The Pharma Innovation Journal 2022; SP-11(9): 2999-3009

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; SP-11(9): 2999-3009

www.thepharmajournal.com
Received: 15-06-2022
Accepted: 19-07-2022

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Residue free farming of fruit crops

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Abstract
Pesticides are one of the major inputs for increasing the agricultural productivity. But the imbalance and improper usage of pesticide has created residual effects and deleteriously impacted the health of humans as well as environment. Pesticide residues in food products is a major bottleneck in the international trade and has lead to huge rejection of consignments from the importing countries. There are different strategies by which the pesticide residue can be reduced such as integrated pest management (IPM), integrated pest management (INM), genetic methods and precision farming. Authoritative agencies are required to monitor and provide accreditation to authentic laboratories which strictly maintains the testing protocols and quality as per the standards of importing countries.

Keywords: Pesticide residues, IPM, INM, genetic methods and precision farming

Introduction
Pesticide residue is a substance or mixture of substances in food, feed, soil, water and air instigating from the use of pesticides and includes the specified degradation and conversion products, metabolites, reaction products and impurities (Dhaliwal, 2006) [26]. Pesticide residue in food not any leads to huge economic losses but also affects the human health. In 2020, products such as mangoes, table grapes etc faced rejections and bans in the international markets such as the US, Vietnam, EU, Saudi Arabia, Japan and Bhutan. European Union rejected approximately 40,000 tonnes of grapes from India due to the higher levels of Chlormequat chloride (CCC) in grapes, as per the standard minimum residue limit (MRL) of CCC set by EU was 0.5 ppm. EU countries issued huge border rejection notifications for almost 147 consignments of food items from India in the year 2019, while the US rejected a total of 1,674 consignments, according to data from the European Commission’s Rapid Alert System for Food and Feed (RASFF) and USFDA.
Products such as mangoes, table grapes, okra, peanuts, curry leaves, chillies, shrimps, prawns, and tamarind have faced rejections and even bans in markets of US, Vietnam, EU, Saudi Arabia, Japan and Bhutan due to concerns such as presence of higher than approved levels of chemical residues, and pest and bacterial infestation. In the short run, such rejections and bans can led to financial losses while in the long run, exporters and farmers can lose market share to exporters from other countries that are able to meet the food safety and health standards of importing countries.
Pesticides such as organ chlorines are banned in many countries but are still used in countries such as California that effects the central nervous system and cause tremors, hyper excitability and seizures. Organophosphates and Carbamates attacks the brain and nervous system and interferes with nerve signal transmission. Pesticides also effect the bees in fruit crops. Some of the high risk insecticide and miticide risk to bees based on EPA toxicity classifications has been listed in Table 1.
The MRL is the maximum level of residues found in crops following the application of a pesticide in accordance with the good agricultural practices and therefore the maximum concentration of pesticide residue that is legally permitted or recognized as acceptable on food, agricultural commodity, or animal feed. Good agricultural practices often leads to a residue concentration below the MRL and is often reflected by three factors time of application or time before harvest, compliance with the dose as indicated by the manufacturer and compliance with the number of application per season.

Reasons for pesticide residue in food products
1. Indiscriminate usage of chemical pesticides.
2. Lack of observance of prescribed waiting period

3. Usage of sub-standard or low grade pesticides
4. Wrong recommendation and supply of pesticides to the farmers by the pesticide dealers
5. Continuation of harmful pesticides such as Dichlorodiphenyltrichloroethane (DDT) etc in Public Health Programmes
6. Effluents from the pesticides manufacturing units
7. Improper disposal of left over pesticides and cleaning of plant protection equipments
8. Pre-marketing pesticides

Review of Literature

Components of residue free farming

Integrated Pest Management (IPM)

Pest Surveillance, Monitoring, and Forecasting: Pest surveillance refers to a constant watch on the population dynamics of insect pests, its incidence and the damage on crop at fixed intervals and alerts the farmers to take up timely plant protection measures. While forecasting pest outbreak is based on the information obtained from the pest surveillance. Pest Surveillance, Monitoring, and Forecasting minimizes the cost of plant protection by reducing the amount of pesticides applied as well as reduces the environmental pollution.

Cultural and mechanical control methods: A complete exclusion system is an effective protection device for controlling key pests of fruits. An experiment conducted by Chouinard *et al.* (2017) [4] on 'Honeycrisp' apple used netting row covers in apple orchard before blossom period for the arthropod and observed that the exclusion system proved to be an effective protection device for various pests of apple fruit such as the *Rhagoletis pomonella*, and *Lygus lineolaris*. Also the nets prevented diseases such as apple scab (*Venturia inaequalis*) and sooty blotch and flyspecks (table 2).

The rainy season guava is severely infested by fruit fly and therefore fetches lower economic returns. Also the farmers use aggressive chemical measures, rendering serious health hazard to the consumers. Brar *et al*. (2019) [2] used different bagging materials for guavas *viz*. non-woven bags of green, white, red and blue colour, leno bags, butter paper bags, perforated polythene bags and newspaper bags. The immature green guava fruits were covered with these materials at the marble stage of fruit development. The results suggested that the fruits covered with non-woven bags eliminated the fruit fly infestation and almost 98-99% fruits were healthy, and marketable while non-bagged fruits exhibited 100% fruit damage (table 3).

Singh (2020) [17] reported that termites were trapped in earthen pot traps in different orchards during May and October (table 4).

Thakur *et al.* (2012) [19] studied the effect of mulches and herbicides on the weed population, fruit yield, and quality in Earli Grande' peaches. The soil covered with black polythene mulch of 100mm controlled 100% weeds at 6 weeks after treatment (WAT) as compared to 12 WAT. While straw mulches of 8 cm controlled around 98.4 & 98.2% and 90.7 & 93.1%, weeds at 6 & 12 WAT during two years study (table 5). Conclusively, plastic and straw mulches can be used as an effective chemical-free alternative to manual or chemical methods of weed control.

Genetic methods: Genetic methods Resources for Biotic Stress are listed in table 6

Marchive *et al*. (2013) [12] reported that over-Expression of VvWRKY1 gene in grapevines induced the expression of Jasmonic acid pathway related genes and conferred higher tolerance to the downy mildew. The resistance was mainly due to transcriptional reprogramming, rapid accumulation of LOX transcripts that activated the jasmonic acid signalling pathway and increased the Jasmonates levels.

