Research Review

© 2024, Centre for Advanced Research in Agricultural Sciences
Research Journal of Agricultural Sciences
Volume 15; Issue 04 (Jul–Aug 2024); pp 1096–1100

ISSN: 0976-1675 (P)
ISSN: 2249-4538 (E)

A Review on Insect-Pest Management in Fruit Crops

Aditya Kumar*[1], Rama Sharma[2], Vikas Chandra[3] and Amit Bagri[4]

[1-2,4] Department of Entomology, Faculty of Agriculture Science and Technology, AKS University, Satna - 485 001, Madhya Pradesh, India

[3] Department of Horticulture (Fruit and Fruit Technology), Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India

Received: 16 May 2024; Revised accepted: 24 Aug 2024

Abstract

A large number of pests are available in the nature; however, most of them are most destructive and badly damage the fruit production. Besides most of them cause yield loss and yet some of them transmit virus diseases. Brown citrus aphid transmits citrus tristiza virus in citrus fruits. Historically it is learnt that broad spectrum pesticides have been used to prevent the yield loss and transmission of bacteria and virus to in the world. However, referred pesticides could cause a several complications in human being. These problems include environmental, human health and also create negative effects on soil health. At the same time, pesticides tend to create negative effect such as food safety. Due to these reasons an alternative management method such as biological, Biotechnical and sterile insect techniques are used in all fruit growing regions of the would.

***Key words*:** Pest, Biological mechanical, Chemical control, Biotechnical

The term "pest" refers to an organism that causes damage to crops or poses a nuisance to animals or humans. Agricultural pests encompass a range of organisms including insects, weeds, bacteria, viruses, fungi, and animals that diminish crop productivity compared to what could be achieved in a pest-free environment [1]. The larvae hatched from eggs undergo a transformation distinct from their adult form. Through feeding and development, they shed their exoskeletons and transition into pupae. Pupation typically occurs on the host plant or primarily underground. After a certain period, adult insects emerge from the pupa, perpetuating the life cycle. In incomplete metamorphosis, the nymphs emerging from eggs laid by adult females closely resemble the adults themselves. These young insects resemble miniature versions of the adults, albeit without developed wings. As they feed, these nymphs undergo molting, gradually increasing their resemblance to the parent insect after each molting period [2]. The onslaught of various harmful insects results in damage to plant leaves, buds, stems, fruits, flowers, and seeds, leading to significant crop losses and a decrease in market value. Hence, the implementation of pest management methods is crucial in agricultural production [1]. Pest control aims to achieve economic, effective, and long-term management of pests. Typically, this involves suppressing pest populations to levels that avoid economic harm rather than attempting complete eradication.

Numerous pests have a detrimental impact on global agricultural production. Producers employ various methods to mitigate the quality and quantity losses caused by these pests in agricultural settings. Among these approaches, which fall under Plant Protection or Agricultural Control, are cultural measures, quarantine measures, mechanical and physical methods, biological methods, biotechnical methods, chemical methods, and integrated pest management—a comprehensive strategy combining multiple techniques [3]. Presently, chemical applications are favored by producers due to their ease of application and effectiveness [4]. Relying on pesticides for plant protection is associated with adverse effects on the environment, human health, and the sustainable efficacy of their usage. The advent of synthetic pesticides has led to the simplification of crop systems, resulting in the abandonment of more intricate crop protection strategies [5]. The term "pesticide" encompasses all chemicals categorized as insecticides (used against harmful insects), herbicides (targeting weeds), fungicides (combatting fungal diseases), rodenticides (aimed at rodents), molluscicides (used to control slugs), avicides (targeting birds), acaricides (used against mites), ovicides (for killing insect eggs), bactericides (fighting bacterial diseases), nematicides (against nematodes), and others [6]. Over 98% of applied insecticides and 95% of herbicides ultimately end up in locations other than their intended targets, including non-target species, air, water, and soil. However, pesticides can contaminate soil, water, and vegetation. Pesticides can harm a variety of other organisms in addition to the insects and weeds they are intended to kill, such as fish, birds, beneficial insects, and non-target plants [7].

