STUDIES ON SOME ASPECTS OF INSECT – PLANT INTERACTIONS

By

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AN ABSTRACT OF THE THESIS

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ABSTRACT

Since the collapse of synthetic compounds in combating and controlling insect pests, there is an urgency to explore other source of insecticides from the plant world. With the advent of Integrated Pest Management, insecticides from botanical sources have also found a major role to play. Although many plant families are rich in such insecticidal sources, somehow their applications in Integrated Pest Management have been largely restricted due to many technical reasons; one may be due to the cost involved in synthesis and production of such compounds in large scale. So the alternatives are either in the form of crude extracts or semi purified forms. The North Eastern Region is rich in flora and fauna, and the human population still depends largely on rice cultivation and production as their livelihood.

The immediate problem is to control the insect pests of rice in the field. One such insect pest is the small rice grasshopper, *Oxya hyla*, which is emerging as a major pest of rice in this region and in adjacent countries.

With this view in mind, the present investigation was undertaken. Common plants namely, *Ageratum conyzoides*, *Artemisia nilagarica*, *Eupatorium adenophorum*, *Eupatorium riparium* and *Lantana camara* were chosen for source of crude extracts for assaying their insecticidal activity against the small rice grasshopper, with the aim of controlling the pest at any stage of its life cycle.

Out of the five plants assayed only *Ageratum conyzoides* has been observed to show more positive results against this pest in comparison to other plants tested. The extracts of this plant apart from disrupting behaviour, feeding and molting in the nymphs and adults, also disrupt normal digestive physiology and affect the histology

of the gastrointestinal epithelial cells of the insects. The extracts also show some inhibition in amylase activity. Another observation is that, the testicular cell cycle is also affected, where some stages like Diplotene of Prophase I, Metaphase I, Metaphase II and Telophase stages are arrested.

Closely monitored experiments in laboratory conditions show that various indices like consumption, growth and conversion efficiencies, etc were affected when specific stages were fed on host leaves *Oryza sativa*, treated with extracts of *A. conyzoides*, and also with the active compounds of *A. conyzoides*, Precocene I and II.

In field experiments where rice plots were sprayed by extracts of *A. conyzoides*, it was observed that the attack by *O. hyla* was lesser than in control plots, thereby leading to higher yield.

Being crude extracts, either in methanol or aqueous, the possible field application of such extracts in controlling the invasion of *O. hyla* in paddy fields during the growing season may be largely controlled. Thereby, paving the way for safer, cheaper, more ecofriendly and biodegradable insecticides from plants source, which may not induce resistance in insects.

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DEDICATION

SPECIALLY TO DEAREST MOM (L) LESIE, & DAD, SISTERS AND BROTHERS

NORTH – EASTERN HILL UNIVERSITY
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DECLARATION

I, Dainingstar Marngar, do hereby declare that the subject matter of this thesis is a record of work done by me, that the contents of this thesis did not form the basis of the award of any previous degree to me or to best of my knowledge to anybody else, and that the thesis has not been submitted by me for any research degree in any other university/institute.

This is being submitted to the North – Eastern Hill University for the degree of Doctor of Philosophy in Zoology.

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After a long journey through the mountains and valleys of darkness, I have finally come to the end of the dark tunnels and into the light, and as I'm walking out, I have to thank all my friends who had walked through the tunnels with me.

As I'm wandering in a vast forest at night, I have only a faint light to guide me. A lovely and kind stranger appears and says to me: 'My friend, you should blow out your candle in order to find your way more clearly.' The stranger is My teacher, my best friend and my Guide, Dr. B. Kharbuli, who officially introduced me to Entomology and dared me to reach new heights in the quest of excellence and for giving me direction. It's been a privilege working and learning from you.

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" Wisdom is the Principal thing: Therefore get wisdom; and with all thy getting get understanding. For Wisdom is better than Rubies; and all the things that may be desired are not to be compared to it." Prov: 4:7 & 9:10.

Dainingstar

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Evolution of Insect – Plant interaction

Four hundred million years ago in Devonian period, plants evolved in terrestrial forms. During the following 40 million years, and the subsequent development of flowering plants have transformed the terrestrial environment into a highly valuable resource with dense vegetation occurred on land together with terrestrial arthropods, including the first insects. By the Carboniferous period, 300 million years ago, all of the major insect orders that feed on plants had evolved. By this time, insects had already partitioned the available food resources, and a number of highly specialized insect feeding types had evolved (Labandeira and Phillips, 1996). Well before 200 million years ago, before the appearance of angiosperms, the number of insect families had already been very high, and by this time some groups disappeared, where as some other groups reappeared. In the last 100 million years, the number of the insect families had more than doubled (Labandeira and Sepkoski, 1993). Proliferation of genera and species in these new groups also appeared to have been extraordinary high, and it is, therefore, among these groups that the explanations for the numerical abundance of herbivorous insects should be found.

Although the extreme diversity of insect herbivores has long been acknowledged, recent phylogenetic studies of insect lineages confirm that herbivorous insect groups are significantly more diverse than their non-herbivorous sister groups (Mitter et al. 1991). This provides important evidence for the role of plants in promoting diversification, which could have occurred by stepwise coevolutionary arms race (Ehrlich and Raven, 1964). This diversification could also have been a result of insects "tracking" plant phylogenies, with minor chemical changes in plants allowing evolving populations of insect to change and spaciate, perhaps long after the chemical changes occurred.

Over the last 100 million years, herbivory has evolved probably 50 or more times independently in several different ancient lineages. The evident success of insect herbivory is somewhat surprising, because the low protein levels of the non-reproductive tissues of most plants make them poor food resources, which enabled the insects to proceed via mixed feeding and switch on for more number of host plants to become generalized types of feeding or Polyphagy. There is evidence that early herbivores from several different orders have relatively specialized diets. For instant, the more primitive groups of grasshoppers tend to be rather specialized, whereas the more derived grasshopper groups such as Acrididae, are generalists.

About one-half of all known species of insects are more or less dependent on plants for their proliferation, shelter, oviposition sites and food. The plants enable the insects to move away from the soil surface and also offer an ideal habitat for their life cycles (Southwood, 1986).

Lawton and Schroeder (1977) first show the relationship between the structural diversity of plants and the richness of their insect fauna. For an insect, the host plant is not merely something to feed on but something to live on (Kennedy, 1953). The fact that these two living systems, plant and insect have evolved together millions of years ago and now co-exist shows clearly their intricate interdependence and interaction.

Insects may be monophagous, oligophagous and polyphagous (Dethier, 1953). Most species of herbivorous insects are monophagous or oligophagous. Polyphagy is generally viewed as the more primitive stage in the evolution of insect-plant interaction (Dethier, 1954). Insects have also frequently been found to switch to a new host plant from a distantly related plant group (Powell, 1980).

These fascinating relationships demonstrate that the insect-plant interactions are complex and highly adaptable. How plant with relatively long generation times and low recombination rates, as compared with their herbivores, have survived in the evolutionary race is a paradox (Whitnam, 1981). The survival of plants through evolutionary time is due to largely to their own defense mechanisms, deterring the feeding of herbivores and toxicity in the widest sense.

Mode of Insect's feeding on plants

Insects acquire nutrients from plants for maintenance, growth and reproduction using a wide variety of mouthparts, in case of grasshoppers the mandibles (Bernays, 1991). There is no evidence that the specialized mandibles of grass-feeding grasshoppers allow them to process grass in the manner that measurably improves digestion compared with the generalized mandibles of many polyphagous grasshoppers (Bernays and Barbehenn, 1987). However, small organisms face a great diversity of natural enemies, and while insects are feeding, their risk of being preyed on may increase 100 fold (Bernays, 1996a).

Cannibalism is more common among generalists than specialists. Among mobile insects such as grasshoppers, individuals switch to different plants and improve their nutrient balance. Such dietary mixing probably has relevance for obtaining adequate levels of carbohydrates and proteins as well as minor but important nutrients.

Plants Defend Themselves from Insect Attack

Plants defend themselves from the attack of insects by storing a number of chemical substances or the secondary plant metabolites which deploy them in two ways (Levin, 1976), (1) a constitutive defense is maintained at all times to repel herbivores through direct toxicity or by reducing the digestibility of plant tissues, and (2) a facultative defense where plants mobilize or produce allelochemicals *de novo* in response to tissues damage from herbivores (Ryan, 1983). These vast numbers of diverse secondary metabolites stored in plants profoundly affect the behaviour of herbivorous insects. These compounds may be repellents or deterrents, insecticides, growth inhibitors, etc that enabled insects to learn to reject a plant (Bernays and Lee, 1988). Many other plant chemicals serve as specific attractants or stimulants for feeding by specific adapted insects.

These secondary plant products have coevolved with insects that would potentially exploit them as a food resource (Berenbaum, 1983). Thus plants are striving to slow down insect attack over evolutionary time by formulating different novel compounds and tirelessly conducting bioassays in order to find out what works and what does not. In return the insect herbivores develop new strategies over evolutionary time to break down some of these defense chemicals to exploit plants if they can. It is because of this never ending back and forth struggles that this vast number of chemical compounds have evolved in the plant kingdom. This defense and counter defense mechanism is known as evolutionary arms race (Ehrlich and Raven, 1964).