Transgenic 'Hamlin' and 'Valencia' sweet oranges expressing an NPR1 gene under the control of a constitutive CaMV 35S promoter were produced. The overexpression of AtNPR1 enhanced the resistance to Huanglongbing (HLB, Citrus Greening).Transgenic plants exhibited reduced diseased severity and some lines remained disease-free even after a period of 36 months of planting in a high disease pressure field sites. The resistance was due the NPR1 gene that regulated the transcription factors which controlled the expression of PR gene and mediated the salicylic acid induced expression of PR genes and systemic acquired resistance (SAR).

Biocontrol measures: Bicontrol measures are very successful, cost-effective, and environmentally safest method of pest management (Babita *et al*., 2015) [1] (table 7).

Maneesh *et al*. (2018) [11] studied the predatory potential of *Cryptolaemus montrouzieri* on different stages of papaya mealybugs (table 8). The mean predatory potential of I, II, III and IV instar grub on Ovisac, I, II and III instar nymphs of mealybug was 1.40±0.12, 30.60±0.51, 20.53±0.98 and 13.46±1.15; 1.68±0.13, 43.52±0.41, 30.40±0.68 and 17.33±0.88; 1.90±0.14, 47.04±0.84, 31.56±0.51 and 20.45±0.84 and 1.91±0.15, 54.10±0.45, 38.20±0.58 and 26.32±1.13. Average consumption capacity of male and female on ovisac, I, II and III instar nymphs was 2.98±0.09, 57.81±0.24, 41.39±0.12 and 28.51±0.02 and 3.05±0.10, 58.19±0.26, 43.00±0.19 and 29.28±0.08, respectively.

A National Consultation on the classical biological control of the papaya mealybug *Paracoccus marginatus* organized by National Bureau of Agriculturally Important Insects (NBAII) The papaya mealybug is causing severe problems in many states. Chemical control methods are often ineffective and also increases the production cost and creates environmental hazards. The NBAII imported three species of exotic parasitoids namely *Acerophagus papayae*, *Anagyrus loecki* and *Pseudleptomastix mexicana* that are specific to papaya mealybug with the help of USDA-APHIS. These parasitoids have subsequently decreased the papaya mealybug in a sustainable and eco-friendly manner on a long term basis.

Growing consumer demands for safe and residue free food products have stimulated research on innovative approaches and tools in pest management. Botanical insecticides are considered as an alternative tool in comparison to synthetic chemicals (table 9). Vassiliou (2011) [21] studied the efficacy of the botanical insecticides *viz* azadirachtin (Neemex 0.3% W/W and Oikos 10 EC), garlic extract (Alsa), and pyrethrins (Vioryl 5% SC) and evaluated against Kelly's citrus thrips larval stage I and II in grapefruits (table 10). Pyrethrins and azadirachtin were found most effective against the citrus thrips compared with the untreated control. Damaged fruits in pyrethrins and Neemex treated fruit 19.2% and 19.5%, respectively in comparison to control (24.3%). Garlic extract showed least effect among all the botanicals used compared. While conventional method for controlling Kelly's citrus thrips relies mainly on the organophosphates or neonicotinoids insecticides and its extensive usage develops insect resistance, outbreaks of secondary pests, disrupts the IPM disruption and impacts environment negatively.

One of the main obstacles in securing the productivity in guava fruit is the fruit fly (*Bactrocera spp*.) infestation which can lead to 50% to 100% yield losses. Farmers mainly use synthetic insecticide to deter the attack of fruit flies, but such control measures are expensive and leads to insecticide residues in fruits and environments adversely affecting human health and the environment. Kardinan (2014) [10] followed an environment friendly technique (table 11) by using botanical insecticides such as basil plant (*Ocimum* spp) and Tea tree (*Melaleuca bracteata*) that effectively controlled the fruit flies in guava orchard attack and consequently increased the income of farmers.

Table 1: Some of the high risk insecticide and miticide risk to bees based on EPA toxicity classifications

Active ingredient	LD $_{50}$ (µg/bee)
Avermectin	0.002
Bifenthrin	0.0146
Carbaryl	1.1
Chlorpyriphos	0.01
Imidacloprid	0.0039
Indoxacarb	0.12
Malathion	0.2
Pyrethrum	0.022
Thiamethoxam	0.0005
Zata-cypermethrin	0.181

Table 2: Effect of netting row covers in apple orchard for the arthropod

		Net	Control
Undamaged apples	-	76.25	69.98
Damaged due to insects	*Rhagoletis pomonella*	0.42	4.47
	Lygus lineolaris	0.42	3.08
	Conotrachelus nenuphar	0	1.57
	Surface feeding lepidopterans	17.12	10.96
	Other hemipterans	0.69	2.07
Damaged due to diseases	Sooty blotch and flyspeck	0.28	1.38
	Russeting	0.83	3.32
	Bitter pit	0.14	0.70

Table 3: Effect of different bagging materials for guavas

Treatment	Fruit fly Infestation (%)	Total damaged fruits (%)
Green NWB	0	2
White NWB	0	2
Red NWB	0	2
Blue NWB	0	1
Leno bags	68	74
Butter paper bags	46	53
Perforated polythene bags	29	34

Table 4: Population of termites trapped in earthen pot traps in different orchards during May and October

Treatment	Pear	Ber	Peach	Grape	Amla
During May	9500	1950	1560	1850	1280
During October	11700	22300	18400	21800	14200

Table 5: Effect of mulches and herbicides on the weed population

	Treatment	Weed control efficiency (%) 6 WAT 12 WAT				Fruit yield (kg tree 21)	
		2009	2010	2009	2010	2009	2010
T 1	Pendimethalin + glyphosate	92.7^{c}	89.2^{e}	96.0^{b}	97.9^{a}	62.2^{bc}	59.1^{bc}
T2	Pendimethalin+paraquat	93.6^{c}	89.5^{de}	95.4^{b}	94.7^{a}	61.0 b^{bc}	58.7^{bc}
T3	Atrazine + glyphosate	94.1^{bc}	89.7^{de}	97.6^{a}	100.0^{a}	62.3^{bc}	59.4^{abc}
T4	Atrazine + paraquat	93.4^{c}	90.8^{cd}	95.0^{b}	97.3^{a}	62.9^{bc}	59.^{abc}
T5	Black polythene	100.0^{a}	100.0^{a}	96.3^{b}	98.6^{a}	67.4^{ab}	62.4^{abc}
T6	White polythene	95.6^{b}	92.00^{c}	83.8^{e}	78.4^{a}	64.5^{ab}	62.0^{abc}
T7	Rice straw (6 cm)	96.1^{b}	91.1^{c}	65.2^{g}	77.6^{a}	66.1^{ab}	65.6^{ab}
T8	Rice straw (8 cm)	98.4^{a}	98.2^{b}	90.7^{d}	93.1^{a}	69.3^{a}	67.9^{a}
T9	Diuron + glyphosate	98.8^{a}	99.0^{ab}	98.4^{a}	100.0^{a}	63.8^{bc}	60.6^{bc}
T10	Diuron + paraquat	98.5^{a}	98.9^{ab}	91.8^{c}	96.5^{a}	62.2^{bc}	60.6^{bc}
T11	Weedy control	0.0^{e}	0.0^{g}	0.0^{h}	0.0^{b}	55.8^{c}	53.7^{c}
T12	Manual weeding	84.4^{d}	83.8^{f}	80.2^{f}	83.3^{a}	59.2^{bc}	54.0^{c}

