



INSECTICIDAL AND REPELLENT COMPARATIVE TOXICANT EFFICACY AGAINST *PAPILIO DEMOLEUS* (L.) INFESTING *CITRUS LIMON*

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ABSTRACT

Five novel insecticides; Belt 480g/L SC (Flubendiamide), Regent 5% SC (Fipronil), Coragen (Chlorantraniliprole 18.5% SC), Helmet 40 EC (Chlorpyrifos), Emamectin Benzoate 1.9 EC, including control (water spray) were tested under field conditions. Their insecticidal and repellent effectiveness against the larval population of *Papilio demoleus* (*P. demoleus*) were examined on *Citrus limon* orchard leaves at district Naushahro Feroze during, 2020. The recommended dose of insecticides was sprayed with five treatments and three replications. The insecticide efficacy and population reduction % of *P. demoleus* were recorded on the 2nd, 3rd, 4th, 6th, and 8th post-spray days. The results revealed that the Belt with the highest efficacy and reduction % against larvae of *P. demoleus* (80.99±9.00), followed by the Regent (79.88±8.94), Coragen (77.06±8.78), Helmet (74.11±8.61), Emamectin (72.53±8.52) when compared with water spray control plot (5.89) mean percent under field conditions. It is proved that Belt insecticide was most effective in the reduction % of the larvae of this pest. The application of these insecticides may be promising in reduction population of *P. demoleus* larvae on *C. limon* orchards. Therefore; it is an immediate call and strongly needed to introduce suitable measures and enhance biological, cultural, and structural remedial to secure the citrus fruits from this plague insect. It is recommended that appropriate controlling strategies and proper insect pest management should be applied to safe and sound the quality and quantity of citrus orchards and their fruit production.

Keywords: *Citrus limon*, efficacy, insecticides, orchards, *Papilio demoleus*.

INTRODUCTION

Citrus, the most popular cosmopolitan fruits belonging to the family Rutaceae (Shakour *et al.*, 2020), these species are not only well admired in the agro-food industry due to economic values but also in the pharmaceutical importance (Addi *et al.*, 2022). This crop with long life contributes global human diet, distinct due to its visual beauty and pleasant smell (Hans-joachime, 2021), sweat-able taste, aromas, and colors including a good source of vitamin C (Tocmo *et al.*, 2020). Citrus fruits comprise health-promoting agents minerals, fibers, and antioxidants (Otoni *et al.*, 2017), protect from various ailments, reduce inflammation, and prevent cardiovascular disorders (Maugeri *et al.*, 2019). The major source of employment generated, and are beneficial for remunerative, decreasing chances of cancer (Xingmiao *et al.*, 2021). More than 120 million tons per year of citrus fruit production is produced in the world (Karn *et al.*, 2021), among them *C.*

reticulata, *C. limon*, *C. paradisi*, *C. sinensis*, and *C. aurantifolia* are commercially important (Ledesma-Escobar and de Castro, 2014). The citrus fruits are the main economical commodity of Pakistan cover more than thirty percent of the total fruit production (Iqbal *et al.*, 2009). The citrus insect pests such as; *P. demoleus*, *A. woglumi*, *D. citri*, *A. trachoides*, *D. melanogaster*, *P. citrella*, *D. femorata*, *S. citrifolii*, *Pseudococcidae*, *Hemiptera*, *Aphidoidea*, *Lepidoptera*, and *Cocidomyiidae*, are the main insect pest of citrus varieties causing considerable damage to the economy of Pakistan because only fruits crop contribute 13% in the GDP of Pakistan (Aziz and Hussain, 2018).

The available literature demonstrated that *C. limon* originated during the 1st century in Rome than in Italy (Pagnoux, *et al.*, 2013). Brazil, United States of America, China, Spain, Bangladesh, India, and Pakistan (13th position), are the top citrus fruit-producing countries in the world (Liu *et al.*, 2012). These perennial, medium-sized, evergreen plants are grown in tropical and sub-tropical regions (Ismail and Zhang, 2004), and are

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more popular owing to their thirst-quenching quality, their juice reduces the risk of tension, makes peace, gives clarity and refreshing fragrance (Kiecolt *et al.*, 2008). The fruit of *C. limon* prevents pathogenic organism, serve as an antibacterial agent, promotes clarity of thoughts, refreshes skin and reduce wrinkles on the face (Kundu *et al.*, 2018), enhance the function of the immune system, decreases liver cancer cells proliferation, prevention from cold, heartburn (de Carvalho *et al.*, 2021), stroke, biliousness, diphtheria, asthma, liver complaints, cough, fever, rheumatism, help in blood antibodies function, WBC production and rich in vitamin "C" content (Nijima and Nagai, 2003). The fruits of citrus varieties are largely affected by several species of bacteria and pathogens (Rehman *et al.*, 2021). On the leaves and fruits of citrus more than eight hundred and twenty-three insects and mite species have been documented throughout the world and 250 insect pests of citrus reported from the Indian subcontinent (Batool *et al.*, 2007), only *Xanthomonas citri* poses stern destruction to the economy of citrus in Pakistan (Bansal *et al.*, 2017). Although the Indian sub-continent is regarded as the center of citrus fruit production variety of citrus insect pests are a major concern for citrus low quality as well as production.

