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EMERGING PEST PROBLEMS IN EXOTIC OLIVE AND GROWER SPECIFIC IPM MODULES FOR JAMMU AND KASHMIR

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ABSTRACT

About 34 insect species were found infesting olive orchards in UT of J&K Among them, olive psylla, *Euphyllura pakistanica*; olive black scale, *Saissetia olea* and tinged bug, *Eteoneus* sp. *sigilatus* Drake caused serious damage. The avoidable yield losses caused by all the pest species were 33 to 53%. On the basis of various field trials conducted neem insecticidal soap (NIS @ 2.5 %) and horticultural mineral oil (HP spray oil 2% of solution) were found effective against major pests. In case of severe infestation imidacloprid (17.8 SL) *a.i.* 0.075 % and cartap hydrochloride 4G @ 100g/ tree resulted in their efficient suppression. As such these treatments were incorporated in grower specific IPM modules evaluated for two years. Amongst the tested modules, integrated module (M1) followed by pesticide module (M3) were found most effective. However, for resource poor farmers and non-disruptive cultural module M_1 and organic growers M_2 could be alternatively practiced. It was concluded that for scale and psyllids, the insecticide protection is necessary but the infestation by lace bug could be managed by non-disruptive methods.

Key words: Olive scales, lace bug, olive psylla, natural enemies, infestation, yield losses, cultural control, non-disruptive practices, organic protection, IPM modules, resource poor farmers, neem, mineral oil, imidacloprid, cartap hydrochloride

Olive is subjected to the attack of wide array of insect pests, diseases and nematodes. More than 125 arthropod species have been reported to attack olive plants globally (Haniotakis, 2005). Among them, olive fly, *Bactrocera oleae* Gmelin (Diptera: Tephritidae) is the major threat to olives. However, less important pests attacking olives include Lepidoptera: olive moth, *Prays oleae* (Bernard), jasmine moth, *Palpita unionalis* Hubner, olive pyralid moth, *Euzophera pinguis* Haworth, and leopard moth, *Zeuzera pyrina* L.; Homoptera: black scale, *Saissetia oleae* (Olivier), olive scale, *Parlatoria oleae* Colvee, and oleander scale, *Aspidiotus nerii* (Bouche); and Coleoptera: olive bark beetle, *Phloeotribus scarabaeoides* Bern, olive weevil, *Rhodocyrtus cribripennis* (Kos et al., 2022) as well as the olive thrips *Liothrips oleae* Costa, and olive psylla, *Euphyllura olivina* Costa.

Ever since its introduction under Indo-Italian project in 1984 in Jammu and Kashmir, India, frequent diagnostic team visits of entomologists and plant pathologists of Sher-e-Kashmir University of Agricultural Sciences and Technology-Jammu have revealed that orchards were principally suffering from neglectosis coupled with pest problem. At the initial phase of introduction, the area appeared to be free of many cosmopolitan pests but the increased orchard expansion has led to more problems of olive moth (*Prays oleae*) and olive knot (*Pseudomonas savastanoi pv. savastanoi*). The interactions between insects and their natural enemies are essential ecological processes that contribute to the regulation of insect population in a particular agroecosystem. Therefore, studies were planned to assess the prevalence of natural enemies on key pests and their role in natural system. Adverse public attitude to pesticides especially in nations, where the opportunity for export of these fruits/oil exists, have intensified in recent years. This has led to a decision of olive growers to reduce dependence on pesticides, with particular reference to broad spectrum compounds that can adversely affect human health and the environment. At global scale, most research has been targeted at individual pest species, with surprisingly little effort invested in conducting surveys of the distribution of pests and their natural enemies, or investigating the complex of organisms in olive agroecosystems which is primarily focused on aspects of their sustainable management (Zipori et al., 2020) including classical biological control (Alberola et al., 1999) and use of semiochemicals (Mazomenos et al.,

1997) because olive fruit fly is prevalent in most of the olive growing countries. In contrast, in India olive fruit fly is not reported so far and hence studies on the ecological aspects of the pest-natural enemy-plants interaction in introduced olive orchard ecosystem were therefore undertaken to evolve IPM module that are ecofriendly, economically feasible and socially acceptable. The possible role of cultural manipulation was considered as the first ditch defence around which to build other control options. This is particularly important for resource poor olive growers of hills, as it does not involve any financial burden upon them. Nevertheless, it represents an important component in the development of a coherent, holistic approach to IPM and warrants a great deal and more attention than it is currently receiving. Since, the individual components of IPM may rarely result in effective suppression of the pest, all the management tactics were integrated as module which were tested and validated in the field trials Further, Information on infestation level and yield losses caused by these insect pests was also generated for future decision making to manage them.