Table 6: Genetic resources for biotic stress in different fruits

Fruit	Causal organism	Genetic resources
Mango	Hoppers, tip borers and seed borers	*Mangifera altissima*
	Malformation	Bhadauran, Rataul
	Powdery mildew	Neelum, Totapuri
	Anthracnose	Parish, *Mangifera laurina*
	Bacterial canker	Bombay, Amrapali
Banana	Burrowing namtode Bunchy top: Poovan	Kadali, Octoman, Thaen Kunnan, Ney Poovan
	Panama wilt	Basrai, Oovan, Champa, Cavendish group, Robusta
	Fusarium wilt	BITA-A, BITA-2
	Leaf spot	H1, H2
Guava	Wilt	*Psidium friedrichsthalianum*, *Psidium chinensis, Feijoa sellowiana.*
Citrus	Rootrot	Rangpur lime
	Nematode	Marmalade Orange
	Tristeza virus	Rangpur Lime
	Xylopsososis	Rough lemon
	Exocortis	Rough lemon
	Gummosis	Trifoliate orange
	Greening	Gajanima
Apple	Scab	Prima, Mac Free, Florina, Liberty, Red Free
	Powdery mildew	*M. robusta*, *M. zumi*, Koster
	Wooly aphid	Northern Spy, Cox's Orange Pippin
	Canker	M-1 and M12
	Collar rot	MM-103, Northern Spy
Pear	Fire blight	*Pyrus pyrifolia*
	Leaf blight and fruit spot	Beurre Del
	Pear psylia	*P. fauriei*
	Wolly pear aphid	*P. pashia*
	Fire blight	*Pyrus pyrifolia*
Peach	Tree borer	Elberta, Goldray, Golden Jubilee.
	Canker	July Elberta, June Elberta
	Mildew	*Prunus ferganensis*.
	Leaf curl	*Amygdalus petummikowii*
	Root knot nematode	Nemaduard, Nemared
	Bacterial leaf spot	Earligrande, Florda king, Harland
	Gummosis	Harbrite, Harken, Harmony, Redskin
Papaya	Root rot	Wiaminalo-23, Line 8 of Solo, Wiaminalo-24, Ranchi
	Viral diseases	*Carica. Cauliflora*, *Carica. monoica*, *Pusa Majesty*, *Carica microcarpa*
	Nematode	Pusa Majesty
Ber	Fruit fly	Katha
	Powder mildew	Chhuhara
	Leaf spot	Safed Rohtak
Grapes	*Phylloxera vitifoliae*	*Vitis rupestis*, harmony, Dog ridge, *Vitis riparia*, St. Geogre
	Aphids	*Vitis cinera*
	Thrips	Karachi, Fakdi
	Nematode	Dog ridge, Salt creek, 1613 (Solonis x *Vitis riparia*)
	Powdery mildew	Bangalore Blue, Bangalore Purple, Concord, Isabella, Muscat Hamburg
	Downy mildew	Bangaore Blue, Catawba, Concord, Champion, James, V. rupestris
	Anthracnose	*Vitis parviflora*, Bangalore Blue, Muscat hamburg, Gulabi, Bangalore Purple, Concord
	Crown Gall	V54-62, v 64-127, Rhine, Riestling
	Cercopora leaf spot	Champion, Champach, Australia No.2
	Pierce's disease	Temple, Lake Emerald, Blue lake

Table 7: List of biocontrol agents for pests and diseases in fruits (Babita *et al*. 2015) [1]

Pest	Biocontrol agents	Attractant/repellent/trap plants
Codling moth	Parasitoids: *Trichogramma embryophagum* (*egg*), *T. cacoeciaepallidum* (*egg*) etc. Predators: Birds (grey tit, *Parus major and Passer domesticus*)	Nectar rich plants with small flowers i.e. anise, caraway, dill, parsley, mustard, sunfl ower, buckwheat (Braconid wasp and other wasps)
San Jose scale	Parasitoids: *Encarsia perniciosi and Aphytis sp* (nymphal and adult) etc. Predators: Coccinellid (*Chilocorus infernalis*, *Pharoscymnus flexibilis*) *etc.*	Sunflower family, carrot family, buckwheat
Woolly apple aphid	Parasitoids: *Aphelinus mali* (*nymphal and adult*) Predators: Coccinellids (*Coccinella septempunctata*, *Menochilus sexmaculatus*), lacewings (*Chrysoperla zastrowi sillemi*), *syrphid* flies (*Syrphus confrator*, *Episyrphus balteatus*) *etc.*	Attractant plants: Carrot family, sunflower family, buckwheat, alfalfa, cosmos (minute pirate bug and lacewing, syrphids, coccinellids)

Indian gypsy moth	Parasitoids: A*nastatuis kashmiriensis* (*egg*), *Telenomus sp* (*egg*), *Cotesia melanoscela* (*larval*), *Glyptapantelos indiensis* (*larval*), *G. fl evicoxis* (larval), tachinid (*Pales sp*) (*larval*), *Brachymeria intermedia* (*pupal*), *B. lasus* (*pupal*) *etc.*	Attractant plants: Carrot family, sunflower family, buckwheat, alfalfa, corn, shrubs (minute pirate bug and lacewing)
Disease (causal agent)	**Biocontrol agents**	**Fruit crops**
Anthracnose	*Trichoderma harzianum*	*Banana, Rambutan*
Gray mold (*Botrytis cinerea*)		Grape, Kiwifruit, pear, strawberry
Green mold (*Penicillium digitatum*)	*Trichoderma viride*	Citrus
Stem-end rot (*Botryodiplodia theobromae*)		Mango
Gray mold (*Botrytis cinerea*)		Strawberry
Brown rot (*Lasiodiplodia theobromae*)	*Bacillus subtilis*	Apricot
Green mold (*Penicillium digitatum*)		Citrus

Table 8: Predatory potential of *Cryptolaemus montrouzieri* on different stages of papaya mealybugs