Fruit cultivation suffers losses due to a variety of economically damaging insect pests. One such example is the Stem borer (*Zeuzera pyrina* L. By attacking tree stems and causing tree mortality, Lepidoptera: Torticidae) pose a serious threat. In contrast, young pomegranate leaves are particularly vulnerable to aphid infestations, making aphids—especially Aphis pomi De Geer (Homoptera: Aphididae)—a serious pest. Although pomegranate production is negatively impacted by these pests, the citrus mealybug, Planococcuscitri (Risso) (Hemiptera: Pseudococcidae), Mediterranean fruit fly, Ceratitis capitata (Wiedemann) (Diptera: Tephritidae), and pomegranate

***Correspondence to:** Aditya Kumar, E-mail: adityakupatel90@gmail.com; Tel: +91 9589783527

Citation: Kumar A, Sharma R, Chandra V, Bagri A. 2024. A review on insect-pest management in fruit crops. *Res. Jr. Agril. Sci.* 15(4): 1096-1100.

butterfly, Deudorixlivia (Virachola) (Klug) (Lepidoptera: Lycaenidae), have the most impact on the market value of pomegranate fruits [8]. Many insects pests feed on plant sap and vertebrate blood, potentially mechanically transmitting pathogens and parasites through their proboscis contamination [9]. Furthermore, pesticide usage can lead to undesirable consequences such as the development of resistance in diseases, insects, and weeds. Therefore, given the emphasis on human health and biodiversity preservation, there has been increasing scrutiny of chemical control methods [4]. This study addresses the topic of chemical control and other management methods employed against economically significant insect pests in agricultural production.

Management methods of insect pests

In contemporary agricultural settings, pests such as insects, diseases, weeds, and animal pests (including birds and rodents) contribute to economic losses. Insects and other organisms that damage crops and have the potential to transmit diseases to humans or animals are considered pests that require effective control measures [1]. Some harmful insects serve as vectors in the transmission of crucial diseases, such as virus diseases. Moreover, weeds serve as hosts to numerous disease agents and harmful insect species. Vector insects encompass aphids, whiteflies, and thrips. For instance, the Brown citrus aphid stands out as a significant vector insect for the citrus tristeza virus (CTV) due to its high vector productivity, particularly with vigorous strains [10].

In the management of these insect pests, Integrated Pest Management (IPM) is an emerging approach that relies heavily on knowledge of pest biology and ecology. This approach enables farmers to make strategic decisions aimed at optimizing ecologically and economically sound control measures against harmful organisms, including pathogens, weeds, insects, and vertebrates [11]. This study provides information on these control methods employed against pests that cause substantial damage and economic losses in fruit cultivation

Integrated pest management method

Toward the end of the 19th century, the concept of Integrated Pest Management (IPM) began to emerge, with some initial applications observed in the early 20th century. Notably, these early applications primarily focused on biological control, alongside chemical control. IPM stands as one of the most contemporary approaches developed in the realm of plant protection. The fundamental objective of this method is to employ multifaceted strategies in a well-coordinated manner to achieve balanced crop production, minimize losses caused by pests to levels that yield the highest economic benefit, meet farmers' other objectives, and mitigate the risks of pesticides on humans, animals, and the environment. IPM aims not only to suppress or eradicate pest populations but also to seek solutions that integrate viable, economically feasible, effective, environmentally friendly, and sustainable methods. Regular inspection of agricultural lands is paramount and should be incorporated into an integrated management program. Without proper monitoring, vital information necessary to determine whether action is warranted and the severity of pest populations may be overlooked. Gathering comprehensive data on the population and spread of pests is crucial before implementing any control measures. This information is essential for making informed decisions about the timing and extent of interventions. Thus, the integrated control method operates on the principle of applying control measures only when pest populations exceed the economic damage threshold, rather than as a routine practice.