On the planet of earth, insects have unrivaled supremacy over other organisms (Tiple *et al.*, 2011). Most species of insects are decomposers, and pollinators, with diverse taxonomy and serve as natural enemies of plants as well as animals (Kremen *et al.*, 2007). In Pakistan, more than 5,000 species of insects have been reported of which more than 400 are butterfly and moth species (Khan *et al.*, 2014). Butterflies give pleasure due to elegant flight, slender-shaped body, knobbed antennae, amazing, magnificent, attractive, umbrella-shaped beautiful body coloration with long-term herbivores history (Prabakaran *et al.*, 2014). Despite that, more than 70% of agricultural insect pests are lepidopteron, recently genes of many lepidoptera have been identified that could be targeted for insect pest control, through genome editing techniques (Guan *et al.*, 2018).

Papilio demoleus, a vigorous insect pest of citrus, is frequently found in a wide range of Pakistan, India, Bangladesh, Iran, Australia, Puerto Rico, America, Japan, Dominican, Jamaica, etc., (Sarada *et al.*, 2014). This plague insect pest in Pakistan is found in all the citrus growing areas throughout the year and breeds both seasons of the year with three to four

generations (Islam *et al.*, 2017). Their larvae occurrence on the surface leaves of the citrus causes negative effects, and its wide dispersal ability makes *P. demoleus* a potential pest to citrus orchards (Ram *et al.*, 2000). The larvae of *P. demoleus* were treated with difenolan at different doses, and certain larvae deformities with failure to pupae (Jahnavi *et al.*, 2018). IPM should establish certain tools and tactics to restrict the population of *P. demoleus*. The chemical method is a widely preferred option to citrus growers but toxic insecticides are the causative agents for contamination of food, health hazards, environmental pollution, the resistance of pesticides, replacement, the resurgence of pests, killing of non-targeted beneficial natural enemies (Raza *et al.*, 2017).

The experimental trials on four plant species namely; *Gerbera jamesonii*, *Salvia splendens*, *Coleus scutellarioides*, and *Begonia semperflorens cultorum* were conducted with the application of thiamethoxam, azadirachtin, sulfoxaflor, pyriproxyfen, spirotetramat, dinotefuran, imidacloprid and flonicamid systematic insecticides against citrus mealybug in greenhouse horticultural crops and proved with sufficient control (Herrick *et al.*, 2019). The vegetable oil, acetylsalicylic acid, neem oil, pheromone trap, spinetoram, natrolite, and mechanical infested parts of plants were used against *P. demoleus* and components worked effectively (Chakraborti and Das, 2021). The insecticides have harmful side effects and these effects are not simply linear but have complex negative interactions with abiotic and biotic factors (Braak *et al.*, 2018). Keeping in view above mentioned studies were carried out to get rid from this voracious pest to control the citrus orchards.

MATERIALS AND METHODS

For the application of five different insecticides, six acres of *C. limon* were selected, each acre comprising 40 lemon plants was allocated for each insecticide application and data collection, one acre for control at district Naushahro Feroze during, 2020. The data was taken before (24) of spray and (2nd, 3rd, 4th, 6th, and 8th) post-treatment days in each replication, respectively.

Under field conditions sprays were done according to recommended doses of promising insecticides namely; T₁= Belt 50ml, T₂= Helmet 200ml, T₃= Coragen 50ml, T₄= Regent 500ml, T₅= Emamectin benzoate 500ml, and T₆= control were for the management of *P. demoleus* population. The two to three years lemon orchards were sprayed with respective chemicals and after the

application of insecticides the population reduction % observations were made to know the toxicity of each insecticide individually and the reduction % after insecticide application compared with water-washed control plots. The name of the brand, chemical compound, name of the company, recommended dose per acre, dose per tank, and insecticide effectiveness are justified in (Table 1).