Different stages of *C. montrouzieri*	Mean consumption of different instars of mealybug per day			
	Ovisac	**1 st instar nymph**	**2 nd instar nymph**	**3 rd instar nymph**
I instar	1.40	30.60	20.53	13.46
II instar	1.68	43.52	30.40	17.33
III instar	1.90	47.04	31.56	20.45
IV instar	1.91	54.10	38.20	26.32
Adult male	2.98`	57.81	41.39	28.51
Adult female	3.05	58.19	43.00	29.28

Table 9: List of botanical insecticides

Source Plant	Mode of action	Target pests
Neem	disrupting the nervous system, Repellence, Repellence, Feeding deterrence, Inhibition of oviposition	Insects
Garlic	inhibit spore germination and production of mycotoxins, Disrupts cellular components	Fungi
Aloe vera	Inhibits cellular activities, Impairs permeability of plasma membrane, Denatures proteins, Inhibits ATP production	Bacteria
Tagetes erecta	Inhibits egg hatching, Larval toxicity, Mortality	Nematodes
Nepeta nuda	Host plant manipulation, Inhibits virus replication and multiplication,	Viruses

Table 10: Effect of botanical insecticides on thrips in grapefruits

	Mean no. damaged fruits				
Year	**Pyrethrins**	**Neemex 0.3% W/W**	**Oikos 10 EC**	**Garlic extract**	**Control**
2008	9.6^{a}	9.7^{a}	10.2^{ab}	11.1^{ab}	12.2^{b}
2009	3.7^{a}	3.9^{a}	5.5^{ab}	6.9^{ab}	8.6^{c}
2010	18.7^{a}	19.6^{a}	21.2^{ab}	27.9^{ab}	29.6^{c}

Table 11: Effect of botanical insecticides on fruit flies in guava

Location	Fruit flies infestation (%)
Garden 1	56
Garden 2	61
Garden 3	60
Control techniques	Average number of fruit flies trapped/trap/2 weeks
Sticky trap	86
Attractant trap	54

Behavioral methods

Semiochemical are the chemicals produced by organisms that modify the behavior of recipient organisms. Pheromones emitted by the members of a species modify the behaviour of other members of same species. Pheromone traps determine the population density and helps in mass trapping and mating disruption of insects. Allomones are emitted by one species in order to modify the behaviour of another species. List of species for mass trapping Witzgall *et al*. (2010) [23] are listed in table 12.

Mango mealy bugs and fruit flies are serious pests of mango fruit and are very difficult to control with insecticides. Muhammad *et al*. (2004) [13] developed an IPM strategy and used sticky bands integrated with burning and burying treatments and observed that the infestation of mango mealy bug was reduced (0.00-15.79%) significantly, while burlap bands reduced the population of nymphs by 78.98%. For fruit fly, methyl eugenol traps were extremely effective in trapping and killing. Stem injection treatments also achieved a high level of mortality (98%) of sucking insects. However, the mortality rates with insecticides were only 55%. Therefore, nonchemical methods were found superior in controlling the mealy bug and fruit fly.

Allelochemicals as herbicides, insecticides and Insect growth regulators (IGRs) are listed in table 13.

Cacopsylla pyricola is an important pest of commercial pear in all pear-growing regions of Iran. In the scope of an integrated pest management, Emami (2016) **[6]** studied the impact of biorational compounds over conventional chemical pesticides for controlling the pear psyllids (Table 14). Diflubenzuron and lufenuron was taken as biorational insecticides and thiacloprid and diazinon as conventional chemical insecticides. The results indicated that the highest mortality rate was registered in diflubenzuron and lufenuron treatments occurred in comparison with conventional chemical insecticides. Thus biorational compounds are efficient methods in the management of the populations of pear psylla.

IPM strategies for the control of Insect/Pest, Fungal diseases and Bacterial diseases have been listed in table 15

Table 12: List of species for mass trapping

Species for mass trapping	Purpose
Red palm weevil *Rhynchophorus ferrugineus*	MT
American palm weevil *Rhynchophorus palmarum*	MT
Banana weevil *Cosmopolites sordidus*	MT
Grapevine moth *Lobesia botrana*	MT
Species for mating disruption	Crop
Codling moth *Cydia pomonella*	Apple, pear
Grapevine moth *Lobesia botrana*	Grape
Oriental fruit moth *Grapholita molesta*	Peach, apple
Species	Lure
Mediterranean fruit fly *Ceratitis capitata*	Trimedlure (MT)
Oriental fruit fly Bactrocera dorsalis	Methyl eugenol (AK)

Table 13: Allelochemicals as herbicides, insecticides and Insect growth regulators

Allelochemicals as herbicides			
Crop	**Allelochemicals**		
Mango	Mangiferin (1,3,6,7-tetra hydroxyl 2-C-Bglucopyranosylxanthone)		
	4-hydroxybenzaldehyde, m-coumaric, p-coumaric, 4-hydroxy benzoic, vanillic, caffeic, gallic and protocatechuic acids		
Walnut	20% methanol, ethyl acetate, hexane 8-octadecenoic acid, 5-hydroxy-1,4-napthaquinone		
Litchi	Epicatechin, Procyanidin, Kaempferol-3-0- galactose and 4-Hydroxybenzaldehyde		
Ber	Zizynummin, Dammarane, Saponin		
Allelochemicals as insecticides			
Combination	**Pests Controlled**	**Crop**	**References**
AZ (0.1%) + monocrotophos (0.02%)	*Toxoptera citricidus*	Citrus	Chaterjee and Mondal (2006) [3]
Nimbecidine (3 ml/l) + Biocatch (5 g/l)	*Aceria guerreronis*	Coconut	Ramarethinam *et al.*, (2000)
Oil of Pongamia pinnata (0.2%) + acephate (1.5 g/l)	Thrips	Flowering plants	IIHR (2008) [9]
Oil of Pongamia pinnata (0.2%) + fenazaquin (0.015%)	Mites	Flowering plants	IIHR (2008) [9]
Nimbecidine (0.5%) + endosulfan (0.07%) + carbosulfan (0.05%)/spinosad® (0.05%)/Halt® (0.3%)	*Acrocercops cramerella*	Litchi	Singh *et al.*, (2009) [18]
Insect growth regulators			
Activity	Examples		
Chitin synthesis inhibitors	Bistfluron, Buprofezin, Chlorfluazorun, Cyromazine, Diflubenzuron		
Juvenile hormone mimic	Epofenonane, Fenoxycarb, Hydroprene, Kinoprene		
Molting hormone agonist	Halofenozide, Methoxyfenozide, Tebufenozide, α-ecdysone		

Table 14: Biorational compounds for management of pear psylla

Mortality percentage pear psyllid of *Cacopsylla pyricola* (Mean ± SE)					
	3 DAT	**7 DAT**	**15 DAT**	**30 DAT**	**45 DAT**
Thiacloprid	$69.65±1.99^a$	$74.66±1.66^a$	$83.55±2.19^a$	$72.23±2.77^a$	$50.74±2.74^a$
Diazinon	$68.04±1.83^a$	$65.47±2.36^b$	$63.77±2.27^b$	$60.42±3.11^b$	$45.31±3.30^a$
Lufenuron (IGR)	$44.84±3.34^c$	$61.22±1.81^b$	$71.01±4.33^b$	$69.12±2.8^{ab}$	$47.79±2.35^a$
Diflubenzuron (IGR)	$58.49±2.54^b$	$66.45±2.01^b$	$82.09±1.86^a$	$73.37±2.87^a$	$49.84±2.71^a$

Table 15: IPM strategies for the control of pest and diseases in various fruit crops.