MATERIALS AND METHODS

Five sites of olive orchards viz Dharmatal (32.732998ºN, 74.864273ºE, 1036 masl), Chenani (33.0355ºN, 75.2852ºE, 1200 masl), Ramban (33.2464ºN, 75.1939ºE, 1156 masl), Pranoo (30.0944ºN, 75.5826ºE, 1103 masl) and Doda (33.1457ºN, 75.5480ºE, 1145 masl) were selected in the North West Himalayas for periodic inspection from August 2006 to June 2020. The collection sites were situated in mid and intermediate hill zone with subtropical climate. All the surveyed trees were 10-15 years old (variety Fronoio) growing in close proximity to naturally occurring wild olives. Usually, these olive orchards were pruned every two years and they were treated with Bordeaux mixture in spring. For sampling insect pests and their natural enemies, five plots, called blocks, were selected per orchard, and five trees per block were sampled. At each site, yellow sticky traps, double sided with dimensions of 16 x 10.2 cm were set up that were replenished every two weeks. Any insect specimens in fruit fly traps were also collected and sent for identification. In addition, twenty branch and leaf samples approximately 15 cm long were cut from trees within the monitoring area and observed every fortnight for detailed inspection (Lopez-Villalta, 1999). In perforated polythene bags, the branch and leaf samples were collected, counted and classified in the laboratory. Yellow sticky traps and branch samples were examined under a stereomicroscope to identify pests, pest damage and beneficial insects present. For each branch sample, incidence of damage or pest species was recorded whereas for the sticky traps, total number of organisms was recorded. Efforts were made to identify emerging parasites down to the species level. For fruit pests green (unripe), partially ripened and fully ripe fruits were collected together directly into plastic bags from trees at random, along with some that had recently fallen and kept in cooler boxes while in the field. They were promptly taken to the laboratory (25.8^{0}C; 16 h L: 8 h D photoperiod) where green fruit was separated from ripe and ripening fruit to provide more resolution to the assessments of insect populations.

The number of fruits attacked by fruit pests was established by collecting samples between July and November. The fruits were checked for presence of oviposition punctures and feeding injuries if any. The infested /damaged fruit were transferred to cages with mesh with holes small enough to retain them but large enough to allow fruit fly larvae and parasitoids exiting the fruit to pass through and maintained at the same environment and reared until pupation concluded and emergence occurred. In the shoots collected, symptoms of attacks by *Prays oleae* were examined in buds and leaves during the leaf generation of this insect (October-April) and in inflorescence during the flower generation (April-June). At the fruit-generation stage (June-October), the fruits collected were examined to check for the presence of viable eggs and larvae. However, attacks by other pests *S. oleae* (March-October), *P. scarabaeoides* (May-October), *L. oleae* (April-October), *P. unionalis* (April-September), *E. pakistanica* (April-September), and *O. cribicollis* (April-November) were monitored by examining 200 shoots (8 shoot/ trees) collected weekly. In these shoots, the presence of insects and/or damage was measured. The diseases were identified on the basis of symptoms and wherever pathogens were suspected, specimens were sent to the pathologists.

For evolving IPM modules trials were laid out for at least two years (2016 to 2017). The experiment on effect of pruning on sedentary insects and the incidence of olive knot was carried out using 15 trees. Three levels of pruning severity, 0% (non-pruned), 10-20% (light) and 40-50% (heavy) were tested. Each treatment was replicated five times. Annual maintenance pruning was done to maintain a normal canopy shape only on lightly and heavily pruned trees. This process was carried out during February and two observations for vegetative growth and fruit set were made. For recording the dynamic of fruit set, shoots were chosen at four different points and counts were made in four inflorescences. According to number of flowers/ inflorescence the number of flowers/ sample was calculated. At the end of June and August, number of fruits was also counted. The final count was made before harvesting to determine the % of fruits in trees. To investigate the effect of timing of copper sprays (copper hydroxide 50% a.i. @ 0.16% using 8-10 liters solution/ tree) to control leaf spot and olive knot, bearing olive trees, about 15 years old were placed in a randomized block design at Pranoo with 6 treatments as T1= one spray in October, T2 = two Spray; first in January and 2nd in February, T3 = one spray in March, T 4 = one spray in April, T5 = two spray; first in January and 2nd in March and T6 = untreated control, each comprising of four replicates. On each of the marked shoots, ten pairs of leaves were removed every month causing a leaf scar wound. Evaluation of the leaf spot infection level was carried out in early summer, counting the spotted leaves in a 100-leaf sample collected from each tree and for olive knot in September counting the galls formed in the 100 leaf scar wounds/ tree.

