USE AND IMPACT OF INSECTICIDES IN MEALYBUG CONTROL.

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Abstract

Mealy bugs infests anumber of crop plants and results a serious economic loss. Although, there are a number of insecticides to overcome the yeild losses in crop plants. But, the presence of waxy layer around its body that make them so difficult to control by means of insecticides. The waxy coating, high reproduction rate, protection by ants and variety of hosts are some of the factors which contribute to the pest status of this pest insect. Most of farmers mainly rely on synthetic chemicals for the management of cotton mealy bug but due to rising environmental and economic concerns there is a dire need to develop eco and environmental friendly measures to combat this menace. The use of synthetic insecticides is extremely toxic to natural enemies of mealy bugs. Plant derivatives can be used as an alternative approach to synthetic chemicals which are cost effective, easily available and safe to environment and biocontrol agents. Similarly, olfactory studies show that odors emitted from plant and mealy bug itself can also be used in pest management strategies.

Keywords: *economic loss, yeild losses, management, biocontrol agents, pest*.

1.INTRODUCTION

Mealybugs (Hemiptera: Pseudococcidae) are small, soft-bodied, plant sucking insects which embrace the second largest family of scale insects (Pseudococcidae) and comprises approximately 2000 species belonging to 300 genera. Their common name is due to the waxy material which covers the bodies of adult females [1,2].

Mealybugs are sexually dimorphic, the female is wingless and does not experience complete metamorphosis, i.e. do not have pupal stage on the other hand males are winged and have complete metamorphosis. Males have two long pairs of white waxy tails. They have non functional mouth parts and live for only 2-4 days [3]. Male passes through four developmental stages, i.e. egg, larva, pupa and adult while female passes through three developmental stages of egg, larva and adult. The fully grown adult female is covered with white waxy powder and has yellowish white color with some black spots on the dorsal side of the body.

Mealybugs of genus Phenacoccus attack a wide variety of crops, fruits, vegetables, ornamentals and weeds but cotton is the prime target. In the initial stage it breeds on all types of weeds round the year and then migrates to cotton crop. Mealybugs have been reported to appear and survive on poorly grown cotton crop [4]. The insect damage at initial stage appears in small pockets and then spreads to whole field.

The co-evolutionary relationship among mealy bug hosts and its parasitoids appear to be strong and successful classical biological control strategy against mealybugs [5]. Two potential parasitoids, the encyrtids *Gyranusoidea tebygi* and *Anagyrus mangicola* are reported to control *R. invadens*. The experiments revealed that *G. tebygi* can control *R. invadens* density even more as comared to *A. mangicola* [6].

All over the world scientists are working for development and establishment of plant based pesticide, usually called as phytopesticide, botanical pesticide, biopesticide or natural pesticides [7,8]. Exposure of mealy bug eggs to sun, removal of alternative host plants and conservation of natural enemies by using garlic oil or neem seed extract around the trunk of trees and application of alkathane bands can eradicate mango mealybug population [9]. Biological activities of neem based insecticides are known for more than 400 pest insects, which has minimal toxicity to non target organisms such as parasitoids, predators and pollinators [10,11].

Although, there are a number of chemical control strategies to overcome the yeild losses in crop plants due to mealy bug attack (Table 1).The use of synthetic insecticides is extremely toxic to natural enemies of mealy bugs (Table 2). The natural enemies include predators such as *Chrysoperla carnea*, *Hippodemia convergens*, *Coccinella septempunctata*, *Brumus saturalus* and *Cryptolaemus montrouzieri.* Azadirachtin and numerous other compounds derived primarily from *Azadirachta indica* A. Juss have insecticidal, antifeedant, and toxicological properties for pest insects control [12-15]. These biological activities of neem based insecticides are known for more than 400 pest insects [16]. Plant derivatives can be used as an alternative approach to synthetic chemicals which are cost effective, easily available and safe to environment and bio control agents. In this paper, we have highlighted the use of insecticides to control mealy bugs and its side effects to bio-control agents. Similarly, olfactory studies show that odors emitted from plant and mealy bug itself can also be used in pest management strategies.