IPM strategies for the control of Insect/Pest		
Insect	**Crop**	**Control**
Mango Leaf hopper	Mango	Conserve the natural enemies like spiders by avoiding sprays of broad spectrum pesticides during the peak activity period Regulate flushes by reducing the inputs Spray insecticides Cypermethrin or fenvalerate (0.01%)
Mango Mealybugs (*D mangiferae*, *Dstebbingi*, *Rastrococcus iceryoides* and *Bactrocera dorsalis*)	Mango, Litchi	Ploughing orchards during summer to expose eggs to natural enemies and sun heat Apply 25 cm wide alkathene bands on tree trunk to prevent migration of crawlers from soil to trees
Stone weevils (*S mangiferae*, *S. gravis* and *S. frigidus*)	Mango	Sticky bands should be applied at upper end of tree trunk to prevent migration of weevils to branches for egg laying on fruits during February. Spray deltamethrin (0.0025%) six weeks after fruit set
Shoot borer (*Bracon greeni*, *Meteorus sp.* and *Goryphus* sp.)	Mango	Spray of contact insecticide
Fruit borer (*Cryptophlebia lepida*, *Rapala varuna*, *Deudorix*	Litchi	To manage this pest, collect all fallen infested fruits and destroy them. At early stage of fruiting which coincides with egg laying, spray fenthion

isocrates, D. epijarbas)		(0.05%) or monocrotophos (0.04%) or phosalone (0.05%).
Mite	Litchi	To check the mite infestation, prune the affected shoots after fruit harvesting and burn them. In the next season, during emergence of new flush and inflorescence, spray dicofol (0.02%) or dimethoate (0.05%).
Fruit borer (*Cryptophlebia lepida, Rapala varuna, Deudorix isocrates, D. epijarbas*)	Litchi	To manage this pest, collect all fallen infested fruits and destroy them. At early stage of fruiting which coincides with egg laying, spray fenthion (0.05%) or monocrotophos (0.04%) or phosalone (0.05%).

IPM strategies for the control of Fungal diseases			
Disease	**Crop**	**Causal organism**	**Control measures**
Collar Rot	Apple	*Phytophthora cactorum; Syringae, megasperma, Citricola*	Drench the soil with carbendazim. Antagonist fungus: Trichoderma virdaei
Scab	Apple, Pear, Quince	*Venturia inaequalis*	Adequate cultural practices
Wilt	Guava	*F. oxysporum, M. phaseolina* and *F solani*	-
Powdery mildew	Apple, Pear	*Podosphaera leucotricha*	Wettable sulphur
	Citrus	*O. Tingitannium*	Resistant rootstock like poncirus trifoliate and its hybrids
	Grape	*Uncinula necator*	
	Mango	*Oidium magniferae*	Wettable sulphur
Rust	Apple, pear	*Gymnosporangium juniper*	Spray Bordeaux mixture
	Amla	*Ravenelia emblicae*	Spray Bordeaux mixture
Anthracnose	Guava	*Colletrotrichum gloeosporioides*	Bordeaux paste to cut portions Copper oxychloride
	Grape	*Gloeosporium ampelophagum*	Copper oxychloride, Bavistin
Downy Mildew	Grape	*Plasmopora viticola*	Bordeaux mixture spray after pruning, before bud opens, and growth of shoots.
Panama wilt	Banana	*Fusarium oxysporum sp. cubense*	Good drainage. Dip suckes in bavistin before planting
Sigatoka	Banana	*Mycospharella musicola*	Dip suckers in Bordeaux mixture before planting Ensure proper drainage
Foot rot	Citrus	*Phyphthora nicotianae var. parasitica* *P. palmivora* *P. citrophthora*	Paint the affected part with Bordeaux paste .
Leaf curl	Stone fruits	*Taphrina defomans*	Bordeaux mixture or copper oxychloride (0.30%)
IPM strategies for the control of Bacterial diseases			
Disease	**Crop**	**Causal organism**	**Control measures**
Moko wilt	Banana	*Ralstonia solanacearum*	Disinfect the planting holes with chloropicrin
Fire blight	Pome and stone fruits	*Erwinia amylovora*	Avoid heavy pruning. Spray streptomycin during flowering
Gummosis	Stone	*Pseudomonas syringae pv. Syringae*	Spray with copper oxychloride or Bordeaux mixture or Streptomycin in spring.
Crown gall	Pome and stone fruits	*Agrobacterium tumefaciens*	Biocontrol: Agrobacterium radiobacter
Bacterial Spot	Stone	*Xanthomonas arboricola* pv. Pruni.	Spray with copper oxychloride or Bordeaux.

Integrated Nutrient Management (INM)

The continuous use of inorganic fertilizers in imbalanced proportion has caused huge economic inefficiency, damaged the environment, affected soil, plant and human health as well. Land is being intensively exhausted to produce higher yields which in turn has a raised the concern of sustainability of soil productivity. Eco-friendly approach of agricultural practices can maintain the long term ecological balance of soil ecosystem. Thus the new approach should be the judicial use of organic inputs with inorganic ones to meet the nutrient requirement. This will improve the soil structure, reduces soil erosion and pest build up, increase yield by 10 to 15% (Frick and Johnson, 2006) [28], control nematodes, suppress weeds, pests and diseases, Improve water use efficiency (WUE) and fertilizer use efficiency (FUE) Bioenhancers: These are concentrated manures, bio products in powder or in liquid form. These are organic preparations, obtained from the active fermentation of animal & plant residues over specific duration. These are rich source of microbial consortia, macro, micronutrients and plant growth promoting substances including immunity enhancers. They are used in seed treatments, enhances the decomposition of organic materials thereby enriching the soil and induces better plant vigour. Some of the bioenhancers have been enlisted in table 16 Biofertilizers: These preparations contain latent cells of microbes capable of transforming the unavailable form of naturally occurring nutrients in to a available form. It can replace about 20-50% of nitrogenous chemical fertilizer and 15-25% of phosphatic fertilizers. They activates the soil biologically and increases its natural fertility without causing any harm to soil and environment.

