*., 82: 1716–1721

Narayanan, E.S., 1953. Seasonal pests of crops. *Ind. Farm*, 3: 8–31

Neilson, W.T.A. and K.H. Sanford, 1974. Apple maggot control with baited and unbaited sprays of azinphos-methyl. *J. Econ. Entomol.*, 67: 556–557

Pandey, R.R., 2004. Plan your sudex borders for melon fly control. *In: HAW-FLYPM Newsletter*. Hiraki, C. (ed.). Coop. Ext. Serv., Col. of Trop. Agric. and Human Resources: Univ. of Hawaii, February 2004, on world wide web at http://www.fruitfly.hawaii.edu/

Pandit M.K., P.K. Pal and B.K. Das, 2010. Effect of date of sowing on flowering and incidence and damage of melon fruit fly in snap melon *Cucumis melo* var. *momordica* genotypes. *J. Plant Prot. Sci*., 2: 86–91

Panhwar, F., 2005. *Mediterranean Fruit Fly (Ceratitis capitata) Attack on Fruits and its Control in Sindh, Pakistan*. Digitalverlag GmbH, Germany. Available on World Wide Web at http://www.chemlin.de/publications/documents/Mediterranean_fruit_fly.pdf, 24th Sep. 2008

Rabindranath, K. and K.S. Pillai, 1986. Control of fruit fly of bitter gourd using synthetic pyrethroids. *Entomon*, 11: 269–272

Reddy, A.V., 1997. Evaluation of certain new insecticides against cucurbit fruit-fly (*Dacus cucurbitae* Coq.) on Bitter gourd. *Ann. Agric. Res*., 18: 252–254

Sarfraz, M., L.M. Dosdall and B.A. Keddie, 2005. Spinosad: a promising tool for integrated pest management. *Outlook Pest Manage.*, 16: 78–84

Singh, H.S., A. Verghese and G. Naik, 2007. *Integrated Management of Fruit Flies*, pp: 2–3. Technical Bulletin No. 11, Central Horticultural Experiment Station (IIHR), Bhubaneswar, India

Singh, S.V., A. Mishra, R.S. Bisan, Y.P. Malik and A. Mishra, 2000. Host preference of red pumpkin beetle, *Aulacophora foveicollis* and melon fruit fly, *Dacus cucurbitae. Ind. J. Entomol.*, 62: 242–246

Tabachnick, B.G. and L.S. Fidell, 2001 .*Using Multivariate Statistics: A Guide to Statistical Technique,* 4th edition, pp: 17–30. Allyn and Bancon, Mass, Tokyo, New York

Tahir, M. and M.S. Haider, 2005. First report of tomato leaf curl New Delhi virus infecting bitter gourd in Pakistan. *Plant Pathol.,* 54: 807

Tan, K.H., 2000. *Area Wide Control of Fruit Flies and other Insect Pests,* p: 782. Sinaran Bros., Sdn. Bhd., Penang, Malaysia

Teixeira, L. and R. Isaacs, 2007. *Options for Organic Management of Blueberry Maggot*. The New Agricultur Network on-line Newsletter, 4(5): June 27, 2007. Available on http://www.new-ag.msu.edu/issues07/6-27.htm, 23rd September, 2008

Weems, H.V. and J.B. Heppner, 2001. *Melon fly, Bactrocera cucurbitae Coquillett (Insecta: Diptera: Tephritidae)*. Florida Department of Agriculture and Consumer Services, Division of Plant Industry and T.R. Fasulo. University of Florida Publication EENY-199, University of Florida, Florida, USA

Williams, T., J. Valle and E. Vinuela. 2003. Is the naturally derived insecticide spinosad® compatible with insect natural enemies? *Biocontrol. Sci. Technol*., 13: 459–475

Yee, W.L., O. Jack and M.J. Nash, 2007. Mortality of *Rhagoletis Pomonella* (Diptera: Tephritidae) exposed to field-aged spinetoram, Gf-120 and azinphos-methyl in Washington State. *Florida Entomol.*, 90: 335–342

(Received 23 July 2013; Accepted 05 October 2013)