In another trial, the effect of emulsifible oil on overwintering adults of olive psyllids, and its phytotoxicity was investigated. This research was carried out in Doda region as a factorial experiment in completely randomized design block with two factors in three replications. First factor was mineral oil dosage at three levels: a1= 1%, a2= 2% and a3= 3% and the second one was time of spraying, at five levels: b1= 4th of November, b2= 4th of December, b3= 4th of January, b4= 4th of February and b5= 4th of March. Each block included 4×4 = 16 trees and sampling was done on 2×2= 4 trees at the center of each block. Adults were collected by hand beating twigs over a 50 cm diameter net at four main geographical directions of each sampling tree. Samples of adults were taken two days before and a week after each oil spraying in order to evaluate the phytotoxicity effects, the treated trees were monitored for yellowing and dropped leaves and also weight of 50 fruits used as an index of yield. For this purpose, about 10 kilos fruit of 2×2 = 4 trees from the center of each block, synchronizing harvesting olive trees to conserve use in late of September, 2003, were gathered and then 50 fruits were randomly picked up and weighted.

A separate trial was conducted on the effect of pesticides, horticultural mineral oils and neem soap on major insect pests of olive at Ramban. Olive trees located at the experimental field were assigned to randomized block design with 6 treatments assigned to four single-tree replications. The treatments and their application rates are detailed in Table 5. The single spray application was done with foot sprayer (ASPEE) with a hollow cone nozzle delivering 6 ℓ of water/ tree except Cartap hydrochloride granules which were applied through soil. Before application the neem soap was properly dissolved in water. Five, one-year-old shoots/ tree around the canopy were marked before each spray in all the trees (including control). The number of survivors were counted on 25 cm twig before and after 7 and 14 days of application. Studies on the IPM module were undertaken for each of four modules viz., M1 Non-disruptive cultural, M2: Organic, M3: Pesticides, M4: integrated that were compared with existing farmer practices. The groove was managed following recommended package of practices of SKUAST except the plant protection measures. Four replications in each block were made. The module details for cultural module (M1) with pruning level of 30% as detailed in trial 1 followed by application of Bordeaux mixture and timely irrigation as and when required. In pesticide-based module application of cartap hydrochloride 4G @ 100g/ tree on 15th February followed by spray application of imidacloprid (17.8 SL) @ 0.075 % in last week of March as detailed in trial 3. However, for organic module M2 cultural module M1 was supplemented with a single spray application of horticultural mineral oil 2% on 15 March followed by one application of neem soap @ 0.01%/ tree at 15 days interval. Integrated module (M4) comprised of all the cultural practices (M1) followed by a single spray application of horticultural mineral oil 2% and imidacloprid (17.8 SL). The observations on the damage were recorded at maximum intensity and yield when the crop attained maturity. The yield data from each block were computed on tree basis for calculating cost: benefit. All the observations were analyzed statistically.

To work out the avoidable losses, 15 trees were assigned to two different treatments viz., protected and unprotected for two consecutive years i.e.; 2017 and 2018. The untreated trees were sprayed with water only while under protected conditions, each tree was treated with granular application of cartap hydrochloride (4G) @ 100g/ tree in the month of January followed by two sprays of imidacloprid (17.8%) @ 0.075 % at 15 days interval starting from 1st week of March. Data on fruit yield were recorded and subjected to paired t-test.

RESULTS AND DISCUSSION

Based on survey and monitoring of orchards about 34 species of insect pests of olives were recorded (Table 1). Foliage pests such as scale insects, olive bug and Olive *Psylla* appeared to be widely distributed, while sporadic attack of white grub was noticed on foliage and fruits, Minor pests like wooly aphid, root knot nematodes and bacterial knot remained persistent. The importance of these pests varies with location, climate, and the intended use of the olives. Ever since olive was introduced in the UT of J&K and Himachal from Italy, serious pest problems were noticed as early as 1985 (Gupta and Thakur, 1991). However, most of the recorded pests are native to India and were not accidently introduced. Many of them were harbored by the wild olive growing in India but assumed serious proportion probably due to expansion in host range as the pest prefer cultivated olive. Insect pest infestations by sucking pests were strongly affected by the characteristics of the surrounding landscape and vegetation. Boccaccio et al. (2008) suggest that landscape characteristics affect functional biodiversity also in well-structured agroecosystems such as the olive groves. Nevertheless, regardless of where olive is grown, several insect groups that attacked exotic olive appeared to be of native origin and no exotic pest like olive fly was observed anywhere in India. The association of tingid bugs with wild olive is well documented world-over. For example, *Teleonemia australis*, *Cysteochila pallens* is found in Africa (Hill, 1987) whereas, the olive lace bug *Froggattia olivina* Froggatt is increasingly being recognized as a major pest, and has for the first time been reported in Western Australia in 2002. The insect is native to New South Wales and southern Queensland, but currently has a distribution in eastern Australia. While sucking pests like scale, psylla and lace bug affected production in nearly all locations, other pests were of only local significance. It is well documented that relatively few species caused significant crop loss, and were only a problem when the population exceeds damaging thresholds.