The initial population of *P. demoleus* larvae before spray was recorded on each lemon plant and the reduction % was calculated with the control plot plants. All five treatments were replicated three times, respectively. Through Random Complete Block Design (RCBD), from 10cm per twig of five leaves, the data was taken top, mid, and bottom of the lemon orchards followed the methodology (Pawandee and Anita, 2020). The population reduction % was statistically analyzed, and the mean value of pest population was calculated through SWX, USA student package 8.1 software, and LSD of homogenous groups conducted at ($P < 0.05$). The reduction % population of the insect pest was calculated through (Handerson and Tilton, 1955) described formula:

$$\text{Corrected \%} = (1 - T_a \times C_b / C_a \times T_b) \times 100$$

Where; T_a = Insect population in treated plot after treatment, T_b = before treatment, C_a = control plot after treatment, C_b = control plot before treatment, respectively.

Table 1. Insecticides used against larvae of Lemon Butterfly (LBF) under field condition during, 2020

Brand name	Compound	Name of company	Dose/ Acre	Dose/ Tank	Effective ness
Belt 480g/l SC	Flubendiamide	Bayer Crop Science (Pvt). Ltd.	50 ml	10 ml	Adults, Larvae
Helmet 40 EC	Chlorpyrifos	Target (Pvt). Ltd.	200 ml	40 ml	Adults, Larvae
Coragen	Chlorantraniliprole	FMC (Pvt). Ltd.	50 ml	10 ml	Eggs, Larvae
Regent 5% SC	Fipronil	Bayer Crop Science (Pvt). Ltd.	500 ml	100 ml	Adults, Larvae
Emamect in 1.9EC	Benzoate	Sino Crop Science (Pvt). Ltd.	500 ml	100 ml	Larvae
Control	Kept without insecticide / only water washed				

RESULTS AND DISCUSSION

Application of belt insecticide on lemon leaves against, *Papilio demoleus* (L.)

Under field conditions, the Belt insecticide was applied (one acre of lemon orchards) against the population reduction % of *P. demoleus* during, 2020. Before the application of belt insecticide the mean pest population was recorded (8.00 ± 2.83), (7.80 ± 2.79) (7.50 ± 2.74) and after the application

of a recommended dose of belt insecticide the reduction % of the pest population in 1st spray recorded at (97.43 ± 9.87) (2nd day) followed (94.54 ± 9.72) (3rd day), (92.73 ± 9.63) (4th day), (83.25 ± 8.59) (6th day), (73.78 ± 8.59) (8th day) with overall reduction % (88.35 ± 9.40), respectively. The reduction % recorded (90.57 ± 9.52) (2nd day), (88.79 ± 9.42) (3rd day), (82.95 ± 9.11) (4th day), (79.29 ± 8.90) (6th day), (64.21 ± 8.01) (8th day) with overall (81.16 ± 9.01) in 2nd spray. The reduction was found (87.41 ± 9.935) (2nd day), (84.84 ± 9.21) (3rd day), (73.12 ± 8.55) (4th day), (63.43 ± 7.96) (6th day), (55.51 ± 7.45) (8th day) with overall reduction (72.86 ± 8.54) in 3rd spray, respectively Figure 1. Our results are with the work similarity of (Singh and Kumar, 1986) proved that methamidophos 0.025%, quinalphos 0.025%, trichlorphon 0.025%, hydroxyl-citronellol, geranyl acetate, diofenolan, limonene, carbaryl, parathion, endosulfan, hexachlorocyclohexane, and dichlorvos are recommended insecticides against the larvae of *P. demoleus*. Under field and laboratory conditions five insecticides with the combination of pine oil were sprayed against the population of *T. erytrae* on the citrus orchards. The only acetamiprid with the combination of pine oil increased their effectiveness and dimethoate, and cyantraniliprole with the mixture of pine oil was observed with high effectiveness against *T. erytrae* (Dionisio *et al.*, 2021). The belt insecticide proved more effective during 24 hours followed by 48, 72, 120, and 160 post-treatment hours. Analysis of variance shows significant difference ($DF = 2$; $F = 37.62$; $P = 0.01$) in treatments and ($DF = 4$; $F = 30.42$; $P = 0.01$) in post-spray days. The least significant difference among replications and treatments taken at ($P < 0.05$).