Nitrogen based biofertilizers are *Rhizobium*, *Azotobacter*, *Azospirillum*, *Acetacter*, Cynobactoberia. Phosphorus based biofertilizers are *Pseudomonas* spp., *Trichoderma* spp., *Bacillus*, VAM. Potassium based biofertilizers are *Fraturia aurentia*. Zinc mobilize are *Bacillus spp., Rhizobium spp.* Pseudomonas spp. All-purpose sprays adjuvant concentrate (APSA-80) is an adjuvant when admixed with insecticides, herbicides, fungicides or foliar fertilizers increases the potential and efficacy without affecting the environment.

These adjuvants also increases the water penetration that helps in reducing any evaporative losses or run off, and reduces the frequency of irrigation. It also prevents the damaging impact of pests, diseases and weeds.

Nurbhanej *et al*. (2016) [14] studied the effect of INM on growth, yield and quality of acid lime (*Citrus aurantifolia* swingle) cv. Kagzi (table 17). Organic manure (FYM, castor cake & vermicompost) and Anand Agricultural University Plant Growth Promoting *Rhizobacteria* (AAU PGPR) consortium were applied on 15th June and after 1st rain while, chemical fertilizers were applied in two splits on 4th October and 12th March. The chemical fertilizers were applied in the form of urea, single super phosphate and muriate of potash. While, well decomposed FYM, vermicompost and castor cake were applied as per treatment requirement. AAU PGPR Consortium was drenched 1 m away from main stem of acid lime tree. The results showed that 37.5 kg FYM, 675 g: 563g: 375 g NPK/tree + Vermicompost 9 kg/tree + AAU PGPR Consortium 3.5 ml/tree were most beneficial in obtaining higher fruit yield and good quality of fruits.

Vashisth and Grosser (2018) [20] compared five different Controlled Release Fertilizer (CRF) on the growth and development of *Citrus sinensis* cultivar 'Valquarius', on rootstock US-897 under prevalent Huanglongbing (HLB) conditions (table 18). The trial was carried out over the span of 4 years and the yields from all treatments were exceptionally high even under high disease pressure. Application of CRFs and SRFs has been shown to improve the plant tolerance of certain pathogens. CRFs, particularly those with micronutrients, provide the plants with complete nutrients required for healthy growth and secondly the controlled release characteristic may synchronize with plants need for nutrients in a prolonging fashion, thus sustaining the nutrient supply through roots. Thirdly Nitrogen is retranslocated bidirectionally in plants, and plant growth in spring generally uses the existing, retranslocated N, rather than freshly applied Nitrogen. Continuous supply of Nitrogen through CRFs allows plants for immediate use in the next spring, which improves the plant health and increases plant tolerance to abiotic and biotic stresses. Fourth, nutrients are completely absorbed by the roots and transported to the shoot through xylem which is a more efficient method of nutrient delivery as compared to the foliar spray of micronutrients.

Table 16: List of bioenhancers

Parameter	Panchagavya	Jeevamrita	Beejamrita	vermiwash
Total nitrogen	0.1%	4%	770ppm	0.27%
Total phosphorus	175.4 ppm	155.3 ppm	166 ppm	0.64%
Total potassium	194.1 ppm	252 ppm	126 ppm	1.73%
Total Zinc	1.27 ppm	2.96 ppm	4.29 ppm	60ppm
Total copper	0.83 ppm	0.52 ppm	1.58 ppm	31ppm
Total iron	29.71ppm	15.35 ppm	282 ppm	485ppm
Total manganese	1.81 ppm	3.32 ppm	10.7 ppm	28pm

Table 17: INM on growth, yield and quality of acid lime

	Treatment	Fruit yield (kg/tree)	TSS (%)	Ascorbic Acid (mg/100 g juice)
T1	100% RDF (50 kg FYM, 900 g: 750 g: 500 g NPK/tree)	33.41	24.10	6.88
T2	75% RDF + 5 kg Castor cake/tree	35.09	25.13	7.42
T3	T2 + AAU PGPR Consortium (3.5 ml/tree)	36.13	26.90	7.73
T4	5s0% RDF + 10 kg Castor cake/tree	34.90	26.20	7.57
T5	T4 + AAU PGPR Consortium (3.5 ml/tree)	42.42	28.03	8.60
T6	75% RDF + 9 kg Vermicompost/tree	37.53	27.67	7.92
T7	T6 + AAU PGPR Consortium (3.5 ml/tree)	46.92	29.63	8.85
T8	50% RDF + 18 kg Vermicompost/tree	41.68	27.83	8.37
T9	T8 + AAU PGPR Consortium (3.5 ml/tree)	46.68	28.53	8.72

Table 18: Effect of Controlled Release Fertilizer (CRF) on the growth and development of Citrus sinensis

CRF	Number of fruit	TSS/TA
A (Florikote; 14N–4P–10K)	91.1	18.4
B (Citriblend; 17N–5P–12K)	178.1	17.2
C (Harrell's; 13N–4P–9K)	139.7	18.2
D (Citriblend; 18N–6P–11K)	113.8	18.7
E (Harrell's; 16N–5P–10K)	127.1	17.4

Precision Farming

Precision farming or precision agriculture is about doing the right thing, in the right place, in the right way, at the right time. Managing crop production inputs such as water, seed, fertilizer etc to increase yield, quality, profit, reduce waste and becomes eco-friendly. The intent of precision farming is to match agricultural inputs and practices as per crop and agro-climatic conditions to improve the accuracy of their applications. Precision Farming enhances the productivity, prevents soil degradation, reduces chemical use, and enables the dissemination of modern farm practices. Technologies of Precision Farming used in Crop Modelling (Sharma *et al*. 2005) [27] are remote sensing, Geographical information system (GIS), Global positioning system (GPS), Variable Rate Technology (VRT), Yield Monitoring and Mapping. Some studies of machine vision systems in precision agriculture have been listed in table 19.