2.USE OF INSECTICIDES

2.1 Control of Phenacoccus solenopsis:

The efficacy of different synthetic insecticides and neem oil against cotton mealybug, *Phenacoccus solenopsis* was tested under laboratory and field conditions in cotton crop. Insecticides, Commando (97% DF), Confidor (20% SL), Lannate (40% SP), Actara (25 WG) were applied at field recommended doses. Neem oil was applied @ 1.5 and 2.0% concentration. In laboratory, Commando resulted 95.2% mortality after 72 hours of exposure. But Commando was persistant as compared rest of insecticides tested. In field, Commando caused 80.6% mortality of the mealybug that was significantly higher than Confidor (73.29%), Lannate (70.93%), Actara (74.36%) and neem oil @ 1.5% (43.48%) and 2.0% (52.97%) concentration. Results revealed that neem oil was less toxic than the rest of the synthetic insecticides at both concentrations but it significantly reduced the population of mealy bug and remained effective

Table 1: Showing the effectiveness of different insecticides on different mealy bug species.

S.N	INSECTICIDE APPLIED	RESULT	REFERENCES
1	Confidor, Lannate, Actara, neem oil	Most effective: Neem oil	[17]
2	Mustang (zetacyper 2% + ethion 36% + 98.8 ml H_2SO_4 + 1186 g soda ash), Curacron (profenofos)2, Supracide (methidathion), Lorsban (chlorpyrifos), Lannate (methomyl)	Least effective: Mustang	[18]
3	Spirotetramate (12%) + imidacloprid (36 %), spirotetramate 150 OD, imidacloprid 200 SL, thiodicarb 75 WP and profenophos	Most effective: Profenophos	[19]
4	NSKE, Neem oil + Nirma powder, Nirma powder, *Verticillium lecanii, Beauveria bassiana, Metarhizium anisopliae, Photorhabdus luminescens,* Fish oil rosin soap, Mealy Quit, Acephate, Chlorpyriphos	Most effective: Acephate	[23]
5	Profenophos, Carbaryl, triazophos	Most effective: Profenophos	[20]
6	Profenophos, triazophos, carbaryl	Most effective: Triazophos	[21]
7	Buprofezin, carbaryl, chloropyriphos	Most effective: Buprofezin	[22]

for a long period of time [17].

Different Field experiments were conducted against cotton mealybug (*Phenacoccus solani* Ferris) during Kharif 2006 and 2007 in Pakistan to evaluate the efficacy of four insecticides viz. Mustang 380 EC @ 2964 and 1976 ml (zetacyper 2% + ethion 36% + 98.8 ml H_2SO_4 + 1186 g soda ash), Curacron 50 EC (profenofos) @ 1976 ml, Supracide 40 EC (methidathion) @ 1235 ml, Lorsban

40 EC (chlorpyrifos) @ 2470 ml and Lannate 40 SP (methomyl) @ 741 g per hectare. All the tested insecticides registered significant control of the pest up to 7 days after treatment during both years. Supracide, Curacron, Lorsban and Lannate were proved to be economical and effective up to 3, 5 and 7 days after treatment (DAT) with mortality range of 85.74 to 95.69 percent and 83.17 to 93.72 percent during 2007 and 2006, respectively. Mustang @ 2964 ml and 1976 ml per hectare was the least effective treatment and registered 72.11 to 84.38 percent population reduction over control for 3, 5 and 7 days after treatment [18].

The effectiveness of combination of spirotetramate (12%) + imidacloprid (36 %) 480 SC, spirotetramate 150 OD, imidacloprid 200 SL, thiodicarb 75 WP and profenophos 50 EC against the mealybug, *P. solenopsis* was investigated on Bt cotton during 2007 and 2008. The results indicated that application of Spirotetramate (12%) + imidacloprid (36 %) 480 SC @ 625 ml/ ha proved to be the most effective combination and significantly reduced the mealybug infestation as compared to other treatments. The lowest population reduction was observed in spirotetramate 150 OD alone treatment. Profenophos registered highest reduction of 86.5, 92.2 and 96.5% respectively in mealybug population after 3, 7 and 10 days of spray [19].

It was reported that profenophos to be the most effective against *P. solenopsis* under field conditions and caused 90.66% population reduction. Carbaryl (89.56) and triazophos (88.66%) also provided good control of the pest [20].