Johnson and Daane (2010) recorded 125 arthropod species on olive. Among them the olive fly, *Bactrocera oleae* Gmelin (Diptera: Tephritidae) was considered as the major threat worldwide. According to them less important pests attacking olives include Lepidoptera: olive moth, *Prays oleae* (Bernard), jasmine moth *Palpita unionalis* Hubner, olive pyralid moth *Euzophera pinguis* Haworth, and leopard moth *Zeuzera pyrina* L.; Homoptera: black scale *Saissetia oleae* (Olivier), olive scale, *Parlatoria oleae* Solve, and oleander scale *Aspidiotus nerii* (Bouche); and Coleoptera: olive bark beetle *Phloeotribus scarabaeoides* Bern, and twig cutter beetle *Rhynchites cribripennis* (Desbrocher des Loges), as well as the olive thrips *Liothrips oleae* Costa, and olive psylla, *Euphyllura olivina* Costa.

Black scale probably originated in Africa, but has since spread around the world. In Asia it is widely distributed in the Indian subcontinent and recorded as polyphagous, feeding on hosts from 77 plant families, especially on ornamental plants of subtropical origin e.g., Ficus and Hibiscus, several agricultural crops like citrus, coffee, cotton, and mangoes. While many workers have identified it as *Saissetia oleae* (Olivier) on olive but considering slight differences, Dr. William has determined it a different species as *S. privigna* De Lotto (Muzaffar and Ahmad, 1977). In sub temperate Himalayan region eleven species of armoured scale insects infesting fruit trees had been identified Among them infestations of following diaspidids viz., *Aonidiella aurantii* (Maskell) was recorded on *Citrus* spp. (hill lemon, rough lemon, sweet lime, sweet orange) and grapes, *A. orientalis* (Newstead) on guava, mango and olive and *Parlatoria oleae* (Clovee) on apple, apricot, pear, plum and sweet cherry (Verma and Dina bandhoo, 2003). The infestation by scale in exotic olive is therefore attributed to shifting behaviour from adjacent vegetation. Black scale on olive was recorded as severe problem resulting in leaf drop in 44%, reduced tree vigour in 33% of total trees observed. In one of the orchards at Doda wherein heavy infestations was recorded twig dieback was a severe problem. Several species of armored scales (Diaspididae) were also recorded causing economic damage in some olive orchards. These include red scale *Aonidiella aurantii*, oleander scale *Aspidiotus* spp. and parlatoria scale, *Parlatoria oleae*. Damage was primarily restricted to leaves (53%) and twigs (19%), although occasional fruit infestations (< 1%) were also observed. Honey dew, sooty mould and ants are not associated with these infestations. It is well evidenced that these scales are cosmopolitan in all olive production areas (Mansour et al., 2010; Kishimoto et al., 2019). Olive lace bug *Eteoneus* sp. was recorded in fully grown orchards especially on older and water stressed trees. This pest is found mostly in sub-Saharan and South Africa (Hlaka et al., 2021) where water stress is a frequent problem. That was why it was observed in the unsprayed and neglected trees at Ramban and Bhaderwah region of Jammu wherein infestation was very serious and even

Table 1. Incidence of insect pest on exotic olive in India

Order/ Family	Common/ Scientific Name	Locality	Nature of damage	Intensity
Coleoptera				
Chrysomelidae	Tortoise beetle, *Taiwania nigriventris* (Boheman)	Kullu Sirmaur Solan	Scrapped leaves from ventral side	+ + +
	Hispa dama Chap	Dharmatal	Larvae mine leaves: adult defoliate	+
	Monolepta erythrocephala Baly	Dharmatal Ramban	Leaf defoliator	+
	Altica caerulescence Baly	Ramban Doda	Leaf defoliator	+ +
Curculionidae	Weevil, *Hyperstylus chloris* Marshall *Myllocerus viridianus F* *Amblyrrhinus poricollis* Boh	Solan, Dhramatal Rajouri	Chewing and irregular holes on leaves	+ + + +
Scarabaeidae	Defoliating beetle, *Apogonia clypeata* Moser *Holotrichia* (*Lachnosterna*) *longipennis* Blanchard, *Anomala polita* Blanchard *Melolontha* sp.	Solan Kullu Doda Doda Doda	Leaf defoliators Fruit damage Leaf and fruit damage	+ + + + + + + + + +
Meliodae	*Mylabris pustulata* Thunberg	Ramban Rajouri	Eat flowers	+ + +
Scolytidae	*Scolytids juglandis* Blackman	Ramban	Adults bore old branches	+
Cerambycidae	*Batocera* sp.	Ramban Dharmatal	Larvae bore trunk	+ +
Heteroptera				
Pentatomidae	*Erthesina fullo* Thunberg *Nezara vridula*	Solan Dharmatal Chenani Doda	Suck sap from leaves	+ + + + + +
Tingidae	*Eteoneus* sp. *sigilatus* Drake and Poor	Kullu Mandi Solan Rajouri Ramban Doda	Sap sucker: leaves become stippled with greenish to rusty yellow dots	+ + + + + + + + + + + + +
Homoptera				
Aphalaridae	Olive psylla *Euphyllura pakistanica* Loginova	Badah Rajouri Sirmaur Kigus Kinnaur Solan Jammu Dhramatal Ramban Pranoo Doda	Sap sucker: infest leaf axils	+ +

(contd.)

