Biological control in cut flowers

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Abstract

While globalization has spread economic, political and social relations among countries, international competition has increased. This competition has also increased the use of pesticides in order to enhance productivity and quality, and now it poses a threat to the environment and human health. While the yield and quality of cut flowers are the most important features for the producer, visual quality is the foreground of consumer satisfaction. Both yield and visual quality are exposed to the threats by many harmful pests (red spider mites, thrips, white fly, mealybug, leaf beetle, fly leaf gallery, etc.) and as a result, economic losses are experienced. In cut flowers, the problems of development of tolerance or resistance to chemical pesticides have led to the extinsive efforts to reduce the use of insecticides against pests and to develop alternative control methods. In this regard, biological control is the leading alternative. The most common natural enemies of cut flower pests such as parasite, parasitoid and predator are insects, mites, bacteria, fungi and nematodes. Cut flowers are produced in many countries such as Kenya, Ecuador, Ethiopia, Italy, Spain and Israel, but the Netherlands and Colombia are considered the world leaders in cut flower production. In the production of many cut flower species, especially cut roses and chrysanthemums, biological control method against pests is applied in some of these countries and it is expected that this method will become more widespread in the future. This article generally focuses on the insects and mites used in biological control of cut flower pests and includes the principles of biological control, its advantages as well as other important issues related to it.

Keywords: cut flower, biological control, pests, useful insects

INTRODUCTION

Yield losses occurring in agricultural production around the world can be attributed to diseases (9.1%), insect pests (11.2%) and weeds (14.7%). This amount is equal to one third of the world agricultural production potential. In general, the total agricultural yield loss could reach 40-48% when 6-12% postharvest loss is included. Various methods are applied for the control of diseases, pests and weeds. The present situation in which agriculture production mainly relies on the use of chemicals is not sustainable, and alternative methods should be developed and used. The pesticide itself or its transformation products contaminate the food products, soil, water and air. The negative effects of chemicals are observed on the non-target organisms and on animals and humans as well. While some of the pesticides used have reduced toxicological effects, others were found to be cancerogenic and have negative effects on nervous system. In this context, the inspection of the agricultural products for pesticide residues in relation to animal and human safety, necessitates the costly certification of the products (Kazaz, 2016). The tendency is to move to eco-friendly agriculture systems is increasing and there is mounting pressure to use alternatives for chemicals that are safe and do not disturb the natural balance. Biological control is an environmentally sound and effective means of reducing or mitigating pests through the use of natural enemies. The natural enemies effective in biological control are grouped under three main groups:

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predators, parasitoids and pathogens. Predators are useful/beneficial animals which become effective by directly feeding on the pests. Parasitoids are mostly beneficials which are effective by laying their eggs into another insect's developmental stage, called mature or pre-mature stage, such as larva and pupa. Pathogens are fungi, bacteria, nematodes or viruses that cause disease in the pests. Today, biological control strategies are applied against several types of pests (red spider mite, thrips, mealybug, white fly, etc.) in the production of many cut flower, primarily cut roses and chrysanthemum, in Kenya, Ecuador, Ethiopia, Italy, Spain, Israel, the Netherlands and Colombia. It is expected that this method will become more widespread in the future. Among the natural enemies, parasitoids and predators, the most commonly used ones are beneficial insects and pathogens such as mites, bacteria, fungi and nematodes. These practices will be applied in roses against white fly, mealybug, red spider mite, thrips, green worm, aphid, and in dianthus against cotton flea-hopper and leaf miner in bulbous cut flowers. The control of pests such as bulb flies will also be undertaken by the use of beneficial insects. In this article, information is given about the principles, advantages, and important issues related to biological control in cut flower production together with currently used and suggested biological control agents against cut flower pests.

BIOLOGICAL CONTROL AGAINST DISEASES AND PESTS

Aphids (*Aphididae*)

Aphids rank among the most serious pests of greenhouse crops. The bodies of aphids are oval and soft, and they are 1.5-3.0 mm tall. The impact of most aphids on plants is minimal and they do not spread any rose disease. Aphids are offensive mostly because they decrease aesthetic value, often cluster in large colonies of feeding on young flower buds and tender unfolding leaves. Larger colonies of feeding aphids can weaken flower bud necks (pedicles) and distort leaf growth (Hoffer et al., 2000).