In an experiment, nine of insecticides were evaluated against *P. solenopsis* in laboratory and field conditions during 2006-07 in India. Among them profenophos (0.05%), triazophos (0.04% and carbaryl (0.2%) resulted into significant reduction in mealybug population both under laboratory and field conditions. Maximum (2759 kg/ha) seed cotton yield was obtained from profenophos treatment followed by triazophos (2679 kg/ha) and carbaryl (2644 kg/ha). Triazophos proved profitable with the maximum cost benefit ratio (1: 21: 70) [21].

Field experiments during 2007-09 were conducted on farmer fields in India to evaluate the efficacy of buprofezin, carbaryl and chloropyriphos against mealybug in cotton. The efficacy of buprofezin was found dose dependant. Buprofezin was found to be the most effective insecticide for the control of mealybug on cotton with more than 95 per cent reduction in pest population over control after 3 days after spray followed by carbary and chloropyriphos. Carbaryl and chloropyriphos were found less effective than buprofezin but exhibited statistically significant efficacy as compared with control. Buprofezin exhibited a significant lethal effect against the early and late instar nymphs of *P. solenopsis* under laboratory conditions. It was found more toxic to early instars than late instar nymphs. Highest dose of buprofezin was most effective against both early and late instar nymphs of cotton mealybug [22].

2.2 Control of P. solenopsis and Paracoccus marginatus

Laboratory experiments were conducted to evaluate the efficacy of botanicals NSKE 5%, Neem oil (2.5 l /ha) + Nirma powder (0.1%), Nirma powder 0.1 %, *Verticillium lecanii* 5gm/lit, *Beauveria bassiana* 5gm/lit, *Metarhizium anisopliae* 5gm/lit), Bacterial symbiont of entomopathogenic nematode (*Photorhabdus luminescens*) 20ml/lit, Fish oil rosin soap 2ml / lit., Mealy Quit (New botanical formulation from CICR, Nagpur) 100ml/lit and synthetic insecticides Acephate 700g a.i. /ha, Chlorpyriphos 500g a.i./ha for the management of *P. solenopsis* and *Paracoccus marginatus* on cotton leaves. Acephate registered the highest mortality of 53.3% and

64.44% of *P. solenopsis* nymphs and adults respectively 48 hours after treatment. Similar mortality trend was obtained for all the tested biopesticides. Chloropyriphos and Mealy Quitwere found equally toxic and caused 48.9% mortality at 48 hours after treatment. Similarly acephate caused maximum mortality 55.56% after 48 hours when tested against *P. marginatus*. Chloropyriphos, Mealy Quit and fish oil rosin soap were found equally effective causing 51.1-52.2% mortality at 48 hours after treatment [23].

3.IMPACT OF INSECTICIDES ON MEALY BUG BIO-CONTROL AGENTS

3.1 Impact on *Chrysoperla carnea:*

The impact of fipronil was evaluated on all developmental stages of *C. carnea* using different modes of exposure under laboratory conditions. Fipronil had no significant effect on the hatchability of *C. carnea* eggs at all the tested concentrations. However, caused a significant reduction (40%) in the1st instar larvae of the predator compared with control at the highest (30 mg a.i./l) tested concentration. Topical treatment of pupae on the silken cocoon caused no significant effect on the adult emergence and without any significant effect on the fecundity and fertility of surviving females of the predator. In contrast, the compound caused a significant mortality of *C. carnea* adults even at rates below the maximum field recommended rate by both ingestion and topical treatment methods [24].

Table 2: Showing the side effect of insecticides on mealy bug bio-control agents

S.N	**Toxic insecticides**	**Affected bio-control agents**	**References**
1	Fipronil	*Chrysoperla carnea*	[24]
2	Diafenthiuron, buprofezin, imidacloprid, carbosulfan, methamidophos, acetamiprid, thiamethoxam	*Chrysoperla carnea*	[25]
3	imidacloprid, quinalphos, endosalfon.	*Trichogramma chilonis*, *Chrysoperla carnea*	[29]
4	imidacloprid, pymetrozine	*Chrysoperla carnea*	[26]
5	acetamiprid, dinotefuran, clothianidion.	*Cryptolaemus montrouzieri*, *Leptomastix dactylopii*	[30]
6	imidacloprid, deltamethrin, heptenophos, lamda-cyhalothrin.	*Coccinella septempunctata*	[31]
7	Trichlorfon	*Chrysoperla carnea*	[27]
8	Phosmet, spinosad	*Cryptolaemus montrouzieri*, *Neoseiulus californicus, Aphidius colemani*	[32]
9	Imidacloprid, diafenthiuron	*Chrysoperla carnea*	[28]