The biochemical composition of the plants changes their nutritional quality for the insects (Schultz, 1983a). Some components may function as allomones, repellents, excitants, suppressants, deterrents, toxins, kairomones, attractants, arrestants, feeding stimulants and antifeedants. Insects feeding on host plants containing vast mixtures of allelochemcals usually have problems in utilizing the food efficiently. Toxins often affect efficiently the nutritional indices which in turn affect the growth and reproduction of insects (Reese, 1983). Tannins block the availability of proteins by forming less digestible complexes (Feeny, 1969), and serve as formidable defensive against many grass-feeding acridids and lepidopterous insects (Zucker, 1983). These secondary compounds are classified into groups like alkaloids, terpenoids, phenylpropanes, steroids, phenols and acetogenins (Whittaker and Feeny, 1971).

The distribution of plant defend chemicals within the plant is another important strategy against herbivores. The limited supply of defensive compounds should be available in those regions of the plant that will result in the greatest defense. For example, plant surfaces need greater defense than inner layers of cells in the same region, because surfaces are more likely to come in contact with potential herbivores. It is, therefore, expected that selection has favored a greater concentration of defense chemicals in external tissues, at the appropriate stage of plant growth (McKey, 1979).

Insects Overcome the Defense Mechanisms of Plants

Phytophagous insects live in an environment full of all sorts of plant chemicals. Phytochemicals present in the plant tissues act upon insects when they start feeding on the plants. The responses may be behavioral, physiologic or ecological. Plants display physical and chemical defensive adaptations against insect attack. Obviously no insect utilizes every plant species as food, and conversely, no plant species is susceptible to attack to every species of plant feeding insects.

In spite of host plant variability, suboptimal plant resources, and the vast array of allelochemicals present in the plant world, 'there is scarcely a plant that does not harbour some insect pest' (Frost, 1942). Surprisingly, plant genera containing well known broad spectrum insecticidal chemicals are utilized as host plants by various insect species (Brues, 1946).

These defensive metabolites in plants has let to the concurrent development of insect herbivores with an ability to detect these chemicals, avoid plant tissues with a high allomone content, and preferentially attack plants that are in vulnerable conditions due to stress. However, when specialists consume highly toxic plant compounds, they must be able to metabolize these natural products for their benefits. Indeed, the virtuosity of insects in exploiting plant compounds is so remarkable that it can best be described as 'better insect living through plant chemistry' (Blum, 1992). These phytophagous insects have broken through the plants' allelochemical defenses by using diverse detoxification mechanisms that also fortify their host plants. Some of the toxicants are sequestered by insect herbivores (Bowers, 1990) and once this has been done an allelochemical may be utilized in variety of ways, such as for production of insect's own pheromones or for their own defense. An increased level of dietary nutrient often mitigates the deleterious impact of allelochemicals on insect growth (Slansky, 1992).

It follows that phytophagous insects have evolved mechanism to over come multiple hurdles posed by host plants. Their behavioural, bio-chemical and physiologic activities are regulated through sensory inputs. In addition, their natural physiologic feed back mechanisms and environmental factors enable them to adapt to changing situations (Slansky and Rodriquez, 1987), utilizing an alternative niche (s), increasing the consumption rate, modifying the nutritive quality of the host plant tissues and establishing associations with micro organisms.

This type of response by some insects to nutritionally variable food is the phenomenon of 'self selection', in which individuals consume the most nutritionally suitable tissue or combination of tissues in order to obtain a balance diet (Waldbauer and Friedman, 1991). Feeding preference differs in generalist and specialist insects, the generalist insects avoid young leaves that are rich in toxins and deterrents, while specialist herbivores prefer them because they have tolerance for the toxins produced by their specific hosts (Cates, 1980).

Some other plant species, for example the agricultural crops which have no defensive mechanism, and are susceptible to attack by a number of the phytophagous insect species. These plants need an external protection from the insects' attack. Man since ancient time has used the plant chemicals to control insect pests that destroy crops and other properties. Development and advancement of science and technology with the discovery of synthetic insecticides marked a major break through in the field of crop protection. These chemicals have made great contributions to plant protection but have also raised a number of ecological and medical problems. The environmental problems caused by these xenobiotics have been recognized from time to time as these chemicals lace the food with residues (Parmar and Devkumar, 1993). It has been estimated that hardly 0.1% of the agrochemicals used in crop protection reach the target pests leaving the remaining 99.9% to enter the environment causing hazards to non-target organisms including humans. Effective pest control is no longer a matter of heavy application of insecticides, because excessive use of insecticides promotes faster evolution of resistant forms of pests, destroy natural enemies, turn formerly innocuous species into pests, harm other non-target species and contaminate the food chain.

Basic research for over more than 50 years in biology and biochemistry has made it possible to envisage not only how new insecticides may be synthesized but also a complete new approach for the protection of plants using secondary plant products which may be toxic to a specific pest yet harmless to other non-target organisms and man. There has been a renewed interest in botanical insecticides because of several distinct advantages, insecticidal plants are generally much safer than conventionally used synthetic insecticides. Insecticidal plants have been in nature as its component for millions of years without any ill or adverse effect on the ecosystem. Some plants have more than one chemical as an active principle responsible for one particular biological effect or may have diverse effects (Singh, 1993). Based on these advantages of botanical insecticides, this study has been pursued to tap the insecticidal property of some locally important plants to control the selected crop pest.

Experimental plants selection

Ageratum conyzoides L (Asteraceae), *Artemisia nilagarica* (Clarke) Pamp. (Asteraceae), *Eupatorium adenophorum* Spreng (Asteraceae), *Eupatorium riparium* Regel (Asteraceae) and *Lantana camara* L. (Verbenaceae) are perennial weeds commonly encountered in the open fields, cultivated areas and even in the forest areas in India. The local people to treat many types of ailments and diseases, as well as for repelling insects and other domestic pests traditionally use these plants. They are very common in Khasi Hills and Meghalaya as a whole. On the basis of traditional uses of the plants by the local people of Meghalaya, these plants will be screened for their insecticidal activity against the small rice grasshopper, *Oxya hyla* (Serville) the common pest of paddy (*Oryza sativa*) in the region. Detail study would be conducted on one of the plants exhibiting the highest insecticidal potential for this pest.

Insect selection

The small rice grasshopper, *Oxya hyla* (Serville) is distributed through out North Eastern India as a major pest of rice (*Oryza sativa* L) and other rice growing countries of South East Asia. It is responsible for serious defoliation at all stages of plant growth in the paddy fields of North - East region in general and Meghalaya in particular. After repeated attacks, leading shoots of the affected host plants start dying from tip downwards ultimately leading to poor quality yield. There are few options for suppression of this insect pest other than chemical insecticides although Biological Control remains a promising area for research. *Oxya hyla* was selected as the target insect in the course of study.

Biological Classification

Phylum	:	Arthropoda
Class	:	Insecta
Order	:	Orthoptera
Family	:	Acrididae
Genus	:	*Oxya*
Species	:	*hyla* (Serville)
Common name:		Small Rice Grasshopper

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SCREENING OF PLANTS FOR INSECTICIDAL ACTIVITY AGAINST THE SMALL RICE GRASSHOPPER, OXYA HYLA (SERVILLE)

CHAPTER - 1

INTRODUCTION

1.1 Natural Pesticides from Plants

The plant world is a rich storehouse of biochemical that could be tapped for use as insecticides. The toxic constituents present in the plant represent the metabolites and have a significant role in primary physiological processes in plants that synthesize them (Cooper and Johnson, 1984). Plants are the richest source of renewable bioactive organic chemicals, whose major role in the plants is defensive. Numerous defensive chemicals belonging to various categories like terpenoids, alkaloids, glycosides, phenols, tannins, etc which cause behavioral and physiological effects on insect pests have already been identified.

Over the past 50 years, more than 2000 plant species belong to different families and genera have been reported to contain toxic principles which are effective against insect pests. These insecticidal plants have received global attention for the last two decades.

Several pressures have accelerated the search for more environmentally and toxicologically safe and more selective and efficacious pesticides. The increasing incidence of insecticide resistance is a fueling the need for new insecticides. Furthermore, most synthetic chemicals that have been commercialized have relatively long environmental half-life and more suspect toxicological properties than most natural compounds. Thus, natural compounds have increasingly become the focus of those interested in discovery of new insecticides.

Tens of thousands of secondary plant products have been identified and there are estimates that hundreds of thousands of these compounds exist (Grainage and Ahmed, 1988). There is growing evidence that most of these compounds are involved in the interaction of plants with other species which is primarily the defense of the plant from plant pests (Klocke, 1987; Lydon and Duke, 1989). Thus, these secondary compounds represent a large reservoir of chemicals with varied biological activity. This resource is largely untapped for use as insecticides.

Among the methods prevalent in insect control measures, biopesticide is unique since it has relatively less harmful effects. Unlike organic insecticides, plant-based extracts are ecologically safer, easily biodegradable and do not induce resistance. Plant-base chemicals have been shown to work in various ways. Some are antifeedants and some are repellents, while others are inhibitors of growth and development. Many plant chemicals are known to have antifeedant and insecticidal properties (Banerjee et al. 1985; Reddy et al. 1990; Guddewar et al. 1991; Chitra et al. 1990, 1991; Tripathi and Tripathi, 2000).