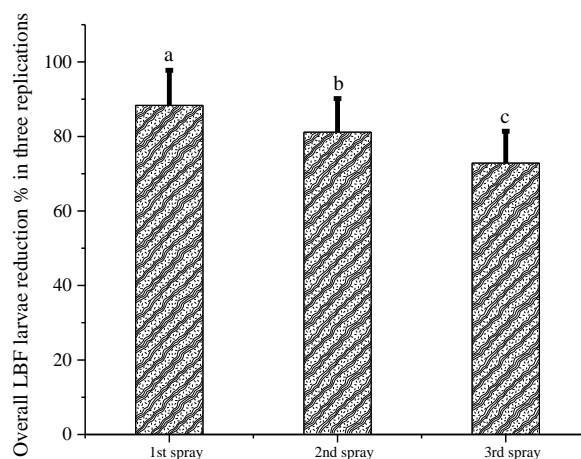


Figure 1. Overall LBF reduction % at post-treatment of belt insecticide under field conditions during, 2020

Application of Regent insecticide on lemon leaves against *P. demoleus*

The one-acre *Citrus limon* orchards was sprayed with the regent, a novel insecticide but before spray, the mean population of the insect pest was recorded at (7.60±2.76), (7.50±2.74), and (7.20±2.68). The reduction % of the pest population after 1st spray was counted at (95.94±9.79), after (24^h), (94.25±9.71) (48^h), (90.81±9.71) (72^h), (87.85±9.37) (120^h), (66.03±8.13) (168^h) with overall (86.98±9.33) reduction in 1st spray. The reduction recorded (88.79±9.42) (2nd day), (85.42±9.24) (3rd day), (83.75±9.15) (4th day), (76.81±8.76) (6th day), (62.87±7.93) (8th day) with overall reduction (79.53±8.92) in 2nd spray. While as; in the 3rd spray, reductions were found (83.61±9.14), (80.70±8.98), (72.00±8.49), (64.29±8.02), (65.10±8.07) in 2nd, 3rd, 4th, 6th, and 8th days with overall reduction (73.14±8.55). The regent insecticide was found to have more efficacy power on the 2nd day as compared to other post-spray days, respectively. (Saini and Sharma, 1970) used 10 different insecticides were applied under field conditions, and from all insecticides mevinphos 0.01%, malathion 0.05%, endrin 0.025%, and parathion 0.025% proved with a high reduction rate against *P. demoleus* larvae. The bioneem plus+1.0 ml/l of water, bioneem plus+0.5 ml/l of water voliam flexi 300SC+1.0 ml/l of water, voliam flexi 300SC+0.5 ml/l of water, and control were applied against the larvae of *P. demoleus*. The maximum population reduction was reported by the application of voliam flexi 300SC+0.5 ml/l and the lowest bioneem plus+0.05 ml/l but in the control plot, no reduction was observed (Khan and Molla, 2021). ANOVA found with significant difference in replications (DF=2; F= 15.00; P= 0.04), and (DF= 4; F= 12.34; P= 0.02) in post-treatment days. The comparison of homogenous groups was done through LSD and T-test recorded at ($P<0.05$) among the homogenous groups as shown in Figure 2.

Application of Coragen insecticide on lemon leaves against *P. demoleus*

The one-acre containing 40 lemon orchards was sprayed with coragen insecticide and before 24 hours of spray mean pre-data of *P. demoleus* larvae were taken and counted as (7.30±2.70), (7.20±2.68), and (7.00±2.65). The reduction % was recorded as (94.36±9.71) (2nd day), (92.52±9.62) (3rd day), (85.65±9.25) (4th day), (77.98±8.83) (6th day), (69.05±8.31) (8th day), with overall reduction (83.91±9.16) after 1st post-spray. In field condition the reduction of the insect pest found (88.32±9.40) (24^h), (84.81±9.21) (48^h), (83.07±

9.11) (72^h), (74.12±8.16) (120^h), (58.81±7.67) (120^h), with overall reduction (77.83±8.82) after 2nd post-spray. In the 3rd spray reduction of the pest was recorded (84.82±9.21) (2nd day), (78.35±8.85) (3rd day), (73.26±8.56) (4th day), (58.37±7.74) (6th day), (52.33±7.23) (8th day), with overall reduction (69.43±8.33), respectively. In Uruguay, imidacloprid, abamectin, difenoconazole, and spinosad were applied on the leaves of orange and mandarin and proved more effective against citrus insect pests (Besil *et al.*, 2019). The coragen insecticide seemed with more efficacy power on the 2nd day compared with other post-spray days. ANOVA found in significant difference (DF= 2; F= 54.81; P= 0.02) in all replications and (DF= 4; F= 34.35; P= 0.01) in post-spray days. The LSD of all pairwise homogenous groups were taken at ($P<0.05$), as shown in Figure 3.