Laboratory studies were conducted to find out the toxicity of eight insecticides viz. Diafenthiuron, buprofezin, thiodicarb, imidacloprid, carbosulfan, methamidophos, acetamiprid and thiamethoxam through leaf dip bio assay trials at low, recommended and high level of concentrations against 1st instar larvae of *C. carnea* in Pakistan. Low and recommended concentrations of diafenthiuron and buprofezin were classified as harmless while high concentrations of both insecticides were found slightly harmful to *C. carnea* larvae after 24 hours of exposure period. Thiodicarb was found harmless to *C. carnea* larvae at lower concentration but slightly toxic at recommended and higher concentrations. Acetamiprid and thiamethoxam were found moderately toxic at lower concentration, however, toxic at recommended and higher concentrations. All the tested insecticides were found extremely toxic to *C. carnea* larvae with > 90% mortality after 48 hours except buprofezin and thiodicarb. Pupal formation was recorded lowest (0.00 %) in the acetamiprid and highest (71.7 %) in the buprofezin treated larvae. All the insecticides had no effect on the adult emergence rates at lower concentrations. The adult emergence of survived larvae was highest (65.00%) for buprofezin and lowest (2.00%) for methamedophos [25].

The toxicity of imidacloprid, propargite and pymetrozine was assessed to the two day old larvae of green lacewing, *C. carnea* in the laboratory using residual glass plate bioassays. All the three tested insecticides caused adverse effects on the survival of larvae. Imidacloprid was classified as harmless and caused no significant effect considering the total effect (E = 27.44%) whereas, propargite (E = 49.78%) and pymetrozine (E = 66.9%) were slightly harmful. Life table analysis indicated that imidacloprid and propargite had no significant effects on the intrinsic rate of natural increase (rm), however, pymetrazine recorded a significant reduction (34%) in intrinsic value. Propargite was classified non-toxic to *C. carnea* larvae. The life table analysis exhibited more adverse effects of pymtrozine following the IOBC guidelines [26].

The effectiveness of five pesticides was tested at maximum field recommended concentrations on *C. carnea* under laboratory conditions. The results revealed that abamectin was slightly harmful to *C. carnea* larvae and phosmet and trichlorfon were slightly and moderately harmful to *C. carnea* adults according to IOBC guidelines when exposed to fresh pesticide residues on glass plates. All the tested pesticides were found harmless after spraying of eggs and pupae. Abamectin and trichlorfon were classified as less persistent pesticides and caused between 56.3 and 75% mortality up to 30 days after treatment [27].

The toxicity of imidacloprid and diafenthiuron to eggs, larvae and adults of *C. carnea* was investigated under laboratory conditions. The recommended dose of imidacloprid at 0.28 ml/l recorded 15.38% egg mortality, 26.67 and 33.33 % larval mortality by ingestion and contact methods and 50.00 % adult mortality. The diafenthiuron caused 15.38 % egg mortality, 23.33 % larval mortality and adult mortality of 26.67 %. According to guidelines given by IOBC/WPRS working group on pesticides and non-target invertebrates both chemicals were classified as harmless at the recommended doses [28].

3.2 Impact on *Trichogramma chilonis* and predator *C. carnea*

The relative toxicity of biopesticides like *Pseudomonas fluorescens* strain pf1 and neem oil was compared with imidacloprid, quinalphos and endosalfon against an egg parasitoid, *Trichogramma chilonis* and predator *C. carnea* under laboratory conditions. Biopesticides were found safer to both natural enemies and exhibited no harmful effects on the behaviour and development of natural enemies. The hatchability of *C. carnea* eggs was found maximum (93.00 %) in *P. Fluorescens* and minimum (43.50%) in imidacloprid treatment. Biopesticide *P. Fluorescens* was found harmless and recorded highest parasitism (≈ 73%) and egg development (≈ 72%) of egg parasitoid *T. Chilonis*. It also resulted into highest development (≈ 75%) of *C. carnea* eggs. The parasitoid emergence was recorded 58.9%, parasitizatism, 59.3% and the egg hatchability was 63.1% in neem oil treatment. All the insecticides were found toxic to both natural enemies [29].