1.2 Discovery and development of natural insecticides

Secondary plant compounds are vast and varied with a wide range of biological activities. This diversity is largely the result of coevolution of hundreds of thousands of plant species with each other and with an even greater number of species of microorganisms and animals. Thus, unlike compounds synthesized in the laboratory, secondary plant compounds are virtually guaranteed to have biological activity and that activity is highly likely to function in protecting the producing plant from a pathogen, herbivore, or competitor (Russell, 1986). Thus, knowledge of the pests to which the producing plant is trying to resist may provide useful leads in predicting how pests may be controlled by compounds from a particular species. This approach has led to the discovery of several commercial pesticides such as the pyrethroid insecticides. Isolation and chemical characterization of the active compounds from plants with strong biological activities can be a major effort compared to synthesizing a new synthetic compound. However, the assurance of biological activity and improvement in methods of purification and structural identification is shifting the odds in favor of natural compounds.

Considering the probability of secondary plant products being involved in plant-pest interactions, the strategy of randomly isolating, identifying, and bioassaying these compounds may also be an effective method of insecticide discovery. Biologically active compounds from plants will often have activity against organisms with which the producing plant does not have to cope. Many secondary plant compounds described in literature have not been screened for insecticidal activity. This is due, in part, to the very small amounts of these compounds that have been available for screening.

The discovery process for natural pesticides is more complicated than that for synthetic insecticides. Traditionally, synthesis, bioassay, and evaluation have helped in the discovery of new insecticides. If the compounds are sufficiently promising, synthesis of analogues may be used to bring in desirable insecticidal properties.

1.3 Plant products with insecticidal potential

Throughout history, plant products have been successfully exploited as insecticides, insect repellents, and insect antifeedants (Rice, 1983; Yang and Tang, 1988). Probably the most successful use of a plant product as an insecticide is that of the pyrethroids. The insecticidal properties of the several *Chrysanthemum* species were known for centuries in Asia. Even today, powders of the dried flowers of these plants are sold as insecticides. After elucidation of the chemical structures of the six terpenoid esters (pyrethrins) responsible for the insecticidal activity of these plants, many synthetic analogs have been patented and marketed.

Many other terpenoids have been demonstrated to have insecticidal or other inhibiting activities (Duke et al. 1988). For instance, azadirachtin and other terpenoids of the limonoid group from the families Meliaceae and Rutaceae are potent growth inhibitors of several insect species (Jacobson, 1986).

Preparations of roots from the genera *Derris*, *Lonchocarpus*, and *Tephrosia*, containing rotenone, were commercial insecticides in the 1930s. Rotenone is a flavonoid derivative that strongly inhibits mitochondrial respiration. No other phenolic compound has been used commercially as an insecticide, although the content of certain phenolic compounds in plant tissues have been correlated with host plant resistance to insects and many have been demonstrated to be strong insect growth inhibitors and antifeedants (Duke, 1985).

Many of the *Artemisia* species have insecticidal properties with wormwood (*Artemisia absinthium*) being the most potent. Wormwood has been used for centuries as a moth repellant, general insecticide and as a tea garden spray to repel slugs and snails.

Before its toxicity was known it was used as the name implies a deworming medicine for human and animals.

Ageratum conyzoides has been reported to contain Precocene I and II which exhibit a battery of activities in insects and the most common is antijuvenile hormonal activity leading to precocious metamorphosis of the larvae, production of sterile, moribund and dwarfish adults (Bowers et al.1976).

Control of insects can be achieved by means other than causing rapid death. Plants produce many compounds that are insect repellents or act to alter insect feeding behavior, growth and development and behavior during mating and oviposition (McLaren, 1986). Most insect repellents are volatile terpenoids. Other terpenoids can act as attractants. In some cases, the same terpenoid can repel certain undesirable insects while attracting more beneficial insects. For instance, geraniol will repel houseflies while attracting honey bees. Compounds from many different chemical classes have been reported to act as insect antifeedants (Green et al. 1987). Thus, polygodial a sesquiterpenoid from *Polygonum hydropiper,* is a potent inhibitor of aphid feeding. Several plant-derived steroids that are close analogues of the insect molting hormone, ecdysterone, prevent insect molting. Other chemically unrelated terpenoids inhibit molting by unknown mechanisms. Plant terpenoids that act as locomotor excitants, biting or piercing suppressants, ovipositioning deterrents, or mating behavior disruptants have been described. More than a dozen plant-produced terpenoid juvenile hormone mimics have been found to effectively sterilize insects.

The wonder tree of Indian origin, neem (*Azadirachta indica*), its seeds are a rich storehouse of over 100 tetranortriterpenoids and diverse non-isoprenoides (Devkumar and Sukhdev, 1993). Neem-based products have different modes of action and are medium to broad-spectrum insecticides. In addition, the neem products are harmless to human and other mammals. *Artemisia capillaris* use for many years by paddy field workers to control fungal infections of the feet (Wain, 1977). The leaves of the wild shrub *Ocimum suave* and the flower buds (cloves) of *Eugenia aromatica* are traditionally use as effective stored grain protectants. Eugenol, a common constituent of the plants was found to be a repellent to the maize weevil, *Sitophilus zeamais*, Hildecarpan, a pterocarpan from *Tephrosia* is an antifeedant against the legume pod borer *Maruca testulalis*, and the retenoids and retenones are very potent antifeedants against a number of lepidopterans (Hassanali and Lwande, 1989).

The essential oils of *Pogostemon heyneanus*, *Ocimum basilicum* and *Eucalyptus* have shown insecticidal activity against *Sitophylus oryzae*, *Stegobium paniceum*, *Tribolium castaneum* and *Callosobruchus chinensis* (Deshphande et al. 1974; Deshphande and Tipnis, 1977).

The nematicidal activity of *Lantana camara* L. constituents from the arial parts, against the root-knot nematode *Meloidogyne incognita* has been reported to have a high mortality percentage at 1% concentration (Begum et al. 2000). The repellent effect of *Lantana* flower extract was evaluated against *Aedes* mosquitoes (Dua et al. 1996). The efficacy of ethanolic extracts of *Ageratum conyzoides* against aphid *Myzus persicae* (Sulz) infesting cabbage, appeared to be comparatively toxic against the test insects in both the laboratory and field trials (Singh et al. 1995). Crude extracts of *A. conyzoides* Linn. obtained from ether and chloroform fractions were bioassayed against III instar nymphs of mustard aphid, *Lipaphis erysimis* (Kaltenbach) inflicted high immediate mortality at treated nymphs (Bhathal et al. 1994). A common weed *Lantana camara* var. *aculeata* has antifeedant effect in the recent past against several insect pests of agricultural (Chitra et al. 1990) and forestry importance (Kulkarni et al. 1996b, 1997). Seeds and flowers of *Lantana camara* have been reported to have oviposition deterrent properties against the rice moth (Dwivedi and Garg, 2000). Anti- ovipositional property of the extract of *Lantana camara*, *Ageratum conyzoides* against stored grain pests is also reported to have high values (Jadhav and Jadhav, 1984; Pandey et al. 1986). The extracts of fresh green leaves of *Lantana camara* exhibit antifeeding, repellency and insecticidal properties against III instar larvae of mustard sawfly, *Athalia proxima* Klug (Pandey et al. 1977). *L. camara* is known to possess certain toxic principles which are hazardous to cattle, fish (CSIR, 1962) and insects. Leaf powder of *Eupatorium adenophorum* has been tested to have hepatoxicity to rats (Katoch et al. 2000). The aqueous and methanol extracts of *Ageratum conyzoides*, *Artemisia nilagarica*, *Eupatorium riparium* and *Lantana camara* show insecticidal activity in small rice grasshopper *Oxya hyla* and exhibit high feeding inhibition property as well on the same pest (Marngar and Kharbuli, 2001; Marngar et al. 2002).

Botanical insecticides are the alternatives to the chemical insecticides, which are often incorporated in insect management programmes (Kulkarni et al. 1997; Kulkarni and Joshi, 1998). Secondary metabolites are not distributed evenly through out the plants, either qualitatively or quantitatively, in space and time. The enormous variation in the distribution of terpenoid substances in plant is apparent at several stages of plant growth. Each plant population often has its own distinctive terpenoid profile and within individual plants, terpenoid levels usually vary among organs, tissues and cells. Finally age, season, or environmental conditions frequently influence terpenoid composition (Gershenzon and Croteau, 1991).

The extracts of *Citrus* seeds work both as toxins and feeding deterrents to insects. It has been reported to have a capability to suppress adult Colorado potato beetle (CPB), *Leptinotarsa decemlineata* population due to repellency from treated plant, inhibit oviposition due to nutritional disruption caused by antifeedant effects (Murray et al. 1995). Extracts from neem seeds containing azadirachtin which has antifeedant activity against over 200 insect species, including the CPB (Jacobsen, 1989), induce morphogenetic defects in larvae, reduce fecundity in adults, and lead to increase feeding inhibition and mortality in both larvae and adults CPB (Kaethner, 1992).

MATERIALS AND METHODS

1.4 Plant collection: - The plants *Ageratum conyzoides, Artemisia nilagarica, Eupatorium adenophorum, Eupatorium riparium* and *Lantana camara* were collected from the North Eastern Hill University Campus, Mawlai, Shillong and its vicinity. Identification of the plants was done in the Department of Botany of the same University.

1.5 Extracts preparation: - Fresh aerial parts of the plants selected were washed, cut into pieces and sundried for two weeks (average temp 18-20°C, Rh 80-90 %). The dried material was grounded to powder in a homogenizer. The crude extracts were obtained by soaking the powdered samples in water, methanol and 1% methanol for two weeks at room temperature. The extracts were filtered through a fine muslin cloth and the filtrates so obtained were distilled off, by a distilling apparatus. The final semi-dried samples were stored in a freezer at –20°C until use (Harborne, 1984 and Macedo et al. 1997).