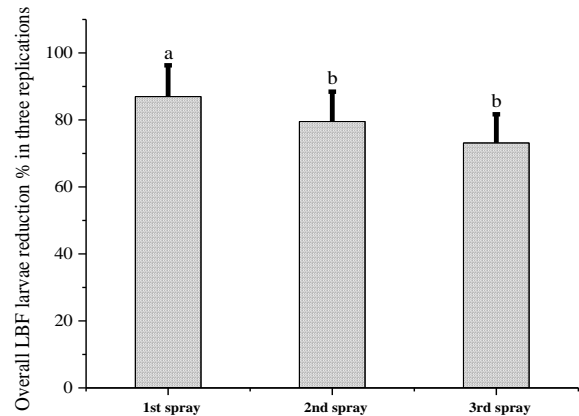


Figure 2. Overall LBF reduction % at post-treatment of regent insecticide under field conditions during, 2020

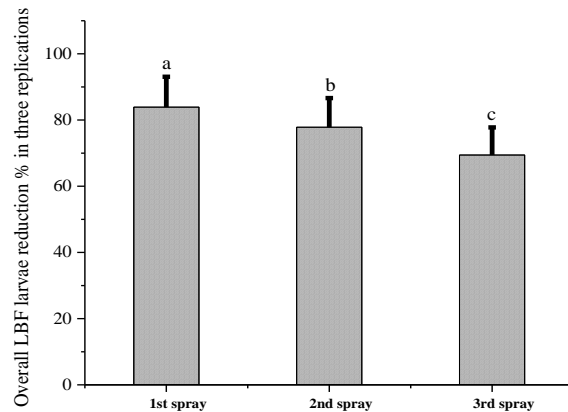


Figure 3. Overall LBF reduction % at post-treatment of coragen insecticide under field conditions during, 2020

Application of Helmet insecticide on lemon leaves against *P. demoleus*

The one acre of *C. limon* was individually sprayed with helmet insecticide but before the application

of insecticide, the mean pe-data of the insect pest was recorded as (6.90±2.63), (6.70±2.59), and (6.60±2.57). After 1st spray reduction % (92.54±9.62) (24^h) of post-spray, (90.50±9.51) (48^h), (84.82±9.21) (72^h), (72.82±9.21) (120^h), (75.91±7.61) (168^h) with overall reduction (79.72±8.93) was recorded. The reduction counted (87.45±9.35) (2nd day), (83.68±9.15) (3rd day), (80.15±8.95) (4th day), (74.04±8.60) (6th day), (53.13±7.29) (8th day) with overall reduction (75.69±8.70) in 2nd spray. The reduction % of the pest was found (76.85±8.77) (24^h), (75.12±8.77) (48^h), (69.45±8.33) (72^h), (61.04±7.81) (120^h), (52.11±7.22) (168^h) with overall reduction (66.91±8.18), respectively. The bioneem plus 1EC+ 1ml/L-1 of water, chlorfenapyr 5SG+1gl/L-1 of water, imidacloprid 70WG+0.5 gl/L-1 of water, spinosad 45SC+1.25ml/L-1 of water and control water spray were evaluated. The highest leaf infestation (31.83%) was recorded on un-treated plants, the lowest (17.83%) on plants treated with chlorfenapyr and spinosad, intermediate (20.58% to 21.33%) treated leaves with bioneem plus and imidacloprid against the larvae of *P. demoleus* (Haque *et al.*, 2019). The reduction % occurred on the 2nd day followed by other post-spray days. The ANOVA found with significant difference (DF= 2; F= 59.48; P= 0.01) in sprays replications and (DF= 4; F= 26.49; P= 0.03) in post-spray days. The LSD among the homogenous groups was found at ($P<0.05$), as shown in Figure 4.

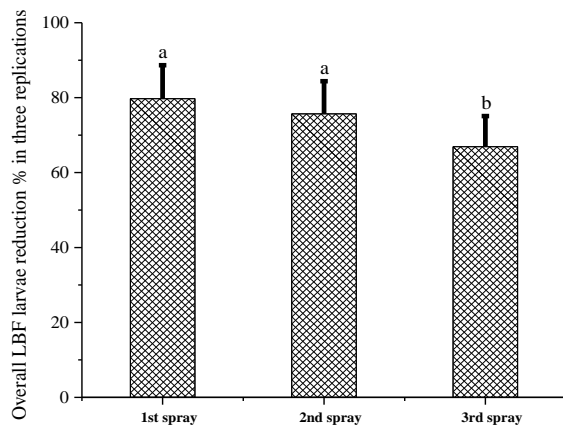


Figure 4. Overall LBF reduction % at post-treatment of helmet insecticide under field conditions during, 2020