1. Biological control.

Although aphids have many natural enemies, especially *Coccinellidae*, *Chrysopidae* and *Cecidiomyiidae*, the application of fungi as biocontrol agents against aphids is considered as the most important biologically based control method. Some viruses have also been developed for use against aphids. Fungi constitute the most suitable natural enemy group to be used in biological control as their effect is relatively high under field and laboratory conditions. This is since they are specialised for particular host plant pest, and they are harmless for other beneficial insects and non-target organisms. *Verticillium lecanii* is the most commonly used one among the commercially available entomopathogen fungi and it has been widely used. In addition to this, fungi such as *Beauveria bassiana* and *Lecanicillium lecanii* are also used. However, the factor that limits the use of these biological preparations is the fact that they need high humidity for extended periods of time to establish and growth in numbers that is essential in maintaining their efficiency. Polyphagous predators have an important role in biological control of aphids, especially in Mediterranean countries. The most-known example of these are insects belonging to the *Miridae* family and *Macrolophus caliginosus* species. The latter is a predator that attacks white fly and controls aphids. Coccinellids constitute the predator group that has been most studied as the natural enemies of aphids. *Aphidolates aphidimyza* from cecidomyids is the most commonly known predator. *Adalia bipunctata* and *Aphidius colemani* are other commercially used species. The parasitoids of aphids belong to *Aphidiidae* and *Aphelinidae* families of the *Hymenoptera* group.

Leaf miner (*Liriomyza trifolii*)

Liriomyza trifolii is a serious problem on cut chrysanthemum and gerbera. The mature leaf miners are 1.3-2.3 mm in length and coloured grey-black. Under greenhouse conditions, the mature insect can be seen during the whole year depending on the temperature. This pest is usually seen during the whole season on weeds and also on vegetables in summer. The female open small cuts on the leaves and feed on juice sap via this cut. The larvae feed with fleshy tissue between the two webs of the leaf (epidermis). Then, the damaged parts turn yellow and get dry and the leaves fall. It detains the development of young plants and seedlings (Hore et al., 2017).

1. Biological control.

The parasitoids of leaf miners found on greenhouse products are *Diglyphus isaea*, *Chrysonotomyia chlorogaster*, *C. formosa*, *Hemiptarsenus zilahisebessi* and *H. varicornis*. The parasitoids of this pest can be active for the whole year on different *Liriomyza* spp. species in the in Mediterranean basin. The most important of these parasitoids is *Diglyphus isae* and the mass production and release method for this biocontrol agent has been developed. *D. isae* is an efficient parasitoid of *L. trifolii*, *L. bryoniae* and *L. huidobrensis* larvae from *Liriomyza* species. For the release of the parasitoid, the density of leaf miner on the plants in the greenhouse is determined by choosing 30 plants from one acre, plucking one bottom and one middle leaf, counting the larvae on the leaf and finding the number of larva per leaf (Table 1).

Two-spotted spider mite (*Tetranychus urticae*)

Populations of the two-spotted spider mite, *Tetranychus urticae*, can increase rapidly in glasshouse production of rose, carnation, especially during summer (Blindeman and Van Labeke, 2003). Red spider mites make the plant yellow as a result of sucking the juice sap that eventually leads to stopping the growth of the plant. Red spider mites usually stay on plant organs like leaf and flower, and they multiply very fast in hot weather (Atalay and Kumral, 2013).

1. Biological control.

Although red spider mites have many natural enemies from different kinds and families in the world, only predator mites are used commercially in biological control programme of this pest. *Phytoseilus persimilis* is the commercially natural predator of red spider mites in biological control programme, and its native in the Mediterranean Region. Predator mite is bigger in size than its hunt and it is capable of moving faster. It is specialised to its hunt and it prefers to feed with its hunt's egg and nymph stages. *Phytoseilus persimilis* reaches from egg stage to maturity in a shorter time than its hunt under the same temperature, and its power of natural reproduction is higher. In spite of these features, the most important factor in the success of the predator on its hunt is the hunt/predator rate at the beginning of the release. The hunt/predator rate suggested in the biological control of this pest changes according to the type of product, climate conditions (Table 1).

Flower thrips (*Thrips* spp.)

Thrips are pests which are as small as a pinpoint. Their body size is 1-1.3 mm in length. They cause severe damage on leaves, especially on the leaves of colourful flowers (petals) and flowers. The colour of the flower whitens and it does not bloom. While feeding, the pest also indirectly causes bacteria and fungal growth on its secretions that leads to the infection of virus diseases.