1.6 Bioassay: - Standardized concentrations of 50mgml^{-1} 100mgml^{-1} and 200mgml^{-1} of plants crude extracts were prepared from the semi-dried samples and stored in refrigerator at -4°C. Freshly hatched or molted *Oxya hyla* were separated into different stages or age groups. Fresh leaves of *Oryza sativa* were cut into smaller pieces, dipped into different concentrations of crude plant extracts prepared, evaporated at room temperature for 10 -15 minutes before the feeding experiment. 10-15 Adults of *Oxya hyla* were sprayed with different concentrations of the above extracts or topically applied with the help of a fine hairbrush. They were then introduced into the experimental flasks (500ml), their activities were observed daily till the sixth day. Mortality, feeding, molting and behavioral activity were observed and recorded daily. Controls were setup using water, methanol and 1% methanol (Macedo et al. 1997 and Singh et al. 1998).

1.7 Statistical evaluation: - Mortality, feeding, molting and behavioral activity were recorded. Mean, standard errors, significance tests and comparison tests were analyzed and compared using Parametric Test of One-Way ANOVA and Parametric Two-Sided t-Test Paired Comparison.

RESULT

1.8 Effects of plant extracts on Mortality of adult *Oxya hyla* (Serv.)

Tests for insecticidal property among the selected plant extracts had shown that all methanol extracts gave a similar range of mortality. The highest mortality had been recorded on *A. conyzoides* (Figure 1.1A). 50mgml^{-1} concentration showed a significantly high mortality and total death of the insects as observed on the sixth day. 200mgml^{-1} conc was observed to possess the highest mortality in *A. conyzoides* having an early total percentage mortality of the insects on the third day. Furthermore, at 100mgml^{-1} concentration *A. conyzoides* extract showed a high mortality rate in the treated insects with total mortality on the fourth day. This clearly indicated that mortality in adults increased in dose as well as time dependent manner.

Other methanol extracts showed almost similar mortality. At 200mgml^{-1} *A. nilagarica* (Figure 1.1B), *E. adenophorum* (Figure 1.1C) and *E. riparium* (Figure 1.1D) exhibited similar effect, showing total mortality of the adult insects within the fourth day of the test. In 50mgml^{-1} concentration no complete mortality in *A. nilagarica* was observed (Figure 1.1B). *E. adenophorum* and *E. riparium* showed much similar activity, with a total mortality on the fifth day. Concentration of 100mgml^{-1} of *E. adenophorum*, *E. riparium* and *A. nilagarica* exhibited similar activity with complete mortality on the fifth day. *L. camara* was far less active when compared to the others. It was shown that a concentration of 200mgml^{-1} showed a complete mortality on the last day (sixth day) of the test (Figure 1.1E). 50mgml^{-1} and 100mgml^{-1} concentrations showed lesser mortality effect on the adult insects when compared with the control.

It was observed that the insecticidal activity of the aqueous plant extracts against the insects was minimum as it was shown in Figure 1.2. There was no complete mortality in all the concentrations tested. However, the activity of the aqueous extracts was significantly different from the control. None of the concentrations showed complete mortality. *L. camara* and *A. nilagarica* extracts were having higher mortality effect with 80% mortality at a concentration of 200mgml^{-1}.

A very diluted solvent of 1% methanol was used for testing to compare the toxicity of methanol. *A. conyzoides* extract again claimed the highest mortality having an early total mortality at a concentration of 200mgml^{-1}. The extracts worked in tandem with the increasing concentrations, hence mortality was significantly effected as shown in Figure 1.3 (A, B, C, D & E).

1.9 Effects of extracts on feeding activity

Variations in the results of feeding activity were observed depending on concentration applied and duration. The insects stopped feeding after one or two days of treatment. It was observed that methanol extracts exhibited the maximum potential for feeding deterrence as shown in Table 1.1. The feeding deterrence of these plant extracts was observed to have similar effects and significance. Among the plants tested *A. conyzoides* showed to be the most potent and *L. camara* the minimum effect on feeding inhibition against adult insects.

It was observed that aqueous extracts exhibited much lesser feeding inhibition compared to the methanol extracts of the same plants as shown in Table 1.2. Again it was found that 1% methanol extracts showed higher potency over the aqueous extracts as shown in Table 1.3. The results clearly explained the higher potency of methanol over aqueous for the extraction of secondary plant compounds.

1.10 Effects of the extracts on behavioral activity

In continuation to the effects in mortality and feeding activity of the plant extracts on the adults of *Oxya hyla*, it was interesting to note that these plant extracts have similar effect on behavior as well. Methanol extracts of *A. conyzoides* showed the most potent in suppressing behavioral patterns in all the concentrations tested. *A. nilagarica, E. adenophorum, E. riparium* and *L. camara* also showed significant effect on behavior of the insect as shown in Table 1.4 and Table 1.7.

In case of aqueous extracts, it was clearly shown in the Table 1.5 & 1.8 that the effect on behavior was not very high and no complete suppression of behavioral activity was observed. However, *L. camara* extracts completely suppressed behavioral activity at the concentrations of 100 and 200mgml^{-1} on the last day of the test. Though no complete suppression was observed with the other plants, however, very high significant effect was abtained. 1% methanol extracts were again observed to have the same activity like the methanol extracts except that of lesser degree (Table 1.6 & 1.9).

DISCUSSION

Methanol extracts of the plants tested exhibit higher insecticidal activity as compared to the aqueous one (Marngar et al. 2002). From the results it is observed that the mortality effect possessed by methanol extract is maximum in almost all the concentrations. *A. conyzoides* extracts possess the highest potency among all the plants tested. It has been noted to kill the experimental insects completely (100%) within the third day at a concentration of 200mgml^{-1}, which shows to have very active insecticidal action. It is obvious that the effect of this plant extract is very high on activity of insects and further study on this plant (*A. conyzoides*) and few of its active principles would be followed in detail against different instar stages of *Oxya hyla*.

A. nilagarica, E. adenophorum, E. riparium and *L.camara* show lesser activity compared to *A. conyzoides*. However, all these plants have the capability to kill 100% of the adult insects within the time frame of the experiment. *A. nilagarica, E. adenophorum* and *E. riparium* extracts killed 100% of the experimental insects in the laboratory at 200mgml^{-1} within four days of bioassay, five days at 100mgml^{-1} and 50mgml^{-1} concentration. *L. camara* extract has the minimum potency. Aqueous extracts of the same plants have been observed to have lower insecticidal activity. The effectiveness of the concentrations of these extracts is high and almost similar values are observed in almost all the plants. It has been concluded that the 1% methanol extract of these plants also confirmed the series of activity as in the case of the methanol extracts.

Inhibitory effect of the plant extracts on feeding activity was observed to have very high activity. As it was in mortality effects, methanol extracts of the plants also have the same activity much higher than that of the aqueous extracts. Treated with the concentrations of the extracts, it is obtained that *A. conyzoides* has the greatest potential on feeding inhibition and mortality from the rest of the plant extracts. This may be due to higher amount of toxic compounds responsible for insecticidal activities against the insects. It may be possible that some of the toxic compounds, which are available in this plant, are not available in other plants. However, it was observed that the extracts have feeding inhibitory effect in all the concentrations of the plant extracts used. These plant compounds can inhibit feeding of the insects completely within 2-4 days of testing depending upon the plant and concentration. It was also observed that specific toxic compounds present in the extract applied have been attributed for insecticidal properties of the plants.

As has been observed earlier that aqueous extracts are far less active than methanol extracts this clearly indicates that very few plant secondary compounds that may be used for insecticides are soluble in water. Furthermore, it shows that the possibility is, the compounds that are soluble in water are not much toxic to this insect species. It is also interesting that when a diluted 1% methanol extract was used as a solvent, it was shown that the effect of the plant extracts is similar to methanol extracts. This again clearly shows that even in very diluted organic solvent, the compounds present in the plants can be dissolved much better as compared to water as a solvent.

Insect behavior depends largely on their food, air and chemical composition within the environment. Changes in the normal behavioral pattern of the insects involve a series of physiological changes in combination with chemoreception, digestion, reproduction and other metabolic pathways.

The reaction of the insects to the secondary plant compounds is due to the presence of chemical compounds, which affect insect activity through various metabolic processes, that ultimately leads to changing and altering the behavior and ultimately death. These chemical compounds collectively interact in various ways including enzyme inactivation and inhibition in the digestive tract, receptor proteins in signal transduction, nervous system, reproduction leading to various defects in the body including feeding inhibition, reduced growth and development and finally death.