(contd. Table 1)

Cicadidae	*Cicadatra* sp.	Solan	Root damage	+
		Chenani		+
Aphididae	*Aphis pomi de Geer*	Doda	Sap sucking from twigs	
Coccidae	Olive white scale, *Metaceronema japonica* Maskell,	Kigus	Encrust and kill twigs and branches	+ +
		Larva		+ +
		Solan		+ +
	Olive black scale, *Saissetia oleae* (Olivier)	Doda	Encrust foliage	+ + +
		Kigus		+ + +
		Dhramatal		+ + +
		Ramban		+ + +
		Rajouri		+ + +
	Paralatoria sp.	Doda	Encrust and kill twigs	+ + +
Diaspidae	*Aspidiotusnerri Bch*	Pranoo		+ + +
Margarodidae	Mango mealybug, *Drosiha mangiferae* (Green)	Solan	Sap sucking from branches	+
		Ramban		+
		Rajouri		+
		Jammu		+ +
Lepidoptera				
Cossidae	*Zeuzera* sp.	Solan	Larvae tunneled branches	+
		Dharmatal		+
		Ramban		+
Noctuidae	*Graniphora fasciata* Moore	Solan	Larvae defoliate	+
		Dharmatal		+
		Ramban		+
Sphingidae	*Dolbina exacta* Walker	Solan	Larvae defoliate	+
		Dharmatal		+
		Ramban		+
Tortricidae	*Phycita jasminophaga* Hampson	Solan	Larvae tunnel fruits	+
		Dharmatal		+
		Ramban		+
Saturniidae	*Actias selene* (Hb)	Dharmatal	Leaf defoliator	+
Crambidae	*Palpita unionalis* (Hubner)	Dharmatal	Fruit feeder	+
Pyralidae	*Cryptoblabes* sp.	Rajouri	Fruit feeder	
Metarbelidae	*Indarbela quadrinotata* Walker	Jammu	Bark feeder	+
Thysanoptera	*Scirtothrips* sp.	Doda	Feeding marks on the unopened buds - parallel brown lines on the leaves.	+

+ = low intensity and sporadic; + + = medium intensity and regular; + + + = high intensity and regular

caused total drying of trees (1%). Other sucking bugs comprised of two species of pentatomids viz. *Erthesina fullo* Thunberg and *Nezara viridula* which were recorded as serious pest on new plantings in Ramban and Dharmatal. Since these were recorded in large numbers on wild castor growing nearby, the possible host expansion is not ruled out.

A psyllid pest olive psylla, *Euphyllura pakistanica* caused damage to flower clusters upto 30.0%, and this pest was reported from Solan, India (Thakur et al., 1989). Two species of olive psylla had been recorded. *Euphyllura olivina* Costa and *E. pakistanica* in commercial olive varieties available in India and Nepal and also found in wild olives, *Olea cuspidata* (Chliyeh et al., 2014). A negligible infestation by aphid, *Aphis pomi* de Geer (Aphididae) was also recorded on twigs which is being reported for the first time in India. Among defoliators three species of weevil viz., *Hyperstylus chloris* Marshall, plum weevil, *Amblyrrhinus poricollis* and grey weevil, *Myllocerus* sp. and four species of beetles viz: *Taiwania nigriventris* (Boheman), *Hispa dama* Chap, *Monolepta erythrocephala* Baly and *Altica caerulescences* Baly were recorded. Flea beetles and weevils were found associated with olive in mediterrarian and other part of the world (Hlaka et al., 2022; Smit et al., 2021) Nevertheless, the range of genus/ species varied as per the climate and presence of insects in the nearby crops grown in the vicinity of olive orchads. Besides a number of caterpillar species were recorded attacking olives viz., *Carmiophora fasciata* Moore, *Artias selene* (Hb) and *Dolbina exacta* Walker and a native butterfly *Parnara bada* (Hespiradae). Among fruit/flower feeding insect the jasmine moth *Palpita unionalis (Hubner)* (Crambidae: Spilomelinae), was reared from green and ripe fruits in very low numbers at one site only. *Phycita jasminophaga* Hampson was recorded from three sites tunneling the fruits. An unidentified species of *Cryptoblabes* (Family Pyralidae) has also been recorded feeding on fruit. All these lepidopterans pest did not cause damage of significance. However, three species of white grubs *Holotrichia* (*Lachnosterna*) *longipennis* Blanchard, *Anomala polita* Blanchard and *Melolontha* sp. damaged the foliage and even fruits. White grubs are rarely found associated with olive crops globally.