Cultural method

One of the most ancient approaches to pest management in agricultural practices is cultural control. However, with the advent of synthetic pesticides, cultural control methods were swiftly disregarded or received less attention, leading to a decline in research efforts focused on them. Adopting good agronomic practices that avoid or reduce pest infestations and damage refers to cultural control. Choosing clean seed or plant material is critical to avoid the chances of introducing pests right from the beginning of the crop production [12]. These methods are typically employed as preemptive measures, as they are often deemed less potent compared to alternative control strategies. Cultural control encompasses various practices such as site selection, planting design and management (including crop rotation, planting of trap plants, timing of planting and harvesting, placement of alternative hosts, etc.), plowing, irrigation, drainage, fertilization, removal of plant residues, mulching, and adjustment of harvest timing [13]. Despite being practiced for centuries; cultural measures remain pertinent and relevant today. They embody a wealth of knowledge and practices accumulated over time, yielding positive outcomes.

Mechanical exclusion

Protecting the fruits from pomegranate fruit borer by wrapping them in a polythene bag. Mealy bug prevention measures for mango trunks include bandaging with grease or polythene sheets [12]. The red hairy caterpillar larvae are being trapped and trenched. Maintain a tidy yard and remove any areas that could draw insect pests. This entails getting rid of any standing water that isn't a part of the landscape design, dead limbs, piles of decaying organic matter, and undesired debris that is in contact with the ground.

Yellow sticky traps

Aphids, thrips, and whiteflies all favor the color yellow. Tin boxes are painted yellow and have sticky materials applied to them, such as Vaseline or castor oil. These insects are drawn to yellow and become stuck on the adhesive substance. In recent decades, it has grown to be one of the most dangerous agricultural pests in many parts of the world. In addition to feeding, this pest can spread over 111 different plant-pathogenic virus species, induce physiological disturbances in plants, and produce sooty mold through its honeydew [14-15].

Blue sticky traps

In blue sticky traps attractant are placed to attract the insect and kill them using insecticides. Lygus bugs (Heteroptera, Miridae) are important pests of several crop plants. For the development of an efficient monitoring and forecasting system for Lygus densities, low catches of bugs with yellow sticky traps have been a problem [16].

Physical method

In recent times, the physical method of pest control in fruit production has gained prominence due to concerns over pesticide resistance development and the avoidance of pesticide residues, which can have both environmental and economic repercussions [17]. Physical control methods involve altering the pest's physical environment to render them harmless to agricultural crops. This can be achieved by inducing stress levels ranging from agitation to death, or by deploying devices such as physical barriers to shield plants from invasion. While chemical methods typically have well-defined and limited modes of action, physical control methods target a broader range of physiological and behavioral processes [18]. These practices include repelling pests, restricting their access to plants, and disrupting their behavior, ultimately leading to the direct death of insects [4]. Physical methods are categorized into two main groups: active and passive [19]. Active methods involve the use of equipment that acts as a barrier between plants and pests, safeguarding plants from insect damage. Passive tools, on the other hand, encompass repellants and traps [20]. While chemical and biological methods often clash, there is a synergy among cultural, biological, and physical methods. Pest exclusion with netting or row covers, handpicking or vacuuming to remove pests, mechanical tools for weed control, traps for rodent pests, modifying environmental conditions such as heat or humidity in greenhouses, steam sterilization or solarization, visual or physical bird deterrents such as reflective material or sonic devices are some examples of physical or mechanical control [12]. When combined, these approaches can prove more effective against pests than relying solely on chemical methods.