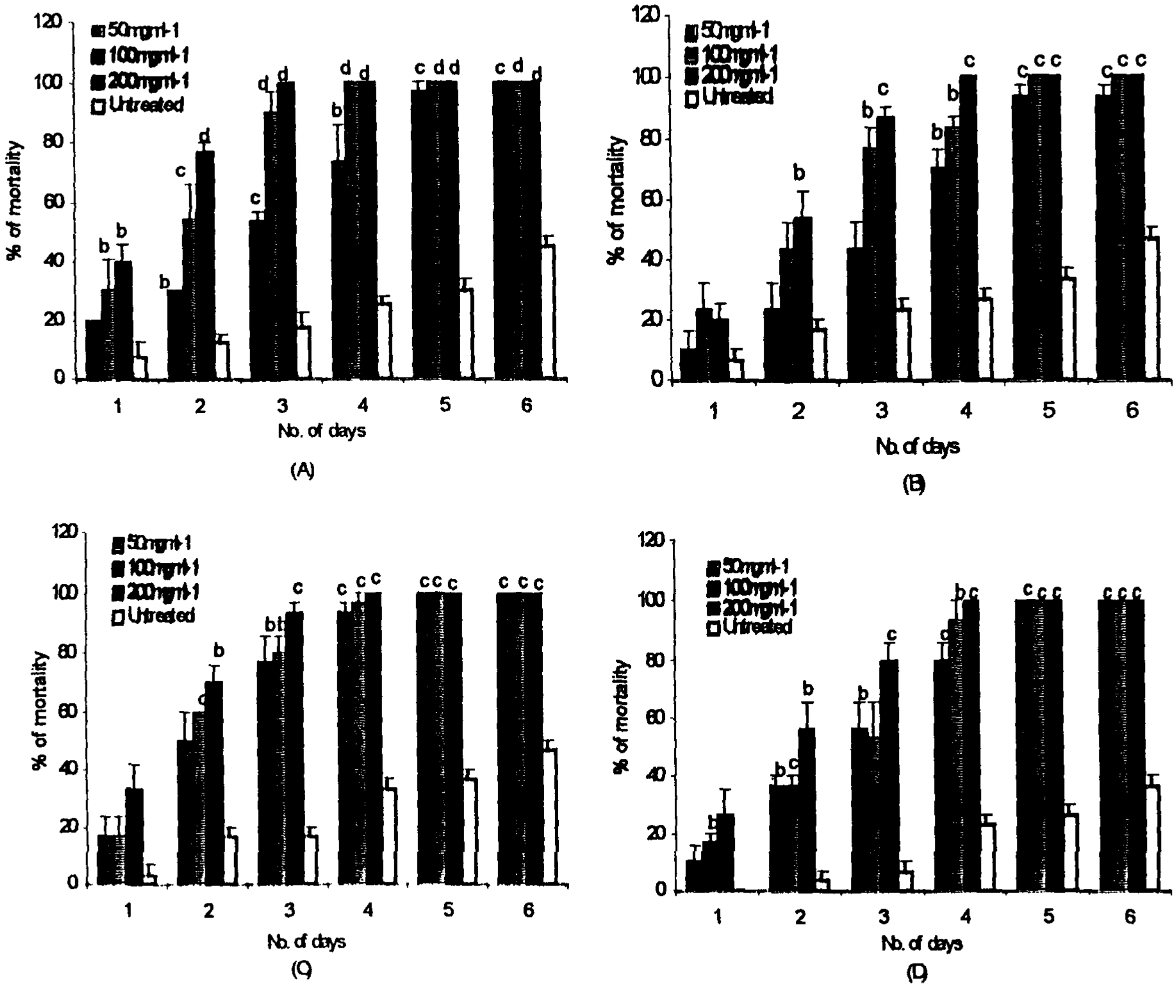
In the present study we have found that, the activity of these plants are in parallel with other reports of activity on mortality, feeding inhibition behavioral pattern activity in various insect species (Yano and Kamimura, 1993; Facknath and Kawol, 1993; Suomi et al. 1986).

As mentioned, the secondary plant compounds or extracts that are used for insecticide assay contain a mixture of several groups of organic compounds. Terpenoids, steroids, phenols, flavonoids, alkaloids and many more. All these plant compounds have insecticidal property in one way or the other. It is found that the above selected plants have the combination of these organic compounds in the extracts, which impart them to act as insecticides, toxicants, feeding deterrents, oviposition deterrents and neurotoxins causing hyperexcitation, uncoordinated movement and paralysis of the insects (Paine and Stephen, 1988; Bowers and Puttick, 1988) and also inhibit insect growth (Bowers and Puttick, 1989; Wagner et al. 1983; Cole et al. 1990). Toxicity effect is also believed to result from its complexation of some compounds with proteins in gastrointestinal tract, causing a reduction in their digestibility or digestion or with the digestive enzyme themselves. Some compounds interfere with hormonal activity causing precocious metamorphosis and sterilization in insects like grasshopper (Bowers, 1991b), by inhibiting as well as terminate JH secretion in the brain, resulting in delayed molting and inducing morphological deformities in several insects (Unnithan et al. 1978; Schmutterer, 1990). Some compounds possess toxicity by interfering with the key components of acetylcholine esterase activity in the nervous system of insects (Levinson, 1976).

CONCLUSION

Plant world contains many interesting and useful insecticides that have not been investigated yet. Only a few have been mentioned here, The entomologists and chemists have passed by many thousands of plants in their search for an insecticide that kills insects but is safe to people and animals. Once a scientist discovers a plant useful as an insecticide, he must take the plant part and discover the active principles in it. The discovery is only the first step towards the commercial usefulness of the plant. The next step takes time and effort. That a plant is poisonous to other animals or to insects but rarely attack a common weed is not a positive indication of insecticidal properties. The insecticidal principles may be present in one or more of the following parts: Leaves and leaflets, flowers, seeds, stems, barks, wood or the whole plant.

The farmers and general public share in the discovery and development of new insecticides from plants. Growing new plants for insecticides means new income to the farmers; the public gets farm products that are clean and free from insects and poisonous residues.



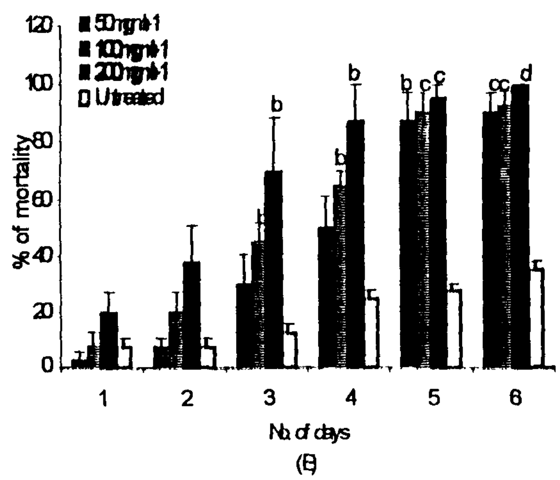


Figure 1.1 Effects of methanol extracts of (A) *Ageratum conyzoides* (B) *Artemisia nilagarica* (C) *Eupatorium adenophorum* (D) *Eupatorium riparium* and (E) *Lantana camara* on mortality of adult *Oxya hyla* [a].

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[a] Means (± SE) were analyzed using Parametric Test, One-Way ANOVA. [b, c & d] Values are significantly different from the control / untreated (Parametric Two-Sided Test for Paired Comparison) at P< 0.05, 0.01 & 0.001 respectively.