1. Biological control.

Orius spp. has an especially important place in biological control of thrips. For instance; *O. aldipennis, O. laevigatus, O. majusculus,* and *O. niger* are widely used in the biological control of *F. occidentalis*. It is stated that among the *Orius* spp. kinds, *O. laevigatus* is the one which adapts to the greenhouse conditions in our country and in the European countries. There is no obligatory diapause in this kind, and only a slight numbness is observed in low temperatures, and it becomes active again and continues to feed and reproduce in suitable temperature. Predator mites are also used for the biological control of the thrips in greenhouses. The native species *Neoseiulus* (*Amblyseius*) *cucumeris* is known as the biological control agent used most in controlling of *F. occidentalis*. *Thrips tabaci* is seen in the greenhouses, do not cause important threat compared to the damage caused by *F. occidentalis*. In general, the natural enemies controlling *F. occidentalis* control *T. tabaci* as well.

Table 1. Usage dosages of some biological control agents and storage conditions (Anonymous, 2018a, b).

	Curative	Rate (m^2)	m^2 $unit^{-1}$	Interval (day)	Frequency	Storage		
						Period (day)	Temperature (°C)	Ambience
Adalia bipunctata	Preventive	-	-	-	-	1-2	8-10	In the dark
	Curative light	10	10	-	1x			
	Curative high	20	2	-	1x			
Chrysoperla carnea	Preventive	-	-	-	-	1-2	8-10	In the dark
	Curative light	10	100	-	1x			
	Curative high	50	20	-	1x			
Aphelinus abdominalis	Preventive	0.25	200	7	-	1-2	8-10	In the dark
	Curative light	2	125	7	-			
	Curative high	4	60	7	-			
Aphidius colemani	Preventive	0.25	4000	7	-	1-2	8-10	In the dark
	Curative light	1	1000	7	3x			
	Curative high	2	500	7	6x			
Phytoseiulus persimilis	Preventive	2	1000	21	-	1-2	8-10	In the dark
	Curative light	6	300	7	1-2x			
	Curative high	20-50	40-100	7	2x			
Amblyseius (Neoseiulu) californicus	Preventive	25	1000	21	-	1-2	8-10	In the dark
	Curative light	100	250	-	1x			
	Curative high	200	125	-	1x			
Macrolophus caliginosus	Preventive	-	-	-	-	1-2	8-10	In the dark
	Curative light	10	50	14	2x			
	Curative high	50	10	14	2x			
Encarsia formosa	Preventive	1.5-3	1000-2000	7-14		1-2	8-10	In the dark
	Curative light	3-6	500-1000	7	3x			
	Curative high	9	330	7	3x			
Orius laevigatus	Preventive	0.5	1000	14		1-2	8-10	In the dark
	Curative light	1	500	14	3x			
	Curative high	10	50	-	3x			
Cryptolaemus montrouzieri	Preventive	-	1000	-		1-2	8-10	In the dark
	Curative light	2	13	14	2x			
	Curative high	10	2,5	-	1x			

Table 1. Continued.

	Curative	Rate (m^2)	m^2 $unit^{-1}$	Interval (day)	Frequency	Storage		
						Period (day)	Temperature (°C)	Ambience
Leptomastix dactylopii	Preventive	-	1000	-		1-2	8-10	In the dark
	Curative light	1	100	14	2x			
	Curative high	2	50	14	2x			
Trichoderma harzianum	Preventive	-	1000	-		-	8-10	In the dark and cool
	Curative light	3	50	7	2x			
	Curative high	30	125	7	2x			
Verticillium lecanii	Preventive	-	-	-		-	2-6	-
	Curative light	0.1	2000	7	2-3x			
	Curative high	0.1	2000	7	3-4x			
Amblydromalus limonicus	Preventive	50	250	-		1-2	12-14	In the dark
	Curative light	100	125	7	2-3x			
	Curative high	250	50	7	3-4x			
Amblyseius swirskii	Preventive	-	2.5	28-42		1-2	10-15	In the dark
	Curative light	-	2.5	28	2-3x			
	Curative high	-	-	-	3-4x			
Neoseiulus cucumeris	Preventive	500/1000	14	-	-	1-2	10-15	In the dark
	Curative light	250/500	14	-	-			
	Curative high	250/500	7	-	-			

Cotton flea-hopper (*Spodoptera litoralis* Boisd)

It is a butterfly the front wings of which are grey-brown with light yellow stripes in various shapes. It is a 2-mm wide dull grey stripe on the front wings, which is parallel to side margins, but extends through the edge and gets narrower from the front to the back. They feed by eating the under epidermis and parenchyma tissue of the leaves and the leaves are left as tegument. In the following stages, they feed by entering into the flowers and buds, and they decrease the market value of the flower (Cakıcı et al., 2014).

1. Biological control

Flea-hoppers have many effective natural enemies. The total rate of parasitization in the larvae of flea-hoppers can reach to 60%, especially in the ends of seasons when disinfection comes to an end. *Microplitis rufiventris* Kok. is the parasitoid of flea-hopper. As to *Nabis pseudoferus* and *Chrysoperla carnea*, they are used for biological control of flea-hopper.