For several Precision Farming (PF) tasks location awareness is essential which has strong spatiotemporal, environmental, public health and food safety characteristics. Costas *et al.* 2010 studied the insecticide-bait ground spraying against the olive fruit fly (Table 20). It requires location awareness, so as to be more efficient, friendly for the environment and the domestic areas, and ensure olive products with low insecticide residues. This research proposes an innovative, integrated, Location-Aware System (LAS) suitable for the ground control of the olive fruit fly. The system enabled rapid prototyping of Location-Aware services combining location sensing technologies with wireless Internet, Geographical Information Systems, and Expert Systems. This framework had specific LAS services such as finding area which is to be sprayed, amount of the spraying solution required, cancellation of spraying process, etc. Results reported no over sprayings occurred; sprayings were based on infestation risk, cultivation features, and meteorological conditions. Also a safe distance was maintained from the biological cultivations, domestic areas and environment was protected avoiding any kind of residues effect.

Site-specific crop management not only increases the profitability but also reduces the environmental risks. An integrated automated system was developed by Farooque *et al*. (2013) [7] which comprised an ultrasonic sensor, a digital color camera, a slope sensor, a real-time kinematics GPS (RTK-GPS), custom software and ruggedized computer. This system was incorporated in a commercial wild blueberry harvester which measured the plant height, fruit yield, slope and elevation simultaneously while harvesting. RTK-GPS mapped the field boundaries, bare spots, weeds and grass patches prior to the start of the experiment which provided information for site specific fertilization, based on field parameters, to optimize the productivity while minimizing the negative environmental impacts. Unnecessary or over-fertilization in bare spot areas deteriorates the water quality, promote weed growth and also increases the production cost. While under fertilization restricts the yield as well as berry quality. Therefore, variable rate fertilization improves the profitability and reduces environmental impact of farming operations.

The Strawberry Advisory System (SAS) is a web-based expert system which was developed by designed by University of Florida researchers to increase the temporal precision of fungicide application (Table 21). It optimized the timing of fungicide application and managed weather and climate related risks. The SAS processes the duration of leaf wetness and average temperature during this wetness period in order to predict the disease conducive conditions. The SAS also issues an alert for the application of fungicides if the conditions for the development of disease are favourable. The primary objective of SAS was to prevent the fruit rot disease development in the earlier growth stages so as to restrict the spread and minimize the unnecessary use of fungicides. In comparison to SAS the Calendar-based method involves a routine application of fungicide as per the specifications of manufacturer while, SAS based method is based on the leaf wetness duration and average temperature during the wetness period. For anthracnose disease the number of fungicide applications in SAS based method was reduced by 47% and yield was increased by 24.5% for more-resistant cultivars and by 22.9% for less resistant cultivars in comparison to the Calendar-based method. In the Botrytis disease, the SAS-based method reduced the number of fungicide applications by 49%, and increased the yield by 25.5% for more-resistant cultivars and by 14.5% for less-resistant cultivars, compared to the Calendar based method. The main objective of the precision agriculture was to facilitate a site-specific, preventive, cost efficient, and environmentally responsible management practices Vorotnikova *et al*. (2014) [22].

Table 19: Machine Vision Systems in Precision Agriculture in fruits

Fruit	Task	Feature Type	Method	References
Grapes	*L. botrana* recognition	Color (gray scale values and gradient)	Clustering	García *et al.* (2017) [8]
	Grapevine bug detection	SIFT	SVM	Pérez *et al.* (2017) [15]
Strawberry	Pest detection in strawberry plants	Color (HSI color space) & morphological (ratio of major diameter to minor diameter in region)	SVM	Ebrahimi *et al.* (2017) [5]
Diseases				
Citrus leaves	-	GLCM	K-means + SVM	Zhou *et al.* (2014) [25]
		Color, texture, and geometric	PCA + Multi-Class SVM.	Prakash *et al.* (2017) [16]
Apple leaves	-	Color, texture and shape features	SVM	Zhang *et al.* (2017) [24]

Table 20: Location aware system against the olive fruit fly

Parameters	Without LAS	With LAS
Over sprayings	Several over sprayings were noted. Tractor attendants sprayed their area more than once or sprayed the area assigned to another tractor attendant	No over sprayings occurred
Sprayings in or nearby biological cultivations	Some biological cultivations were sprayed or sprayings occurred nearby biological cultivations	Biological cultivation was not sprayed. A safe distance from these areas was kept
Sprayings nearby domestic areas	Sprayings occurred nearby domestic areas	A safe distance from these areas was kept
Spraying density	Subjective sprayings occurred, i.e. high (low) volume solution, in areas with low (high) olive fruit fly population was applied	Sprayings were based on infestation risk and cultivation characteristics
Spraying duration (Gun trigger)	Higher than the proposed by official regulations	As proposed by official regulations
Meteorological conditions for spraying	Several violations were noted	The sprayings were based on meteorological data

Table 21: Anthracnose and Botrytis production trials: the number of days with weather conditions conducive for the fruit rot, derived weather variables, and the number of fungicide application

Season	Number of days	Number of fungicide applications			% Change in Applications
Anthracnose production trials	when% $Inf^{AFR} \leq 0.15$	Control	Calendar-based	SAS-based	between SAS and Calendar
2006-2007	33	0	16	10	47%
2007-2008	34	0	16	12	
2008-2009	13	0	17	5	
2009-2010	36	0	14	6	
2010-2011	14	0	10	6	
2011-2012	32	0	15	8	
Botrytis Production Trials					
2006-2007	13	0	17	8	49%
2007-2008	17	0	16	8	
2008-2009	4	0	17	3	
2009-2010	6	0	18	8	
2010-2011	13	0	12	8	
2011-2012	14	0	4	10	

Good Agricultural Practices for Management of Pesticide Residues

- An inventory should be kept for all the chemicals and stored in their original containers.
- Herbicides should never be stored with other pesticides.
- Only recommended Pesticides should always be used as per the recommendations in terms of dose, frequency, and time.
- Never use the banned pesticides.
- Proper training should be provided to avoid the misuse of pesticides that creates residue problems.
- Avoid indiscriminate usage of pesticides.
- Adopt IPM and INM.
- Beneficial insects or predators can be preserved through proper use of safe pesticides.
- Waiting period should be strictly followed before harvesting.
- Spray drifts in orchards can be reduced by using spraying machine with low pressure and large nozzles. Also less volatile pesticides should be used and should be sprayed when there is little or no wind.
- Promote usage of botanicals or microbial insecticides rather than chemicals.
- Pesticides should be strictly purchased from authorized dealers
- The product labels should be carefully read and followed as per the directions before applying any pesticides, or Mixing.