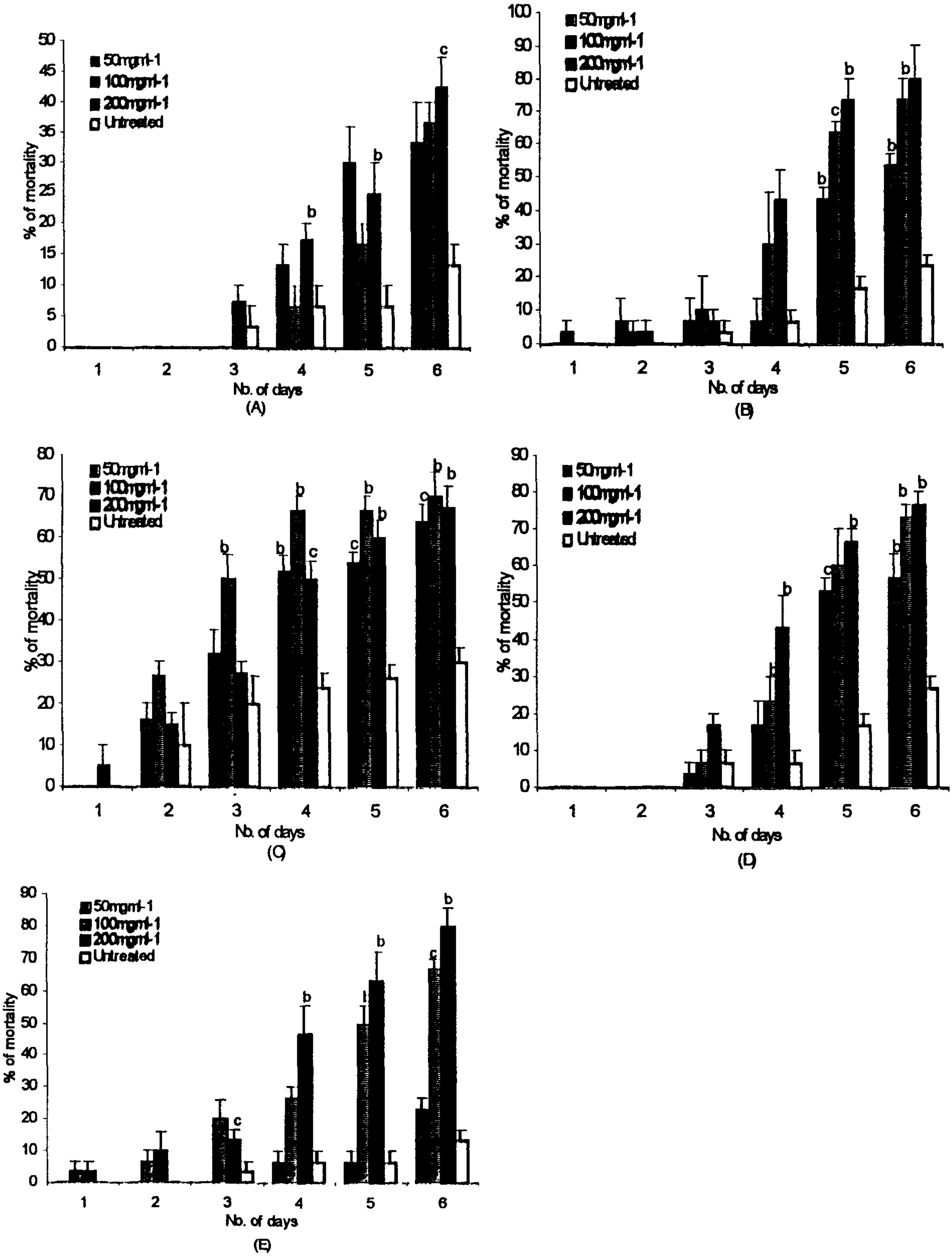

Figure 1.2 Effects of aqueous extracts of (A) *A. conyzoides* (B) *A. nilagarica* (C) *E. adenophorum* (D) *E. riparium* and (E) *L.camara* on mortality of adult *Oxya hyla*. [a]

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[a] Means(±SE) were analyzed using Parametric Test, One-Way ANOVA, [b, c & d] Values are significant (Parametric Two-Sided Test for Paired Comparison) at P< 0.05, 0.01 & 0.001 respectively

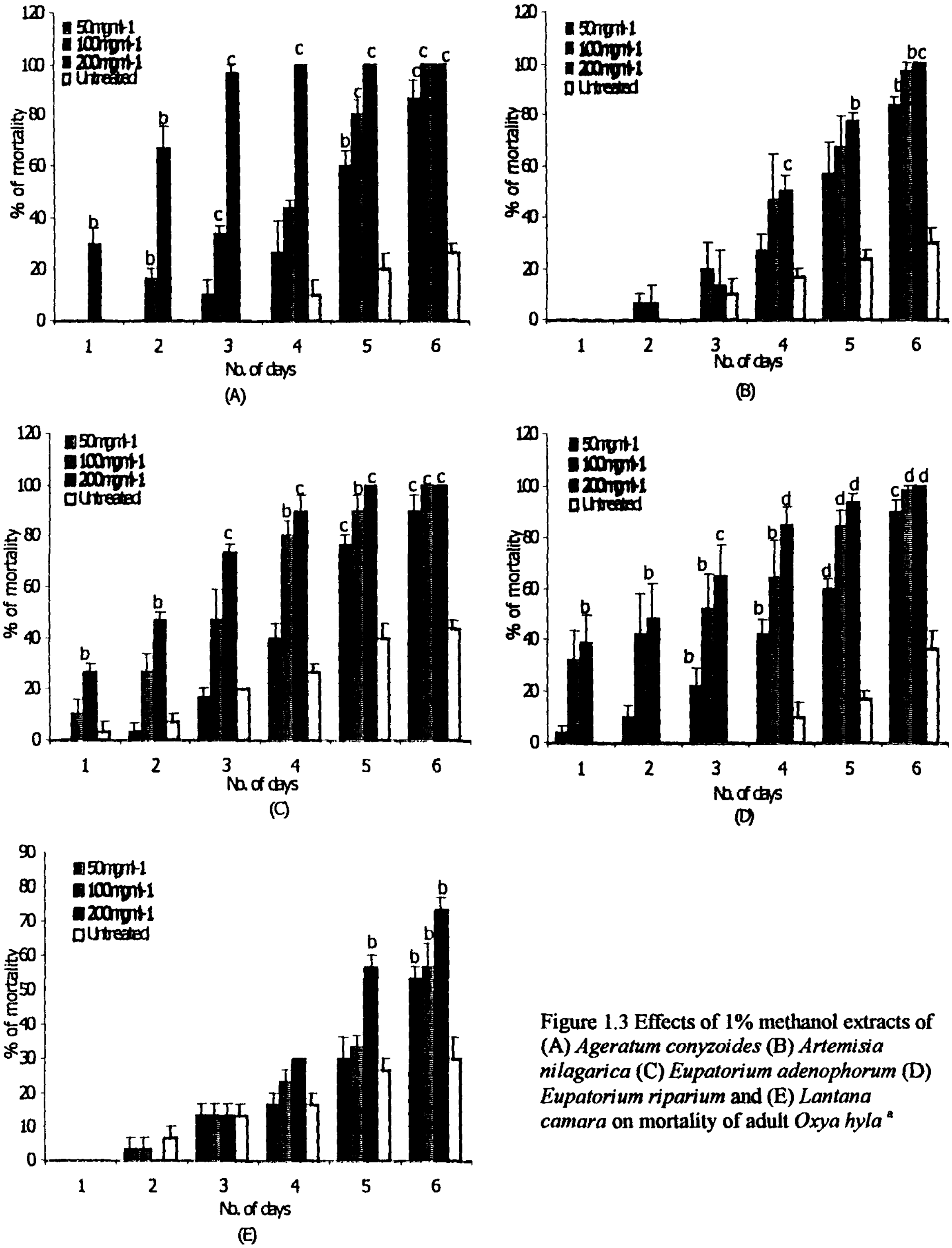

Figure 1.3 Effects of 1% methanol extracts of (A) *Ageratum conyzoides* (B) *Artemisia nilagarica* (C) *Eupatorium adenophorum* (D) *Eupatorium riparium* and (E) *Lantana camara* on mortality of adult *Oxya hyla* [a]

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[a] Means(±SE) were analyzed using Parametric Test, One-Way ANOVA, [b, c & d] Values are significant from the untreated (Parametric Two-Sided Test for Paired Comparison) at P< 0.05, 0.01 & 0.001 respectively

Table 1.1 Effect of methanol extracts of selected plants on feeding of adult (females and males) *Oxya hyla*.[a]

Name of the plant	Conc $mgml^{-1}$	Days of observation 1	2	3	4	5	6
Ageratum conyzoides	50	3.20 ± 0.37^{d}	1.40 ± 0.40^{d}	0.40 ± 0.24^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}
	100	2.20 ± 0.49^{d}	0.60 ± 0.40^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}
	200	1.60 ± 0.51^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}
Artemisia nilagarica	50	3.00 ± 0.57^{c}	2.66 ± 0.66^{c}	1.00 ± 0.57^{c}	0.33 ± 0.33^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}
	100	2.00 ± 0.57^{c}	0.60 ± 0.40^{c}	0.33 ± 0.33^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}
	200	1.00 ± 0.57^{d}	0.66 ± 0.33^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}
Eupatorium adenophorum	50	2.33 ± 0.33	0.66 ± 0.33^{d}	0.00 ± 0.00^{c}	0.00 ± 0.00^{b}	0.00 ± 0.00^{b}	0.00 ± 0.00
	100	2.33 ± 0.33^{d}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{b}	0.00 ± 0.00^{b}	0.00 ± 0.00
	200	1.00 ± 0.57^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{b}	0.00 ± 0.00^{b}	0.00 ± 0.00
Eupatorium riparium	50	2.66 ± 0.66^{b}	1.33 ± 0.88^{b}	1.00 ± 0.57^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}
	100	2.00 ± 0.00^{c}	0.66 ± 0.33^{c}	0.66 ± 0.33^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}
	200	1.00 ± 0.00^{b}	0.50 ± 0.50^{b}	0.00 ± 0.00^{b}	0.00 ± 0.00^{b}	0.00 ± 0.00^{b}	0.00 ± 0.00^{b}
Lantana camara	50	4.75 ± 0.63^{b}	4.00 ± 0.41^{c}	0.75 ± 0.75^{c}	0.50 ± 0.50^{c}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}
	100	4.25 ± 0.48^{c}	2.25 ± 0.25^{c}	0.50 ± 0.50^{d}	0.50 ± 0.50^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}
	200	1.75 ± 0.25^{d}	1.00 ± 0.41^{d}	0.25 ± 0.25^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}

[a] Means ($\pm$SE) were analyzed by Parametric test, One - Way ANOVA, [b, c & d] Values are significantly different at $P < .05$, 0.01 & 0 .001respectively. Treated and control are calculated and compared using Parametric Two- Sided t-Test Paired Comparison.