Application of Emamectin insecticide on lemon leaves against *P. demoleus*

One acre of lemon orchards containing forty plants was sprayed with emamectin insecticide and the mean data of the pest population was recorded before twenty-four hours of the spray

recorded as (6.60±2.57), (6.50±2.55), and (6.30±2.51). The reduction % of the pest was recorded as (90.65±9.52) (2nd day), (86.76±9.31) (3rd day), (80.60±8.98) (4th day), (73.61±8.58) (6th day), (60.88±7.80) (8th day) with overall reduction (78.50±8.86) in 1st spray. In 2nd spray (85.44±9.24) (24^h), (81.50±9.03) (48^h), (77.84±8.82) (72^h), (71.33±8.45) (120^h), (75.05±7.55) (168^h) with overall (74.63±8.64) reduction was counted. While as; in the 3rd spray, the reduction was recorded (75.64±8.70) (2nd day), (71.93±8.48) (3rd day), (65.71±8.11) (4th day), (56.46±7.51) (6th day), (52.61±7.25) (8th day) with overall reduction (64.47±8.03) post-spray, respectively. The talstar, polytrin, Amazone, and confidor insecticides were used to determine the effectiveness against *Citrus psylla*. The polytrin insecticide proved more effective (Iqbal *et al.*, 2022). The 100% population reduction in the 3rd instar stage of *P. demoleus* was documented after the application of *Bacillus thuringiensis* and spinosad (Segarra-Carmona *et al.*, 2010). After insecticide application, most efficacy was observed 2nd day as compared with days replication. ANOVA found (DF=2; F= 74.91; P= 0.03) significant in replications and (DF= 4; F= 56.26; P= 0.02) in post-spray days. The LSD among the replication and larvae reduction % was calculated at ($P<0.05$), as shown in Figure 5.

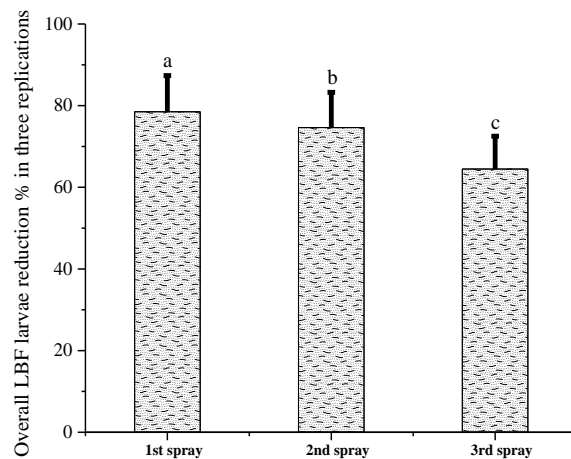


Figure 5. Overall LBF reduction % at post-treatment of emamectin insecticide under field conditions during, 2020

The *P. demoleus* larvae population in the Control plot on lemon orchards

One acre of *C. limon* was individually kept for control and before water wash spray pest population data was counted as (7.10±2.66), (8.20±2.86), and (7.20±2.68). The mean population of the pest was recorded as (6.90±2.63) (2nd day), (6.50±2.55) (3rd day), (6.10±2.47) (4th day), (5.30±

2.30) (6th day), (4.40±2.10) (8th day) with an overall mean (5.84±2.42) in 1st water spray. The mean population recorded (7.80±2.79) (24^h), (7.50±2.74) (48^h), (7.40±2.72) (72^h), (6.60±2.57) (120^h), (4.70±2.17) (168^h) with overall (6.80±2.61) mean population of the pest. In 3rd water, spray means population recorded (6.10±2.47) (2nd day), (5.70±2.39) (3rd day), (5.00±2.24) (4th day), (4.20±2.05) (6th day), (4.10±2.02) (8th day) with overall (5.02±2.24) mean population of the pest, respectively. Our findings are with the work agreement of (Ghafoor *et al.*, 2019) suggested spinosad for the population reduction of *D. mangiferae*. The parasitoid species and bio-pesticides can offer an effective and safe alternative to conventional insecticides for pest population control (Rupak and Sikha, 2019). From eight locations of citrus groves in central Florida, adults of *D. citri* were collected and resistance of 10 insecticides was recorded by using a bottle bioassay, imidacloprid, spinetoram, dimethoate, cyantranilprole, flupyradifurone, chlorpyrifos, bifenthrin, fenpropathrin, and carbaryl. Moderate resistance was found after the application of thiamethoxam and low resistance with the application of cyantranilprole and imidacloprid (Chen *et al.*, 2018). The ANOVA found significant difference (DF= 2; F= 22.68; P= 0.02) water washed post-sprays and (DF= 4; F= 29.15; P= 0.02) water washed spray post-days. The LSD and T-tests were taken at (P<0.05), for the variation among the homogenous groups, and validation is shown in Figure 6.