Onion flies (*Eumerus* spp. and *Merodon* spp.)

The mature ones are 6-8 mm in length, having steel blue and bronze gleams. The fly can lay eggs in healthy bulbs, as well as in damaged onions. Brown cracks and scars are seen on the neck of the plant. The mature larva passes to soil from the rotten onion and becomes pupa in a place near to surface. The imagoes of the first germ appear for three weeks in the months of April and May. Small fly gives three offspring in a year. The hatchings enter into the onion from the basis and begin feeding. There can be 20-50 larvae in an onion. Especially small daffodil fly larvae cause quite important damages by carrying *D. dipsaci* into the onion (Alford, 2012).

1. Biological control.

Bacillus thrungiensis, a carnivore bacteria, *Phytoseillus persimilis* and *Deraeocoris* spp. from the beneficial insects are used in biological control of the onion flies.

Grey worms, earthworms, cutworm (*Agrotis* sp.)

The mature ones and larvae are active at night. During the day, the larvae hide under the soil and the imagoes hide in secret places. The earthworm larvae get out towards evening and they feed with root collars of the onions, leaves and twinges. They give 4-5 offspring in a year. They overwinter as larva at different periods. This kind is known as a pest for the cut lilies and gladiolas in Taiwan (Anonymous, 2012).

1. Biological control.

The most important agents used in biological control of grey worms are entomopathogen nematodes, *Bacillus thuringiensis* from bacteria and *Syrphid* spp. belonging to the predator fly group that can feed with grey worms and earthworms.

Mealybugs (*Hemiptera: Pseudococcidae*)

The body is slightly oval in mature females, they are 3-5 mm tall, and their colour can be cream, straw yellow, light pink or greenish. They seem white because of a white waxy dust layer covering the body, and so they are named as mealybug. The larvae hatching out of the eggs are light coloured and they look like an imago in terms of shape. The spread and infection of mealybugs happen mostly during this period. They pass the winter in the hidden places of the plants and at different periods (Williams, 2004). As a result of their feeding with pedicles, the flowers cannot develop and they fall. The sweet substances they secrete form fumigant. They are considered the carriers of important virus diseases.

1. Biological control.

Cryptolaemus motrouzieri Muls. (*Col.*: *Coccinellidae*) predator insect and *Leptomastix doctiilopii* (*Hym.*: *Encyrtidae*) parasitoid are the most important natural enemies. Release of predator *C. montrouzieri* and parasitoid *L. doctylopii* to an area, where predator and parasitoid have not been released before and intense mealybug is seen, decreases the population of mealy bugs by applying summer white oil, and one week after the application, the release of parasitoid and predator.

Nematodes damaging cut flowers

Nematodes stick in via their prick and damage the plant by absorbing the juice sap. They lead to excrescence and fringe on the root as well as the formation of stubby root. The plant cannot get nutrient or water. The plants that are severely contaminated by the disease die (Anonymous, 2017).

1. Biological control.

Methods such as inner and outer quarantine precautions, plant alternation and hot water application together with entomopathogenic fungi, and entomopathogenic nematodes are the groups used in its biological control.

Powdery mildew (*Sphaerotheca pannosa* var. *rosae*)

It is seen on the leaves, twinges and buds of the rose. The diseased leaves bend and harden. They slightly redden and become covered with a mould coating similar to white dust. The mould coating is seen on sepals and stalks, too. Powdery mildew sometimes causes the buds to shrink and not to bloom (Pasini et al., 1997).

1. Biological control.

Within the scope of struggle against powdery mildew, biological control includes *Bacillus megaterium* TV-20E isolate, *Bacillus pumilus* TV-67C isolate, RK-43 isolate; *Bacillus subtilis* TV-85F isolate, TV-6F isolate, RK-6 isolate, TV-17C isolate, RK-341 isolate; *Brevibacillus brevis* RK-342 isolate; *Bacillus thuringiensis* TV-72F isolate; *Pantoea agglomerans* RK-79 isolate; *Pseudomonas marginalis* RK-304 isolate; *Pseudomonas fluorescens* RK-255 isolate can be used (Demir and Kotan, 2016).