These pests require continuous monitoring programme keeping in mind the vast damage they inflict to the foliage of olive in India. Blister beetle *Mylabris pustulata* Thunberg caused extensive damage to crop at two localities which was reported for the first-time damaging olive crop in India and elsewhere. Plague thrips *Scirtothrips* sp. are one of the most common insects recorded on sticky traps. They were found associated with feeding marks on the unopened buds and parallel brown lines on the leaves. A cerambycid *Batocera* sp. was found boring the trunk of few old trees at Ramban, while a tiger moth *Zeuzera* sp. (Cossidae) was associated with tunneling of branches at three locations while *Cicadatra* sp. (Cicadidae) and termite *Odontotermes obesus* (Termitidae) were found damaging the roots of old trees A bark eating caterpillar *Indarbela quadrinotata* Walker (Metarbelidae) was also recovered from bark of trees at few locations. As per previous reports, the information on the above pest is negligible/scanty. Considering their occurrence in the region proper measures like pruning of the heavily infested plant parts and their immediate destruction minimized scale infestation.

Apart from these pests, the olive agrosystem supported abundant beneficial species like wasps (Hymenoptera), which were divided into large (> 2 mm) and small (micro) (< 2 mm). Micro-hymenoptera was by far the most numerous, and was consistently recorded in high numbers throughout the warmer months in all locations. These wasps were primarily from the superfamily Chalcidoidea, particularly the families Aphelinidae, Chalcididae, Encyrtidae and Pteromalidae. Most members of these diverse families are parasitic on small arthropods, including scales, aphids and insect eggs. The larger Hymenoptera were primarily from the families Braconidae, Ichneumonidae and Sphecidae. Braconids and ichneumonids are large diverse families which prey on larger insects, particularly caterpillars (Lepidoptera). Sphecids, commonly known as flower wasps, have adults which feed on nectar or honeydew. Natural enemies of black scale include the small wasps *Metaphycus* spp., which are true parasites of immature stages. Field parasitism by this species was as high as 40% and pooled mean over the locations was 14.23%. *Scutellistaca erulea,* was recorded as primarily an egg predator but this was prey density-dependent and only reaches these high levels later in the season. Other predators include several species of ladybird beetles (Coleoptera: Coccinellidae), lacewing larvae (Neuroptera: Chrysopidae and Hemerobiidae) and the scale-eating caterpillar *Catoblemma dubia* (Lepidoptera: Noctuidae). Natural enemies of armored scales are commonly parasites, including *Aphytis melinus,* C*omperiellabi fasciata* and several *Encarsia* spp. However, predators played an important role in scale control, particularly the ladybirds *Rodalia cardinalis*, *Chilocorus* sp. and *Harmonia* spp. and to a lesser extent some species of lacewings and predatory mites. Psylla nymphs were parasitized by species of Pteromalidae and Encyrtidae. The most common are *Psyllaephagus euphylurae*, and *Elasmus* sp. (Elasmidae), *Tetrastichus* sp. (Eulophidae), *Trechnites* sp. (Encyrtidae). Coccinellid predators, lacewings, hover flies and spiders were observed feeding upon the eggs, nymphs and adults. *Chrysoperla carnea, Anthocoris* sp. and *Xanthandrus comtus*, were commonly observed. All these findings corroborate the observations recorded earlier in Egypt (Amro, 2017).

Challenges arise with pests when exotic plants are grown in new environment especially where a decline in the productivity is clearly evident. In Union territory of J&K, the introduced trees displayed lower/ negligible yield for the past few years. Therefore, the state government desired a strategic plan to increase the production. To overcome the challenge an effort to develop management strategies for olive pests was initiated including cultural, ecofriendly and even disruptive practices. On the basis of two years, it was found that avoidable losses in fruit yield caused by all the pest species ranged from 33.0 to 53.3%. The magnitude of losses in yield was higher than reported by pests worldwide as 15% (Kalaitzaki and Nikos, 2005). This is attributed to changes in growing environments that altered pest abundance over the years and less important species assumed serious proportion at many locations in absence of the control measures. In the present investigation it was found that heavy pruning of olive trees increases the vegetative growth, fruit set and olive fruit production (Table 2). The fruit yield/ tree was significantly higher in treatments with 50% pruning that reduced pest intensity to 41% with increased yield by 110.5%. Previous studies in central Italy suggest that olive pruning can be performed also after full bloom to increase the fruit set, control the vegetative growth of the canopy and exploit the whole plant pollination potential (Palliotti et al., 1997; Lodolini et al., 2010).