Biological method

The biological method encompasses measures aimed at utilizing natural enemies, entomopathogenic microorganisms, or enhancing their efficacy against pests, diseases, and weeds that afflict crop plants. "A pest control strategy utilizing living natural enemies, antagonists, competitors, and other self-reproducing biological entities" is the definition of biological control given in the 1996 FAO "Regulation on the Import and Release of Exotic Biological Control Agents". Insect parasites, more precisely termed parasitoids, are smaller than their hosts and develop inside or attach to the outer surface of their hosts [21]. Natural enemies such as predatory arthropods and parasitic wasps can be very effective in causing significant reductions in pest populations in certain circumstances [12]. Predator insects lay their eggs adjacent to their prey, and upon hatching, the larvae consume their prey through stinging, sucking, or chewing. Parasitoid insect larvae emerging from eggs lead to the demise of the pest's egg or the pest itself, thus suppressing the pest population and bolstering their own. Entomopathogens encompass bacteria, viruses, fungi, and nematodes utilized against harmful insects. These naturally occurring entomopathogens infect harmful insects, inducing illness and occasionally death. A prime example of entomopathogens is the beneficial bacterium named "Bacillus thuringiensis," commonly known as "Bt spray" in agricultural circles. This bacterium serves as a biological insecticide.

Natural enemies have been employed as a pest control method for centuries. However, in the past 100 years, there has been a substantial increase in understanding among humans, especially producers, regarding how biological control agents, integral to safe and effective pest control methods, can be better harnessed to manipulate pests [22]. Three types of biological control strategies are implemented in pest control programs: importation (sometimes termed classical biological control), augmentation, and conservation. Classical biological control involves the intentional introduction of an exotic (non-native) biological control agent for permanent establishment and long-term pest control [21]. These practices, which have been conducted for years, have not exhibited any negative effects [4]. Augmentation entails the additional release of natural enemies, augmenting the population already present naturally. Beneficial insects can be released in small quantities or in large numbers (inundative release) during critical growth stages. However, a key challenge lies in determining the effectiveness of these beneficial insects produced in artificial nutrient media under natural conditions, necessitating appropriate preparation and production of nutrient media. Moreover, the production and release of predators and parasitoids into the environment must adhere to certain standards. Consequently, the production and release of predators and parasitoids are predominantly practiced in high-value crops and greenhouses [4]. Conservation of natural enemies in an environment constitutes the third method of biological pest control. Since natural enemies are already adapted to the habitat and target pests, their preservation through vegetation manipulation can be straightforward and cost-effective. Classical Biological Control provides control over both primary and secondary pests, thereby reducing the likelihood of pest outbreaks and resurgence [21]. This form of biological method can be achieved through two approaches: altering pesticide use and manipulating the growing environment to favor natural enemies [23]. If natural enemies are adversely affected and their population dwindles, pests are relieved of natural enemy pressure and can rapidly proliferate, surpassing the economic damage threshold. Additionally, microbial control includes the use of fermentation byproducts from some microbes against plant pathogens, plant parasitic nematodes, and arthropod pests. These agents can include fungi, microsporidia, nematodes, viruses, and entomopathogenic bacteria.

Biotechnical method

Biotechnical Control endeavors to hinder or regulate the typical biological or physiological activities of pests through the utilization of artificial or natural compounds. Essentially, it disrupts the behavior and development of pests within their natural life processes, including feeding, mating, egg laying, and flying. The compounds employed in this method specifically target only the harmful organisms while preserving the natural balance. Biotechnical control can be integrated harmoniously with Organic Agriculture and Integrated Pest Management methods [24].

The most prevalent pheromones utilized in biotechnical control methods within the realm of agricultural pest management are sexually attractive pheromones, emitted by females to entice males for mating, and aggregation pheromones, which indicate a food source or suitable nesting sites. Generally, pheromones serve four main purposes: Monitoring pest populations in conjunction with traps (Monitoring) Employing mass trapping techniques to diminish pest populations (Mass Trapping) Disrupting mating by emitting a potent signal, hindering males and females from locating each other and mating (Mating Disruption) Utilizing the attract-and-kill technique in combination with insecticides (Attract and Kill). However, due to the high cost associated with these types of traps, alternative options can be considered. For instance, makeshift traps can be fashioned by puncturing holes in 1-liter plastic bottles commonly found in households, filling them with a mixture of apple juice and sugar. These homemade traps can effectively target harmful insects, belonging to various families, that cause substantial yield losses in fruit cultivation.