Table 1.2 Effect of aqueous extracts of selected plants on feeding of adult (females and males) *Oxya hyla*.[a]

Name of the plant	Conc $mgml^{-1}$	Days of observation 1	2	3	4	5	6
Ageratum conyzoides	50	7.33 ± 0.66	6.00 ± 0.57^{b}	5.66 ± 0.33^{c}	4.66 ± 0.33^{c}	3.66 ± 0.33^{b}	3.33 ± 0.33^{c}
	100	7.33 ± 0.66	5.66 ± 0.33^{c}	6.00 ± 0.57^{b}	5.33 ± 0.33^{c}	4.33 ± 0.33^{c}	3.66 ± 0.66^{b}
	200	7.33 ± 0.33^{b}	6.33 ± 0.33^{c}	6.33 ± 0.33^{b}	5.66 ± 0.33^{c}	5.00 ± 0.57^{c}	4.00 ± 0.57^{c}
Artemisia nilagarica	50	5.66 ± 0.33^{c}	5.00 ± 0.57^{b}	4.66 ± 0.33^{c}	4.00 ± 0.57^{b}	3.33 ± 0.33^{c}	2.66 ± 0.66^{c}
	100	5.66 ± 0.66^{b}	4.33 ± 0.33^{c}	3.66 ± 0.33^{b}	3.33 ± 0.33^{b}	2.66 ± 0.33^{c}	2.33 ± 0.33^{c}
	200	5.33 ± 0.33^{c}	4.33 ± 0.33^{b}	3.66 ± 0.33^{c}	3.33 ± 0.33^{c}	2.00 ± 0.57^{b}	0.33 ± 0.33^{c}
Eupatorium adenophorum	50	7.20 ± 0.37	4.00 ± 0.31^{c}	3.20 ± 0.37^{c}	2.20 ± 0.37^{d}	2.20 ± 0.37^{c}	2.00 ± 0.31^{c}
	100	6.33 ± 0.33^{b}	4.66 ± 0.33	3.00 ± 0.57^{b}	2.66 ± 0.66	2.00 ± 0.00^{b}	1.33 ± 0.33^{c}
	200	5.33 ± 0.66	4.00 ± 0.00^{b}	3.33 ± 0.33^{b}	2.66 ± 0.33	2.33 ± 0.33^{b}	1.33 ± 0.33^{c}
Eupatorium riparium	50	5.33 ± 0.33^{b}	3.33 ± 0.33^{c}	3.33 ± 0.66^{c}	3.33 ± 0.66^{b}	1.33 ± 0.33^{c}	1.00 ± 0.00^{c}
	100	5.00 ± 0.57^{b}	3.66 ± 0.66^{b}	3.00 ± 0.00^{c}	2.66 ± 0.33^{c}	2.33 ± 0.33^{c}	1.66 ± 0.33^{c}
	200	4.33 ± 0.33^{c}	4.00 ± 0.00^{c}	3.00 ± 0.57^{b}	2.66 ± 0.33^{c}	2.00 ± 0.57^{c}	0.66 ± 0.33^{c}
Lantana camara	50	7.00 ± 0.57	7.66 ± 0.33	6.00 ± 1.00	5.33 ± 0.33^{c}	5.00 ± 0.00^{c}	4.33 ± 0.33^{c}
	100	5.50 ± 0.50	3.50 ± 0.50	2.00 ± 0.00^{b}	1.50 ± 0.50^{b}	1.00 ± 1.00	0.50 ± 0.50^{b}
	200	5.33 ± 0.33^{c}	4.33 ± 0.33^{b}	3.66 ± 0.33^{c}	3.33 ± 0.33^{c}	2.00 ± 0.57^{b}	0.33 ± 0.33^{c}

[a] Means (±SE) were analyzed by Parametric test, One - Way ANOVA. [b, c & d] Values are significantly different at $P < .05$, 0.01 & 0 .001respectively. Treated and control are calculated and compared using Parametric Two- Sided t-Test Paired Comparison.

Table 1.3 Effect of 1% methanol extracts of selected plants on feeding of adult (females and males) *Oxya hyla*.[a]

Name of the Plants	Conc $mgml^{-1}$	Days of observation 1	2	3	4	5	6
Ageratum conyzoides	50	5.50±0.50	4.50±0.50	3.00±0.00	1.50±0.50^b	0.00±0.00^b	0.00±0.00^b
	100	4.66±0.33^b	3.66±0.33^b	2.00±0.00^c	1.00±0.00^c	0.00±0.00^c	0.00±0.00^c
	200	2.00±0.00^c	0.33±0.33^c	0.00±0.00^c	0.00±0.00^c	0.00±0.00^c	0.00±0.00^c
Artemisia nilagarica	50	5.00±1.00	4.50±0.05	4.00±1.00	1.50±0.50^b	1.00±0.00^b	0.00±0.00^b
	100	5.33±0.33^b	4.33±0.33^c	3.33±1.20	1.33±0.66^b	0.33±0.33^c	0.00±0.00^c
	200	4.00±0.57^b	3.66±0.33^b	2.66±0.66^c	1.33±0.66^c	0.33±0.33^d	0.00±0.00^d
Eupatorium adenophorum	50	2.75±0.47^b	1.75±0.25^c	1.50±0.28^c	0.75±0.25^c	0.00±0.00^c	0.00±0.00^d
	100	2.75±0.25^c	2.00±0.41^c	1.00±0.41^c	0.50±0.50^c	0.00±0.00^c	0.00±0.00^d
	200	2.00±0.41^c	1.50±0.28^d	0.75±0.25^c	0.00±0.00^d	0.00±0.00^c	0.00±0.00^d
Eupatorium riparium	50	4.00±0.00^d	2.75±0.48^c	2.00±0.41^d	1.25±0.25^d	0.25±0.25^d	0.00±0.00^d
	100	2.00±0.70^c	1.25±0.48^c	2.00±0.41^d	0.75±0.48^c	0.50±0.28^c	0.00±0.00^d
	200	1.50±0.28^d	0.75±0.25^d	0.50±0.28^d	0.00±0.00^d	0.00±0.00^d	0.00±0.00^d
Lantana camara	50	5.50±0.50	5.50±0.50	3.50±0.50	2.50±0.50	2.00±0.00	0.50±0.50
	100	5.33±0.33^b	3.66±0.33^c	3.33±0.33^b	3.00±0.57^b	1.33±0.33^b	0.66±0.33^c
	200	4.33±0.33^c	3.00±0.58^c	2.33±0.33^c	1.66±0.33^c	0.66±0.33^c	0.00±0.00^c

[a] Means (±SE) were analyzed by Parametric test, One - Way ANOVA, [b, c & d] Values are significantly different at $P < .05$, 0.01 & 0 .001respectively. Treated and control are calculated and compared using Parametric Two- Sided t-Test Paired Comparison.

Table 1.4 Effect of methanol extracts of plants selected on the behavioral activeness of adult *Oxya hyla* [a]

Plants	Conc mgml^{-1}	N	Days of observation 1	2	3	4	5	6
Ageratum conyzoides	50	10	2.00±0.25^{d} (8.40±0.16)	1.40±0.26^{d} (7.80±0.20)	0.40±0.16^{d} (7.30±0.15)	0.10±0.10^{d} (7.10±0.23)	0.00±0.00^{d} (6.40±0.24)	0.00±0.00^{d} (6.00±0.31)
	100	10	1.70±0.15^{d} (8.40±0.16)	1.00±0.25^{d} (7.80±0.20)	0.10±0.10^{d} (7.30±0.15)	0.00±0.00^{d} (7.00±0.57)	0.00±0.00^{d} (6.66±0.33)	0.00±0.00^{d} (6.33±0.33)
	200	10	1.50±0.40^{d} (8.40±0.16)	0.40±0.22^{d} (7.80±0.20)	0.00±0.00^{d} (7.30±0.15)	0.00±0.00^{d} (7.00±0.57)	0.00±0.00^{d} (6.66±0.33)	0.00±0.00^{d} (6.33±0.33)
Artemisia nilagarica	50	6	2.00±0.25^{d} (8.00±0.31)	1.66±0.33^{d} (7.83±0.20)	1.50±0.22^{d} (7.33±0.37)	0.33±0.21^{d} (6.83±0.20)	0.00±0.00^{d} (6.33±0.37)	0.00±0.00^{d} (6.00±0.31)
	100	5	2.20±0.37^{d} (8.00±0.40)	1.40±0.24^{d} (7.60±0.40)	0.80±0.20^{d} (7.00±0.40)	0.00±0.00^{d} (6.80±0.37)	0.00±0.00^{d} (6.40±0.24)	0.00±0.00^{d} (6.20±0.20)
	200	5	1.60±0.24^{d} (7.80±0.37)	0.80±0.20^{d} (7.60±0.40)	0.60±0.24^{d} (7.20±0.37)	0.00±0.00^{d} (6.60±0.40)	0.00±0.00^{d} (6.40±0.24)	0.00±0.00^{d} (6.00±0.31)
Eupatorium adenophorum	50	6	2.16±0.30^{d} (8.33±0.33)	1.50±0.22^{d} (8.33±0.33)	0.83±0.16^{d} (7.33±0.33)	0.50±0.22^{d} (7.33±0.33)	0.00±0.00^{d} (6.66±0.33)	0.00±0.00^{d} (5.66±0.33)
	100	3	2.66±0.33^{c} (8.00±0.57)	2.00±0.00^{c} (7.66±0.33)	0.66±0.33^{c} (6.66±0.33)	0.00±0.00^{c} (6.33±0.33)	0.00±0.00^{c} (5.66±0.33)	0.00±0.00^{c} (5.33±0.33)
	200	3	2.33±0.33^{b} (8.33±0.66)	1.33±0.33^{b} (8.00±0.57)	0.00±0.00^{c} (7.33±0.66)	0.00±0.00^{c} (7.00±0.57)	0.00±0.00^{c} (6.33±0.66)	0.00±0.00^{c} (6.00±0.57)
Eupatorium riparium	50	5	2.60±0.24^{c} (8.80±0.58)	1.60±0.24^{d} (8.20±0.37)	1.20±0.20^{d} (8.00±0.44)	0.20±0.20^{d} (7.40±0.40)	0.00±0.00^{d} (7.00±0.44)	0.00±0.00^{d} (6.60±0.51)
	100	5	1.80±0.37^{d} (8.80±0.37)	1.40±0.24^{d} (8.80±0.37)	0.60±0.24^{d} (8.00±0.31)	0.00±0.00^{d} (7.60±0.40)	0.00±0.00^{d} (7.20±0.37)	0.00±0.00^{d} (7.00±0.44)
	200	5	1.00±0.44^{d} (8.20±0.37)	0.40±0.24^{d} (8.20±0.37)	0.20±0.20^{d} (7.60±0.51)	0.00±0.00^{d} (7.00±0.31)	0.00±0.00^{d} (6.80±0.37)	0.00±0.00^{d} (6.40±0.24)
Lantana camara	50	5	2.60±0.24^{d} (8.50±0.28)	1.80±0.20^{d} (8.50±0.28)	1.20±0.37^{d} (7.75±0.25)	0.60±0.40^{d} (7.50±0.28)	0.40±0.40^{d} (7.00±0.41)	0.00±0.00^{d} (6.25±0.47)
	100	5	3.00±0.31^{c} (7.75±0.47)	2.00±0.54^{c} (7.50±0.64)	1.60±0.40^{d} (7.25±0.47)	0.60±0.60^{d} (7.00±0.41)	0.00±0.00^{d} (6.50±0.64)	0.00±0.00^{d} (6.00±0.41)
	200	4	1.00±0.00^{d} (7.66±0.33)	0.50±0.28^{d} (7.33±0.66)	0.25±0.25^{d} (7.00±0.57)	0.00±0.00^{d} (6.66±0.33)	0.00±0.00^{d} (6.00±0.57)	0.00±0.00^{d} (5.66±0.33)