Two diseases of olive were noticed for which application of copper-based fungicides like copper hydroxide was evaluated. This is because it is allowed in organic agriculture, and still considered to be traditional organic practice. The best protection was obtained when two spray applications were applied, one in Autumn (October) and 2nd in March which could suppress the disease to a level below 50% in case of leaf spots or upto 58% for olive knots (Fig. 1). These studies corroborate the findings of Buonaurio et al., 2023 who stated that application of copper-based fungicides was the main method to control olive leaf spot in Italy. This is because spraying probably reduced the possibility of spring infections (Obonar et al., 2008; Katalinic et al., 2009). Time and dosage of oil spraying to control overwintering adults of *Euphyllura pakistanica* indicated significant differences among of spraying times but no significant differences between the dosages of sprayings (Table 3). It was found that effect of time of spraying on fruit weight was significant but doses and their interaction were non-significant (Table 4). Although, mean weight of olive fruits increased with oil spraying as the season advanced (Fig. 2). It was also illustrated that the spraying with 2 and 1% oil dosages were successful in enhancing the fruit weight but at 3% side effects in term of phytotoxicity coupled with leaves necrosis and dropping of trees were recorded.

These results indicated that adult mortality was significantly lowered when spraying was carried out in autumn in comparison to the spring season probably because as the season continued, the sensitivity of overwintering adults increased. Mustafa (1989) reported that the body fat residue of overwintering olive psyllids decreased through autumn and winter so it could be the

Table 2. Effect of pruning intensity on the tree characters, insects and diseases of olive trees

Treatments	Vegetative growth (cm)	Yield/ tree (kg)	Pest intensity (% reduction)	Diseases (% reduction)
1 (un-pruned)	9.90a	3.8a	-	-
2 (pruned 20%)	12.36b	5.8b	31	21
3 (pruned 50%)	30.6c	8.0c	41	30

Means followed by the same letter within a treatment are not significantly different (Turkey HSD[a])

Table 3. Two-way ANOVA of time and dosage of oil spaying to control overwintering adults of *Euphyllura pakistanica*

Source	df	Mean square	F	Sig.
Month	4	144.556	11.679	.000
Dose	2	6.067	.490	.617
Month * dose	8	56.289	4.548	.001
Error	30	12.378		
Total	45			

a R Squared = .737 (Adjusted R Squared = .614)

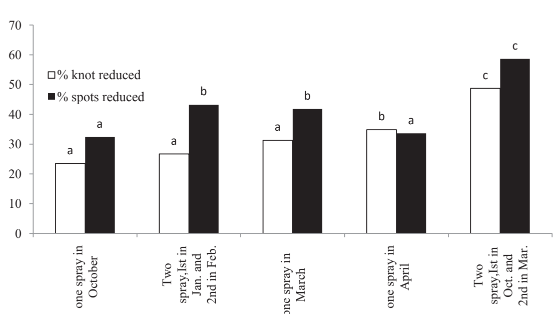

Fig. 1. The efficacy of copper hydroxide in the control of leaf spot and olive knot

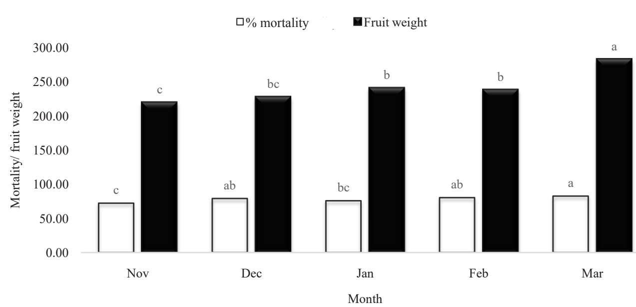

Fig. 2. Means of adult mortality and weight of 50 olive fruits caused by oil spraying

probable reason for the increase in adult sensitivity by going on the season. It seems that the reason for the exception of November in view point of adult control could be resulted from its high mobility and incomplete transition to overwintering places. Overall, the interaction effects of oil dosage and times of spraying on mortality of overwintering adults showed that March was the best time of oil spraying. When insecticides, mineral oil and neem soap were evaluated against major pest, it was revealed that all the treatments were found effective over control for suppression of olive lace bug after 7 (F=18.92, $df_{5,12}$, $p<0.05$) and 14 (F=13.01, $df_{5,12}$, $p<0.05$) days of application (Table 5). Similarly, for scale insect, all treatments gave effective protection over control after 7 (F=11.83, $df_{5,12}$, $p<0.05$) and 14 (F=15.28, $df_{5,12}$, $p<0.05$) days after treatment. Although, imidacloprid remained the most effective against both the pests, yet bifenthrin and cartap hydrochloride were found equally effective. Neem soap and mineral oil were found less effective and remained at par with each other. Based on counts in the water control, it appeared a substantial number of nymphs disappeared from the plants prior to the 7 and 14 day counts. Laboratory results indicated that horticultural oil killed a greater percentage of armored scales than soft scales, whereas insecticidal soap gave greater control against soft scales (Quesada and Sadof, 2017). This was because the waxy cover of an armored scale might reduce penetration of polar insecticidal soap whereas polar integument of a soft scale might impede infiltration of the lipophilic horticultural oil. In contrast insecticides act systemically causing damage to both crawlers and settlers. Therefore, timing application to crawler stage is important for effective management of armored or soft scale with horticultural oils and insecticidal soaps.