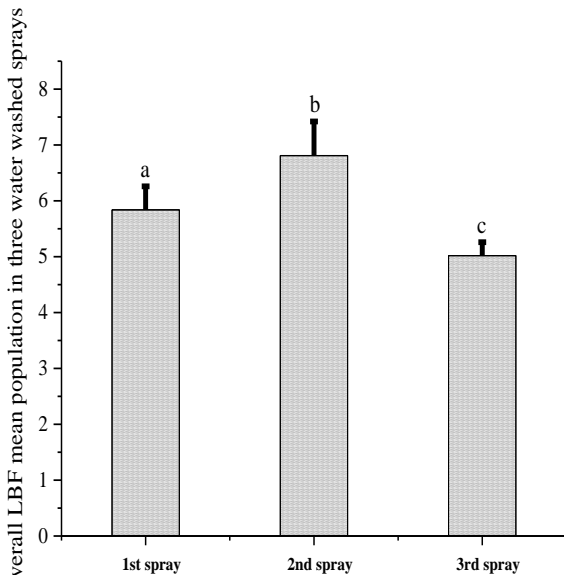


Figure 6. Overall LBF mean population at post-treatment of water washed sprays in control plot under filed conditions during, 2020

Overall toxicant efficacy of five insecticides against *P. demoleus* on lemon leaves

Before the application of any insecticides, the overall mean population of the insect pest was recorded in pre-treatment as (7.77±2.78). The *C. limon* containing one acre in which sprayed with belt insecticide, followed regent sprayed (7.43±2.73), coragen sprayed (7.17±2.68), helmet sprayed (6.73±2.59), emamectin sprayed (6.47±2.54), and (7.50±2.74) in the control plot. The belt insecticide proved more effective in population reduction % and recorded as (91.80±9.58) (2nd day), (89.39±9.45) (3rd day), (83.93±9.16) (4th day), (75.32±8.86) (6th day), (64.50±8.03) (8th day) with reduction (80.99±9.00), respectively. The efficacy of the regent insecticide recorded (89.45±9.46) (2nd day), (86.79±9.32) (3rd day), (82.19±9.07) (4th day), (76.32±8.74) (6th day), (64.67±8.04) (8th day) with overall reduction (79.88±8.94) against the population of the pest. The reduction counted (89.17±9.44) (2nd day), (85.23±9.23) (3rd day), (80.66±8.98) (4th day), (70.16±8.38) (6th day), (60.06±7.75) (8th day), with overall reduction (77.06±8.78) with the application of the coragen insecticide. With the application of helmet insecticide (85.61±9.25) (2nd day), (83.10±9.12) (3rd day), (78.14±8.48) (4th day), (69.30±8.32) (6th day), (54.38±7.37) (8th day), with overall reduction (74.11±8.61) reduction was counted. The minimum reduction was recorded after the application of emamectin (83.91±9.16) (2nd day), (80.06±8.95) (3rd day), (74.72±8.64) (4th day), (67.13±8.190) (6th day), (56.85±7.54) (8th day) with overall reduction (72.53±8.52), as compared with other insecticides. While as; the mean reduction in the control plot was recorded as (6.93±2.63) (2nd day), (6.57±2.56) (3rd day), (6.17±2.48) (4th day), (5.37±2.32) (6th day), (4.40±2.10) (8th day) with overall mean reduction (5.89±2.43), respectively. The effect of thiamethoxam, imidacloprid, neonicotinoids, and chlorantranilprole was examined against the probing behavior of *C. liberibacter asiaticus* responsible for the transmission of huanglongbing disease in citrus through the contact of *D. citri*. All insecticides reduce the 73% to 57%) psyllids population when test plants were sprayed with systematic insecticides (Carmo-Sausa *et al.*, 2020). The ANOVA of all five insecticides found at (DF=4; F= 225.68; P= 0.01) significant difference post-spray days and (DF= 5; F= 28.97; P= 0.02) in treatments. The LSD of all treatments and post-spray days was found (P<0.05), further justification is given in Figure 7.

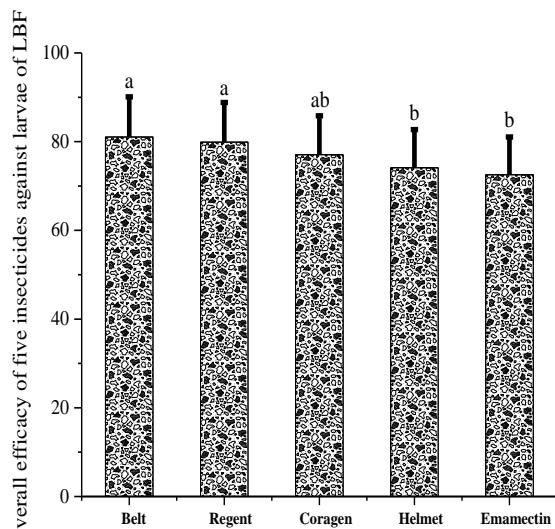


Figure 7. Overall comparative toxicant efficacy of five insecticides against larvae of LBF under field conditions during, 2020