Sterile insect technique

Modern pesticides were not created or used until after the idea of sterilizing insects was first proposed. *Lasioderma serricorna* was used in the initial attempts at sterilization. 1916, which led to the development of sterile eggs (Tobacco beetle). There are two main methods used for sterilizing insects: radiation and chemicals called chemo-sterilant. The two most often utilized sources for this purpose are cobalt-60 and cesium-137. Insect gametes experience dominant, deadly mutations brought on by radiation. Mutations like this stop zygote maturation rather than having an effect on sex cell maturation or zygote formation directly. In males, radiation disrupts spermatogenesis, leading to the cessation of sperm production (aspermia) or a reduction in sperm activity, resulting in diminished mating capacity. Consequently, males may fail to mate, or fertilization may not occur due to their inability to maintain a mating position for a sufficient duration. In females, egg production decreases or ceases altogether, as radiation damages the ovaries or the nutrient cells within them [25]. This method has proven effective against pests such as the Olive fruit fly and the Mediterranean fruit fly, yielding positive results as a management strategy against these harmful insects.

Plant defense chemicals

Plants have protective metabolites that reduce the flavor of the tissues in which they are produced rather than impeding normal vegetative growth and development [26]. Put simply, plants deploy a range of inducible and constitutive defense mechanisms to protect themselves against attacks. These mechanisms encompass structural defenses like spines and waxy cuticles, as well as protein-based and chemical defenses [27]. Plant defenses against herbivores are activated through a complex network of direct and indirect pathways. Direct defense substances like protease inhibitors or glucosinolates have an immediate effect on the feeding and performance patterns of insects. Meanwhile, indirect defenses, such as the release of volatile organic compounds following herbivore attack, serve as attractants for parasitic wasps that prey on the attackers. As plants evolve new defense compounds or mechanisms, herbivores and their predators devise novel strategies to circumvent or detoxify them [26]. These defense compounds induced by insects, termed low molecular weight phytoalexins, are antimicrobial compounds synthesized and accumulated in plants following exposure to microorganisms. Similarly, phytoanticipins, also low molecular weight antimicrobial compounds, are present in plants either before microbial threats emerge or are produced post-infection from pre-existing components. These defense compounds (phytoalexins) triggered by insects may serve crucial functional roles as nutritional deterrents. However, inducible defense systems have a drawback: they entail a delay in the synthesis of new compounds. These compounds, known as phytoanticipins, are produced in anticipation of a potential threat [27].

Chemical method

Using artificial or naturally occurring chemicals with lethal (toxic) effects, chemical control aims to manage harmful organisms that result in financial losses for plants. These substances—known as pesticides—are artificially produced or biological agents that are intended to draw in, entice, eliminate, or lessen the presence of any pest [28]. Furthermore, any intervention that modifies the handling, preservation, manufacturing, distribution, or retailing of agricultural crops and animal products is classified as chemical control by the FAO [7]. Historically, in the 1930s, DDT gained widespread acceptance as a pesticide, significantly contributing to the increase in agricultural crop turnover, particularly food products. However, it fell out of favor in the 1960s due to its adverse effects [1]. The impact of pests on agricultural products is considerable. Therefore, insects and other organisms that damage agricultural production and pose threats to humans or animals have become pests that require stringent control measures.

Pesticides are categorized according to the pest species or target organism they address, resulting in three main groups: insecticides, fungicides, and herbicides. Furthermore, pesticides are classified based on their chemical structures, with notable classifications including organic chlorine pesticides, phosphorus-based compounds, carbamates, and natural and synthetic pyrethroids). One of the most crucial aspects of increasing agricultural production is maximizing yield per unit area. Effective management of harmful organisms that impede plant production is vital in achieving this goal. Pesticide applications are commonly employed in fruit cultivation due to their ease of application and rapid effectiveness.