3.3 Impact on *Cryptolaemus montrouzieri* and *Leptomastix dactylopii*

The effectiveness of synthetic insecticides buprofezin, pyroproxyfen, flonicamid, acetamiprid, dinotefuran and clothianidion on mealybug destroyer, *Cryptolaemus montrouzieri* and parasitoid *Leptomastix dactylopii* natural enemies of citrus mealybug *Planococcus citri* was evaluated under laboratory conditions. Dinotefuran was found extremely toxic at label rate to the adult parasitoid producing 100% mortality within 24 hours, whereas, buprofezin, pyriproxyfen and flonicamid were found harmless. Insecticides dinotefuran, acetamiprid and clothianidin were harmful to parasitoid at 4x the recommended label rate causing 100% mortality 72 hours after application. In contrast buprofezin and flonicamid both were totally harmless to *L. Dactylopii* with 100 % adult survival after 72 hours. Pyriproxyfen and flonicamid, both at label and at 4 x the recommended label rate did not affect the parasitisation rate or adult emergence of *L. Dactylopii*. Acetamiprid, dinotefuron and clothianidin were extremely toxic to C. montrouzieri adults causing 100 % mortality after 48 hours, whereas, buprofezin, pyriproxyfen and flonicamid exhibited negligible (10-20 %) mortality [30].

3.4 Impact on *Coccinella septempunctata*

Laboratory studies were conducted to find out the toxicity of five insecticides (Pyriproxyfen, imidacloprid, deltamethrin, heptenophos, lamda-cyhalothrin and *Bacillus thuringiensis* Berliner subsp. tenebrionis) through surface contact method to adults of seven-spotted lady bird beetle *Coccinella septempunctata*. Based on the classification given by IOBC, preparations of pyriproxyfen and *B. thuringiensis* were classified as harmless to adult *C. septempunctata*, however, the other two preparations deltamethrin+heptenophos and lamda-cyhalothrin were classified as moderately harmful. According to LT_{50} values, lambda-cyhalothrin was declared as moderately harmful whereas, the combination of deltamethrin+heptenophos was found extremely toxic to adult *C. septempunctata* [31].

3.5 Impact on *Cryptolaemus montrouzieri*, *Neoseiulus californicus* and *Aphidius colemani:*

The efficacy of four insecticides was investigated against Mediterranean fruit fly and measured their side effects on three natural enemies, *Cryptolaemus montrouzieri*, *Neoseiulus californicus* and *Aphidius colemani* under laboratory conditions. All the tested insecticides causes significantly higher mortality of *C. montrouzieri* (≈ 60%) compared with control. The toxic effects of karate king were faster compared with other treatments when ten day old *C. montrouzieri* adults were exposed to; fresh residues, 3-day old residues and 6-day old residues. However none of the insecticide caused any significant effect on the fecundity and fertility of the surviving females in any case [32].

4.OLFACTORY RESPONSES OF MEALY BUGS AND BIOCONTROL AGENTS USING PLANT VOLATILES

4.1 Use of Cassava plant:

The response of predatory ladybeetle, *Exochomus flaviventris* towards cassava mealybug, *Phenacoccus manihoti* was tested using Y-tube olfactometer. The response of *E. flaviventris* to the odor of cassava plant, unparasitized mealybugs, plant–mealybug complex with or without feeding prey (parasitized or not), and plant–mealybug complex with or without conspecific coccinellids was investigated. Dual-choice tests revealed that mealy bug infested plants were preferred to *P. manihoti* alone and mealybug-damaged plants. Similarly, mealy bug damaged plants are found to be the major source of volatiles that attract *E. flaviventris* to its prey. Female *E. flaviventris* showed a preference for sources of odor from an infested plant with conspecific predator females (alone or with conspecific males) as compared to uninfested plants. Female *E. flaviventris* preferred infested plants with unparasitized *P. manihoti* over the plant infested with parasitized *P. manihoti*. The results revealed that *E. flaviventris* females use herbivore-induced plant volatiles to detect its prey [33].