Overall efficacy of five insecticides against *P. demoleus* in post-spray days on *Citrus limon*

After the application of all five novel insecticides, the maximum reduction % was counted with the application of a belt followed by the regent, coragen, helmet, and emamectin against the population of *P. demoleus*. The overall efficacy of all five insecticides after post-treatment was recorded (74.48±6.63) (2nd day), (71.86±8.47) (3rd day), (67.64±8.22) (4th day), (60.60±7.48) (6th day), (50.81±7.12) (8th day), respectively. All insecticides were proved with maximum reduction (2nd day) followed by other post-spray days. The *C. javanica*, and spinetoram were mixed with white oil, against Asian citrus psyllids and observed 100% population reduction (Avery *et al.*, 2021). The sub-lethal and lethal effects of 11 insecticides were assessed against *Ceraeochrysa cubana*. The malathion and chlorpyrifos were observed with lethal effects and lambda cyhalothrin+ chlorantraniliprole, azadirachtin, thiamethoxam+lambda-cyhalothrin, thiamethoxam with sub-lethal effects (Rungo *et al.*, 2019). ANOVA was found with a significant difference (DF= 5; F= 225.68; P= 0.03) on post-spray days. The LSD, T-test was recorded through (P<0.05) student package (8.1) the USA, (SWX) software. The overall maximum to minimum population reduction % graph of post-spray on different days was formulated with the help of Origin 2017 64 Bit graphing and analysis software as shown in Figure 8.

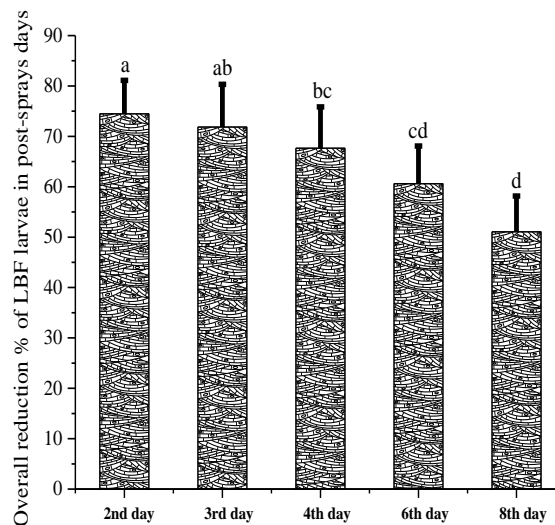


Figure 8. Overall post-spray efficacy of five insecticides against the larvae of LBF in different days under field conditions during, 2020

CONCLUSION AND RECOMMENDATIONS

In the present research study, five insecticides were applied, under field conditions against the larval population of *P. demoleus*, and toxicity comparisons of the recommended insecticides were subjected to analysis. The belt insecticide found with more efficacy power against the population reduction % of *P. demoleus* larvae at 80.99, regent 79.88, coragen 77.06, helmet 74.11, emamectin 72.53, control 5.89 mean. It is further recommended to modify the phytosanitary, grade standards, international quality criteria, fruit packaging, and certain norms of fruits are needed. These factors must improve the fresh citrus fruits value in international trade markets. The lemon butterfly is the plague of *C. limon* and causes an extensive hazard to the citrus industry in Sindh, Pakistan. It is strongly needed to make quick steps, and appropriate eco-friendly management to bring immediately restriction measures to control the population of this vigorous insect pest and secure the citrus industry. The present research study is the first attempt to explore and control the population of the *P. demoleus* in the lemon orchard through the application of novel insecticides under field conditions in the district Naushahro Feroze, a Sahati central region of Sindh, Pakistan. Previously, there is no such type of research has been reported from this area in this scenario, present strong stout scientific research work will be a supportive tool in a population reduction of *P. demoleus*, the plague insect pest of citrus varieties.

IMPACT STATEMENT

The citrus especially, citrus lemon is the main economical and commercial commodity of this area but is massively harmed by varieties of citrus insect pest species. It is mandatory to bring attentiveness and through integrated pest management strategies certain control measures should be applied to combat from the vigorous citrus insect pest and to secure the citrus fruits and industry. Keeping in viewpoint this research study was performed to compare the toxicant efficacy of mentioned five insecticides against the population of *P. demoleus*.

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AUTHOR'S CONTRIBUTION

W. M. Mangrio: The conducted research, took data, analyzed

H. A. Sahito: Wrote the article under the kind supervision

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