CONCLUSION

Urbanization along with global climatic change jointly increased the pressure on climate, soil and water which are supposed to be natural resources of agricultural production. Due to presence of these condition and resultant effect is to cause damage of breeding system. Therefore, it is an important fact that reduction should be made towards increasing pressure and to develop natural resources suitable for agriculture for future generation as the population increased. As the population increases the production area are decreasing, however, to meet the needs of people with agricultural product –produced in this declining area, the amount of agricultural products produced per unit area should be increased. It is not at all possible to increase agricultural commodities only by the judicious application of nutrition to the plants. Therefore, at the same time it becomes imperative to use of plant protection measures which is fully implemented in agricultural products. Further it may also be mentioned that due to living and nonliving influences there is drastic regression which is noted in the growth and development of the plant. There are some signs of diseases in plants; however, severity and intensity of these symptoms indicate the extent of these diseases. Therefore, looking the importance of these symptoms found in plants which are further very important to find out the source of the problem by detecting it well and taking measures in terms of agricultural management. With this such information obtained, method that cause the least harm to the environment and nature should be applied to combat. Time is important in the fight against diseases. When the right time is not selected, the success of the control measure applied decreases. However, it is costly and challenging process for a diseased plant to bring them into healthy position. Therefore, it becomes important to prevent the plants from contacting disease, and will provide long term gain. It is also important to mention that most effective methods should be used without harming the living creatures in nature. When all the sever control methods as mentioned above if they are used in right time as well as right manner, the yield, quality and pest protection methods in agricultural production would become easier. Now it may be said that all the methods as stead above are used properly in case of sustainable agriculture.

LITERATURE CITED

1. Alalade OA, Matanmi BM, Olaoye IJ, Adegoke BJ, Olaitan TR. 2017. Assessment of pest control methods and it’s perceived on agricultural output in Kwara state, Nigeria. *Journal of Tropical Agriculture, Food, Environment and Extension* 16(1): 42-47.
2. Truman JW, Riddiford LM. 2019. The evolution of insect metamorphosis: a developmental and endocrine view. *Philos. Trans. R. Soc. London B Biological Science* 374(1783): 20190070. doi: 10.1098/rstb.2019.0070.