In an experiment, the host finding capability and effectiveness of parasitoid wasp, *Epidinocarsis lopezi* was tested towards cassava mealybug, *Phenacoccus manihoti* in cassava field. Using a four-armed olfactometer, the effect of host-plant odors to female *E. lopezi* was determined. In this experiment, 50 choices were made between the odour and a blank, or between two odors in choice test experiments. Female *E. lopezi* were attracted by mealybug-infested cassava leaves, but not by the odor of cassava mealybugs alone or by uninfested plants. These results revealed that *P. manihoti* infested plants are attractive towards *E. lopezi*. It was concluded that *E. lopezi* uses the odour which is emitted from infested cassava plants to find its host in field [34].

4.1 Use of Mango plant:

The host stage selection and sex allocation behaviors of *Anagyrus mangicola* was tested towards mango mealybug, *Rastrococcus invadens.* For this purpose, choice and no-choice tests were performed under controlled conditions. All instars of *R. invadens* were parasitized significantly as compared to first instar. However they preferred host feeding. Population of female wasps emerging from any size of host was significantly higher as compared to males. Similar results were found when *Gyranusoidea tebygi* was tested to control *R. invadens*. The results revealed that both *G. tebygi* and *A. mangicola* parasitoids can be used to control populations of *R. invadens* successfully [35].

The efficacy of parasitoid *Gyranusoidea tebygi* was tested against mango mealybug, *Rastrococcus invadens,* in mango trees using paired sleeve cages. Sleeve cages left open and allowed for *G. tebygi* attack. It was found that *G. tebygi* reduced mealybug levels 2.7-fold within 1.5 host generations as compared to the closed-sleeve cages. In open-sleeve treatment a parasitism index was found up to 34.4%. The results revealed that the lower level of the mealybug population on uncaged leaves as compared to the one on leaves protected by open cages is attributed to higher mortality. This was due to parasitism and abiotic factors such as rain and wind [36].

5.OLFACTORY RESPONSES OF LADY BEETLES TOWARDS MEALY BUGS ODORS

The olfactory response of mealybug ladybird, *Cryptolaemus montrouzieri* was tested at varied levels of its starvation in controlled conditions. Results indicated that *C. montrouzieri* oriented more significantly to its prey odor when it was starved for certain period of time as compared to without starvation. Both larvae and adult of *C. montrouzieri* showed maximum response towards its prey at 4, 8, 12, 12 and 24 hours of starvation. Continued starvation for more than certain ideal period can affect predator olfactory response negatively. But *C. montrouzieri* responded positively for longer period of its starvation. It is concluded that *C. montrouzieri* can search its prey by its odor and it can maintain its population in mango orchards for a long without food [37].

Experiments were conducted to study the biology and predation of mealybug ladybird, *Cryptolaemus montrouzieri* on mealybugs, *Planococcus citri* and *Dactylopius tomentosus* under controlled conditions (29.4-32.1°C, 65-71% RH). *C. montrouzieri* completed its life cycle on both species, but preferred *P. citri* as compared to *D. tomentosus*. The egg and larval periods were 4.00 and 12.42 days with *P. citri*, and 4.23 and 17.67 days with *D. tomentosus*. The male to female ratio was 1:1.75 and 1:1.49, respectively. Feeding preference by *C. montrouzieri* on *P. citri* was twice that with *D. tomentosus* (150.83 and 72 mg, respectively). The results revealed that *C. montrouzieri* is an efficient biological control agent for several mealy bug species [38].

CONCLUSION

Biological control of mealybug on cotton crop can yield promising results. Several predators such as *Chrysoperla carnea*, *Hippodemia convergens*, *Coccinella septempunctata*, *Brumus saturalus* and *Cryptolaemus montrouzieri* can be used for the effective management of cotton mealybug on cotton crop. Several genera of coccinalids feed voraciously on all larval instars of cotton mealybug. An Australian lady bird beetle *Cryptolaemus montrouzieri* commonly known as mealybug destroyer is considered an important predator of mealybug. It is a voracious feeder of cotton mealybug in both the larval and adult stages. In larval stage it resembles with its prey, the mealybug, although they are almost twice as large as the adult female mealybug. They are most effective when mealy bug populations are high. Similarly, olfactory studies show that odors emitted from plant and mealy bug itself can also be used in pest management strategies. These odors show negligible activity to environment and attract the natural enemies.

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