Grey mould (*Botrytis cinerea*)

One of the primary diseases of cut flowers, grey mould can do harm in the greenhouse and during the short storage period before being put on market. The disease is seen primarily in rose, carnation, chrysanthemum, hydrangea and peony. At the beginning, stains occur on the flowers as if they got wet in the water and then the petals turn into brown because of the disease infection. Besides, the disease causes burnt flower and under high humidity conditions, the surface of the flowers are covered with intense grey mycellia and spore mass. The disease is caused by a wound-dependent pathogen that infects the plant through injuries or mechanical damage on the tissues. In the time when the flowers are harvested, the latent infections on the flower can continue during short-term refrigerated storage and marketing process.

1. Biological control.

Beneficial biological control elements such as *Trichoderma harzianum* and *Bacillus subtilis* QST 713, QST 716 or QST 708 isolates, *Pseudomonas syringae* ESC 10, ESC 110 isolates, *Streptomyces lydicus* WYEC 108 isolate, *Streptomyces griseoviridis* K61 isolate, *Candida oleophila* I-182 isolate and *Pichia quilliermondii* can be used against grey mould (*Botrytis cinerea*) on cut flowers (Özaktan et al., 2010).

Downey mildew (*Peronospora sparsa*)

It has a widespread impact in the greenhouses which are not ventilated in autumn and spring when night temperature is low. The disease is seen especially on the leaves and branches of young plants, on the pedicle, bud and sepals. Shapeless stains, which are coloured differently from magenta to black, are observed on the leaves. The leaves become yellow and drastic defoliation is seen in the end. The underside surfaces of the leaves are full of with spores in humid environments. As opposed to this, the upper surface of the leaf is full of with spores in powdery mildew (Hoffer et al., 2000).

1. Biological control.

Bacillus subtilis QST 713, QST 716 or QST 708 isolates can be used against rose mildew (*Peronospora sparsa*) disease (Özaktan et al., 2010).

***Fusarium* spp.**

It is one of the most common diseases seen on cut flowers, primarily dianthus, and rose and gerbera. The most important pathogen that causes root and crown diseases is *Fusarium oxysporum* f. sp. *dianthi* (Prill and Delacr.). Apart from dianthus, *Fusarium oxysporum* Schlecht. leads to significant yield loss in cyclamen, chrysanthemum, bulbous ornamental flowers and other ornamental flowers (Campbell, 1985). Other pathogens that cause root and crown disease on dianthus are *F. culmorum* (W.G.Sm), *F. roseum* and *Rhizoctonia solani* Kühn. After the studies carried out in our country and abroad, it has been found out that *F. solani, F. avenaceum* (Fr.) Sacc. *F. oxysporum* Schlecht. are the most important pathogens for lisianthus and gerbera (Altan and Altan, 1997).

1. Biological control.

Compared to other diseases, the control of soil borne diseases is quite difficult. Therefore, more effective control can be obtained by using combination of physical and biological methods in the control of root and crown diseases in dianthus and chrysanthemum. Fumigation and solarisation methods are applied within the scope of physical control approaches. Among biological methods, the use of antagonistic microorganisms against *Fusarium* was also suggested (Gullino et al., 2002). In addition to *Trichoderma harzianum* Rifai KRL-AG2 isolate, *Streptomyces griseoviridis* K61 isolate, *Streptomyces lydicus* WYEC 108 isolate, *Pseudomonas fluorescens* A506 isolate can be applied against *Fusarium* in cut flowers (Özaktan et al., 2010).

Alternaria (*Alternaria dianthi*)

Alternaria leaf spot disease appears on cut flowers such as rose, gerbera, and primarily dianthus, especially during the early season. The disease can be controlled as far as there are no extreme conditions in the following periods. This disease creates stains, encircled with purple borders, on the leaf. Olive-coloured micelle and spore masses of the element form on these stains under humid conditions. At the same time, stains may occur on the stem over the nodes and as the disease progresses, collar rots are observed around the nodes.

1. Biological control.

Beneficial elements like *Bacillus subtilis* MBI 600 isolate, GBO3 isolate, *Streptomyces griseoviridis* K61 isolate can be used within the scope of biological control against *Alternaria dianthi*, which is a leaf spot disease (Özaktan et al., 2010) (Table 1).

CONCLUSIONS

It is estimated that the total yield loss reaches to 40-48% together with diseases, pests, weeds, and postharvest loss. The fact that international competition has brought the use of pesticides for yield and quality increase to important dimensions has made it something that threatens environmental and human health today. At the present time, both the buying behaviours of the consumers have changed, and the importance of sustainability of quality, product range, certification and production has increased. The mentioned reasons have canalized many countries to biological control in many kinds in cut flower sector, primarily cut rose, chrysanthemum, gerbera, lisianthus, orchid, lilium and anthurium. This system, which is environmentally friendly, is expected to become more widespread as an alternative for chemical control in the future.

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