3. Mamay M, Mutlu C. 2019. Trend biotechnological management methods against agricultural pests: Mating disruption, mass trapping and attract and kill. *1st International Gobeklitepe Agriculture Congress* (IGAC 2019). Sanlıurfa, Turkey. pp 511-517.
4. Tudi M, Daniel Ruan H, Wang L, Lyu J, Sadler R, Connell D, Chu C, Phung DT. 2021. Agriculture development, pesticide application and its impact on the environment. *Int. Jr. Environ. Res. Public Health* 18(3):1112. doi: 10.3390/ijerph18031112.
5. Barzman M, Barberi P, Birch ANE, Boonekamp P, Dachbrodt-Saaydeh S, Graf B, Hommel B, Jensen JE, Kiss J, Kudsk P, Lamichhane JR, Messéan A, Moonen AC, Ratnadass A, Ricci P, Sarah JL, Sattin M. 2015. Eight principles of integrated pest management. *Agronomy for Sustainable Development* 35(4): 1199-1215.
6. Hussain S, Siddique T, Saleem M, Arshad M, Khalid A. 2009. Impact of pesticides on soil microbial diversity, enzymes, and biochemical reactions. *Advances in Agronomy* 102: 159-200.
7. Maksymiv I. 2015. Pesticides: Benefits and hazards. *Journal of Vasyl Stefanyk Precarpathian National University* 2(1): 71-76.
8. Kahramanoglu I, Usanmaz S. 2013. Management strategies of fruit damaging pests of pomegranates: *Planococcuscitri*, *Ceratitis capitata* and *Deudorix* (*Virachola*) *livia*. *African Journal of Agricultural Research* 8(49): 6563-6568.
9. Hill DS. 1997. Damage caused by insecta and Acarina. *In*: The Economic Importance of Insects. Springer, Dordrecht. https://doi.org/10.1007/978-94-011-5348-5_4.
10. Pena I, Batista L, Acuna M, Casin JC, Llauger R, Perez MC. 2002. Citrus tristeza virus epidemiological surveillance and eradication program in Cuba: Recent results. *International Organization of Citrus Virologists Conference Proceedings* 15(15): 335-336.
11. Vanbergen AJ, Aizen MA, Cordeau S, Garibaldi LA, Garratt MPD, Kovács-Hostyánszki A, Lecuyer L, Ngo HT, Potts SG, Settele J, Skrimizea E, Young JC. 2020. Chapter six - Transformation of agricultural landscapes in the Anthropocene: Nature's contributions to people, agriculture and food security. (Eds): David A. Bohan, Adam J. Vanbergen. Advances in Ecological Research, Academic Press. 63: 193-253.
12. Surendra KD. 2019. The new integrated pest management paradigm for the modern age. *Journal of Integrated Pest Management* 10(1): 12, https://doi.org/10.1093/jipm/pmz010.
13. Hill SB. 1987. Cultural pest control. *American Journal of Alternative Agriculture* 2(40): 191. https://doi.org/10.1017/S0889189300009383.
14. Yaobin L, Yawei B, Jinming Z. 2012. Are yellow sticky traps an effective method for control of sweet potato whitefly, *Bemisia tabaci*, in the greenhouse or field. *Journal of Insect Science* 12: 113.
15. Lu Y, Bei Y, Zhang J. Are yellow sticky traps an effective method for control of sweet potato whitefly, *Bemisia tabaci*, in the greenhouse or field? *Jr. Insect Science* 12:113. doi: 10.1673/031.012.11301.
16. Holopainen JK, Raiskio S, Wulff A, Tiilikkala K. 2001. Blue sticky traps are more efficient for the monitoring of *Lygus rugulipennis* (Heteroptera, Miridae) than yellow sticky traps. FINLAND. *Agricultural and Food Science* 10: 277-U3.
17. Banks HJ. 1976. Physical control of insects-recent developments. *Journal of the Australian Entomological Society* 15: 89-100.
18. Thakur K, Sharma A, Sharma K. 2021. Management of agricultural insect pests with physical control methods. *The Pharma Innovation Journal* 10(6): 306-314.
19. Vincent C, Hallman G, Panneton B, Fleurat-Lessard F. 2003. Management of agricultural insects with physical control methods. *Annu. Rev. Entomology* 48: 261-281. doi: 10.1146/annurev.ento.48.091801.112639.
20. War AR, Paulraj MG, Ahmad T, Buhroo AA, Hussain B, Ignacimuthu S, Sharma HC. 2012. Mechanisms of plant defense against insect herbivores. *Plant Signal Behaviour* 7(10): 1306-1320. doi: 10.4161/psb.21663.
21. Sanda S, Sunusi M. 2014. Fundamentals of biological control of pests. *International Journal of Chemical and Biological Sciences* 1(6): 1-11.
22. Leftwich PT, Bolton M, Chapman T. 2015. Evolutionary biology and genetic techniques for insect control. *Evol. Appl*. 9(1): 212-30. doi: 10.1111/eva.12280.
23. Rebek E, Frank S, Royer T, Bogrn C. 2012. *Alternatives to Chemical Control of Insect Pests*. *In book*: Insecticides - Basic and Other Applications. pp 171-96.
24. Kaptan S, Aksit T, Baspinar H. 2018. Biotechnical methods used in control of olive fruit Fly (Bactroceraoleae). *Zeytin Bilimi* 8(1): 1-12.
25. Ozbek H, Pande YD. 1992. Possibilities of pest management with the use of sexually sterile insects. *Ataturk U. Jr. Zir. Fak. Der*. 23(2): 149-159.
26. Sánchez-Sánchez H, Morquecho-Contreras A. 2017. Chemical plant defense against herbivores. (Eds) Vonnie D. C. Shields. Herbivores. Publisher Intech Open. doi10.5772/67346.
27. Yactayo-Chang JP, Tang HV, Mendoza J, Christensen SA. 2020. Plant defense chemicals against insect pests. *Agronomy* 10: 1156.
28. Luschak VI, Matviishyn TM, Husak VV, Storey JM, Storey KB. 2018. Pesticide toxicity: A mechanistic approach. *EXCLI Journal* 17: 1101-1136.