Future thrust

The increasing residue levels in food products, testing protocols by the laboratories and their tolerance levels followed by different importing countries is a major issue on which unified efforts are required. Competitive laboratories with their ability to carry out tests in accordance with tolerance limits set by importing countries need to be mapped. As part of the Agriculture Export Policy, the Department of Commerce proposes to have a single portal which will provide the facility for single accreditation of labs and prevent different organizations from carrying out accreditation activities separately. National Accreditation Board for Testing and Calibration Laboratories is leading organization for joint assessments and accreditations and facilitate the root cause analysis in case of any default and also penalize the laboratories at default in case of irresponsible sampling or testing protocols for exported products. Residue monitoring plans would help in creating an online platform for tracing, facilitating exports through standard testing protocols. APEDA has already initiated this for grapes. There is a need to develop a Manual of Importing Country Requirements for major agriculture products that are exported from India. This will help the exporters to look up for requirements of importing countries and comply. This will minimize the rejection risk of exported consignments.

References

1. Babita Ahmed N, Thakur M. Organic farming: a holistic approach towards sustainable fruit production. European Journal of Pharmaceutical and Medical Research. 2015;2(6):108-115.
2. Brar JS, Arora NK, Kaur K, Kaur G, Gill KS, Gill MIS. Fruit bagging for improving quality of rainy season guava under Punjab conditions. Agricultural Research Journal. 2019;56(3):475-479.
3. Chaterjee H, Mondal P. Efficacy of some neem-based formulations against citrus brown aphid, Toxoptera citricidus Kirkaldy in Darjeeling hills. Journal of Insect Science. 2006;19:103-104.
4. Chouinard G, Veilleux J, Pelletier F, Larose M, Philion V, Cormier D. Impact of exclusion netting row covers on arthropod presence and crop damage to 'Honeycrisp' apple trees in North America: A five-year study. Crop Protection. 2017;98:248-254.
5. Ebrahimi MA, Khoshtaghaza MH, Minaei SN, Jamshidi B. Vision-based pest detection based on SVM classification method. Computers and Electronics in Agriculture. 2017;137:52-58.
6. Emami MS. Field evaluation of two biorational compounds in the control of pear psylla, *Cacopsylla pyricola* (Förster), on pear trees. Archives of Phytopathology and Plant Protection. 2016;49(1-4):11-18.
7. Farooque AA, Chang YK, Zaman QU, Groulx D, Schumann AW, Esau TJ. Performance evaluation of multiple ground based sensors mounted on a commercial wild blueberry harvester to sense plant height, fruit yield and topographic features in real-time. Computers and Electronics in Agriculture. 2013;91:135-144.
8. García J, Pope C, Altimiras FA. Distributed means segmentation algorithm applied to Lobesia botrana recognition. Complexity. 2017;63:1-14.
9. IIHR. Annual Report for 2007-08. Indian Institute of Horticultural Research, Bangalore, India; c2008. p. 125.

10. Kardinan A. Control of fruit flies pest on guava fruit by using organic insecticide. Building Organic Bridges. 2014;3:675-678.
11. Maneesha A, Rao SK, Krishna TM, Sudhakar P. Predatory potential of Australian lady bird beetle *Cryptolaemus montrouzieri* Mulsant on papaya mealybug. Journal of Entomology and Zoology Studies. 2018;6(6):837-40.
12. Marchive C, Léon C, Kappel C, Coutos-Thévenot P, Corio-Costet MF, Delrot S, *et al*. Over-expression of VvWRKY1 in grapevines induces expression of jasmonic acid pathway-related genes and confers higher tolerance to the downy mildew. PLoS One. 2013;8(1):1-7.
13. Muhammad I, Asif M, Khan I. Integrated pest management of mango against mealy bug and fruit fly. International Journal of Agriculture and Biology. 2004;3:452-454.
14. Nurbhanej KH, Patel MJ, Barot HR, Thakkar RM, Gadhavi AV. Effect of Integrated Nutrient Management (INM) on growth, yield and quality of acid lime (*Citrus aurantifolia* swingle) cv. Kagzi. International Journal of Agricultural Science. 2016;8:2360-2363.
15. Pérez DS, Bromberg F, Diaz CA. Image classification for detection of winter grapevine buds in natural conditions using scale-invariant features transform, bag of features and support vector machines. Computers and Electronics in Agriculture. 2017;135:81-95.
16. Prakash RM, Saraswathy GP, Ramalakshmi G, Mangaleswari KH, Kaviya T. Detection of leaf diseases and classification using digital image processing. In2017 international conference on innovations in information, embedded and communication systems (ICIIECS) 2017 Mar 17 p. 1-4. IEEE.
17. Singh S. Termite trap: A novel technology for eco-friendly management of termites in orchards. Agricultural Research Journal. 2020;57(2):184-187.
18. Singh S, Gaur RB, Singh SK, Ahuja DB. Development and evaluation of farmers-participatory integrated pest management technology in groundnut. Indian Journal of Entomology. 2009;71:160-164.
19. Thakur A, Singh H, Jawandha SK, Kaur T. Mulching and herbicides in peach: Weed biomass, fruit yield, size, and quality. Biological Agriculture and Horticulture. 2012; 28(4):280-90.
20. Vashisth T, Grosser J. Comparison of controlled release fertilizer (CRF) for newly planted sweet orange trees under Huanglongbing prevalent conditions. Journal of Horticultural Sciences. 2018;5:244-249.
21. Vassiliou VA. Botanical insecticides in controlling Kelly’s citrus thrips (Thysanoptera: Thripidae) on organic grapefruits. Journal of Economic Entomology. 2011;104(6):1979-85.
22. Vorotnikova E, Borisova T, Vansickle JJ. Evaluation of the profitability of a new precision fungicide application system for strawberry production. Agricultural Systems. 2014;130:77-88.
23. Witzgall P, Kirsch P, Cork A. Sex pheromones and their impact on pest management. Journal of Chemical Ecology. 2010;36(1):80-100.
24. Zhang Q, Reid JJF, Noguchi N. Agricultural vehicle navigation using multiple guidance sensors. In Proceedings of the international conference on field and service robotics. 2000;19:293-298.
25. Zhou R, Kaneko S, Tanaka F, Kayamori M, Shimizum M. Disease detection of Cercospora Leaf Spot in sugar beet by robust template matching. Computers and Electronics in Agriculture. 2014;108:58-70.
26. Dhaliwal D, Heitzman S, Zhen Li OL. Taxes, leverage, and the cost of equity capital. Journal of Accounting Research. 2006 Sep;44(4):691-723.
27. Sharma GP, Verma RC, Pathare P. Mathematical modeling of infrared radiation thin layer drying of onion slices. Journal of food engineering. 2005 Dec 1;71(3):282-6.
28. Bergman AJ, Burke J, Larson P, Johnson-Levonas AO, Reyderman L, Frick G *et al*. Effects of ezetimibe on cyclosporine pharmacokinetics in healthy subjects. The Journal of Clinical Pharmacology. 2006 Mar;46(3):321-7.