Table 4. Two-way ANOVA of time and dosage of oil spaying on 50 fruit weight of olive

Source	df	Mean Square	F	Sig.
Month	4	285.256	1.029	.041
Dose	2	55.022	.198	.821
Month * Dose	8	352.189	1.270	.296
Error	30	277.311		
Total	45			

Among the various modules that were examined during two-year period, integrated module M_4 followed by M_3: Pesticides were found effective in managing pest population (Table 6). The mean reduction over farmer practice by scale insect, psyllids and lace bug ranged from 84 to 84.6% and 75.4 to 90.2% and 78.4 to 86.0% in M_3 and M_4 respectively. Allahyar et al., 2017 emphasized to strengthen growers' technical knowledge of IPM through community involvement and extension services among inexperienced small-scale olive farmers for reducing unnecessary insecticide sprays. On an average, the increase in fruit yield over farmers' practice was higher in M_4 (50.5%), followed by M_3 (42.8%) in comparison to the other modules i.e., M_2: organic (25.3%) and M_1: non-disruptive cultural module (21.4). The highest fruit weight was also recorded in M_4 (277g/ 50 fruits) and M_3 (264g/ 50 fruits). The highest cost: benefit (C:B) ratio was obtained in M_4 (1:5.01), followed by M_3 (1:4.3) (Table 6). Although, least population of natural enemies was recorded in M_5, the module proved superior to other modules for managing pest population and C:B ratio and hence could be utilized by medium to large farmers. However, for resource poor farmers and organic growers' module M_1 and M_2 could be alternatively practiced. It was concluded that for scale and psyllids the insecticide protection is necessary but the infestation by lace bug could be managed by non-disruptive methods.

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Table 5. Efficacy of neem soap, HMOs and pesticides against olive scales

Treatment	Application rate	Pre count		+ 7 days		+ 14 days	
		OLB	BS	OLB	BS	OLB	BS
Neem soap	70 g/ tree	23.00	33.00	14.13b	11.90b	11.23b	11.03b
Imidacloprid 17.8%	5 ml/ tree	25.00	35.50	3.06a	3.70a	2.63a	1.90a
Cartap hydrochloride 4G	100 g/ tree	20.30	31.60	7.16ab	5.83ab	5.60ab	4.90ab
Horticultural Mineral Oil	2 %	21.50	32.40	13.56b	9.43ab	10.20b	7.06ab
Bifenthrin (100 EC)	3 ml/ tree	23.50	33.50	8.63ab	7.13ab	2.20a	3.40a
Control	Water only	25.00	35.00	36.93c	26.13c	24.13c	23.16c

OLB: Olive lace bug; BS: Black scale; Within each series means followed by the same letter within a treatment not significantly different (Turkey HSD[a])

Table 6. Evaluation of various IPM modules against major pests of olive

Module	Component	Pest intensity/ Target farmers	Major Pest Reduction (%)	% Increase in fruit yield	Weight (50 fruits)	Benefit: cost Ratio
M 1 Non-disruptive cultural	Pruning 30 % after every two years + Application of Bordeaux mixture + removal of alternate hosts+ timely irrigation	Low: resource poor	Scale (38.2) Psyllids (24.8) Lacebug (41.3)	21.4	231	2.8:1
M 2: Organic	M1 + applications of HMOs + neem soap (March)	Low to medium: small growers	Scale (45.3) Psyllids (44.2) Lacebug (51.4)	25.3	243	3.1:1
M3: Pesticides	Cartap hydrochloride + imidacloprid	High: organized growers	Scale (84) Psyllids (75.4) Lacebug (78.4)	42.8	264	4.3:1
M4: Integrated	M1+HMOs+imidacloprid	Low to high: medium to large growers	Scale (84.6) Psyllids (90.2) Lacebug (86.0)	50.5	277	5.01:1
Control	Farmer practice	High: small	-	-	189	

AUTHOR CONTRIBUTION STATEMENT

R K Gupta and Md Monobrullah conceived and designed experiments and wrote the manuscript. K Bali carried out survey work and recorded data from trials while Shafiya Rashid curated and preserved the specimen of insect pests.

CONFLICT OF INTEREST

No conflict of interest.

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