[a] Means (± SE) were analyzed using Parametric, One-way ANOVA. Figures in parentheses represent the control; [b, c & d] Values are significantly different at $P < 0.05, 0.01$ & 0.001 respectively, N: Number of observation.

Table 1.5 Effect of aqueous extracts of plants selected on the behavioral activeness of adult *Oxya hyla* [a]

Plants	Conc mgml^{-1}	N	Days of observation 1	2	3	4	5	6
Ageratum conyzoides	50	6	4.16±0.87^{c} (9.33±0.33)	3.83±0.47^{d} (9.00±0.57)	3.66±0.33^{d} (9.00±0.57)	3.16±0.16^{d} (8.33±0.33)	2.66±0.21^{d} (8.33±0.33)	2.50±0.22^{d} (8.00±0.57)
	100	6	4.33±0.61^{d} (9.66±0.33)	3.50±0.34^{d} (9.33±0.33)	3.33±0.42^{d} (9.33±0.33)	2.83±0.31^{d} (8.66±0.33)	2.16±0.16^{d} (8.33±0.33)	1.83±0.16^{d} (8.33±0.33)
	200	6	4.16±0.87^{c} (9.66±0.33)	3.66±0.66^{d} (9.33±0.33)	3.50±0.56^{d} (9.00±0.57)	2.50±0.56^{d} (8.33±0.33)	1.83±0.40^{d} (8.00±0.57)	1.66±0.31^{d} (7.66±0.66)
Artemisia nilagarica	50	6	3.83±0.40^{d} (9.66±0.33)	3.16±0.16^{d} (9.66±0.33)	3.00±0.26^{d} (9.33±0.33)	2.33±0.21^{d} (8.66±0.33)	1.66±0.21^{d} (8.33±0.33)	1.66±0.40^{d} (8.33±0.33)
	100	6	4.00±0.44^{d} (8.66±0.33)	3.33±0.21^{d} (8.66±0.33)	2.83±0.16^{d} (8.33±0.33)	1.83±0.16^{d} (7.66±0.33)	1.00±0.25^{d} (7.33±0.33)	0.33±0.21^{d} (7.00±0.57)
	200	6	3.66±0.21^{d} (9.66±0.33)	3.16±0.16^{d} (9.33±0.33)	2.50±0.22^{d} (9.33±0.33)	1.66±0.33^{d} (8.66±0.33)	0.66±0.33^{d} (8.33±0.33)	0.33±0.21^{d} (7.66±0.33)
Eupatorium adenophorum	50	4	3.75±0.25^{b} (5.66±0.33)	3.50±0.28 (4.33±0.33)	2.75±0.25 (4.00±0.00)	2.25±0.25^{b} (4.00±0.00)	1.50±0.28^{b} (3.66±0.33)	1.25±0.25^{b} (3.00±0.00)
	100	3	4.33±0.33 (5.66±0.33)	3.66±0.66 (4.33±0.33)	2.00±0.57 (4.00±0.00)	1.33±0.33^{b} (4.00±0.00)	1.33±0.33 (3.66±0.33)	1.33±0.33^{b} (3.00±0.00)
	200	3	3.33±0.33 (5.66±0.33)	3.00±0.00 (4.33±0.33)	2.66±0.33 (4.00±0.00)	1.66±0.33^{b} (4.00±0.00)	1.66±0.33 (3.66±0.33)	1.00±0.00^{b} (3.00±0.00)
Eupatorium riparium	50	6	3.66±0.33^{d} (9.66±0.33)	3.16±0.16^{d} (9.33±0.33)	3.16±0.16^{d} (9.33±0.33)	2.00±0.25^{d} (8.66±0.33)	1.33±0.33^{d} (8.66±0.33)	1.00±0.36^{d} (8.33±0.33)
	100	6	3.83±0.31^{d} (9.66±0.33)	3.33±0.21^{d} (9.66±0.33)	2.83±0.16^{d} (9.66±0.33)	2.16±0.31^{d} (9.00±0.57)	1.33±0.33^{d} (8.66±0.33)	0.50±0.34^{d} (8.33±0.33)
	200	6	3.83±0.16^{d} (9.66±0.33)	3.33±0.21^{d} (9.66±0.33)	2.66±0.21^{d} (9.33±0.33)	2.33±0.33^{d} (8.66±0.33)	1.33±0.21^{d} (8.33±0.33)	1.16±0.16^{d} (7.66±0.33)
Lantana camara	50	6	3.83±0.70^{d} (9.00±0.57)	3.33±0.84^{c} (9.00±0.57)	3.50±0.22^{d} (8.66±0.33)	3.83±0.31^{d} (7.66±0.33)	3.16±0.31^{d} (7.33±0.33)	3.00±0.25^{d} (7.33±0.33)
	100	4	3.75±0.25^{d} (8.33±0.33)	2.75±0.25^{d} (8.33±0.33)	1.50±0.28^{d} (8.33±0.33)	1.25±0.25^{d} (7.33±0.33)	0.25±0.25^{d} (7.33±0.33)	0.00±0.00^{d} (6.66±0.33)
	200	6	3.16±0.31^{d} (8.00±0.57)	3.00±0.25^{d} (8.00±0.57)	1.83±0.40^{d} (7.66±0.33)	1.00±0.25^{d} (7.00±0.57)	0.50±0.34^{d} (6.66±0.33)	0.00±0.00^{d} (6.33±0.33)

[a] Means (± SE) were analyzed using Parametric, One-way ANOVA. Figures in parentheses represent the control; [b, c & d] Values are significantly different at $P<$ 0.05,0.01 & 0.001 respectively, N: Number of observation.

Table 1.6 Effect of 1% methanol extracts of plants selected on the behavioral activeness of adult *Oxya hyla* [a]

Plants	Conc mgml^{-1}	N	Days of observation 1	2	3	4	5	6
Ageratum conyzoides	50	4	4.00±0.41^{c} (9.33±0.33)	3.50±0.28^{c} (8.66±0.33)	2.50±0.28^{c} (8.33±0.33)	1.25±0.47^{c} (7.66±0.33)	0.00±0.00^{d} (7.33±0.33)	0.00±0.00^{d} (6.66±0.33)
	100	6	3.66±0.33^{d} (8.66±0.33)	3.16±0.16^{d} (8.33±0.33)	1.66±0.33^{d} (8.33±0.33)	0.83±0.31^{d} (7.33±0.33)	0.00±0.00^{d} (7.33±0.33)	0.00±0.00^{d} (6.66±0.33)
	200	6	2.00±0.25^{d} (9.00±0.57)	0.33±0.21^{d} (8.33±0.33)	0.00±0.00^{d} (7.66±0.33)	0.00±0.00^{d} (7.66±0.33)	0.00±0.00^{d} (6.66±0.33)	0.00±0.00^{d} (6.33±0.33)
Artemisia nilagarica	50	4	3.75±0.47^{c} (8.66±0.33)	3.25±0.25^{d} (8.66±0.33)	2.25±0.47^{d} (7.66±0.33)	0.75±0.47^{d} (7.33±0.33)	0.25±0.25^{d} (6.66±0.33)	0.00±0.00^{d} (6.33±0.33)
	100	6	4.00±0.36^{d} (9.00±0.57)	3.00±0.26^{d} (8.33±0.33)	1.66±0.42^{d} (8.00±0.00)	1.00±0.36^{d} (7.33±0.33)	0.50±0.22^{d} (6.66±0.33)	0.00±0.00^{d} (6.33±0.33)
	200	6	3.66±0.21^{d} (8.66±0.33)	3.16±0.16^{d} (8.66±0.33)	2.50±0.34^{d} (8.00±0.57)	1.00±0.25^{d} (7.66±0.33)	0.16±0.16^{d} (7.66±0.33)	0.00±0.00^{d} (6.66±0.33)
Eupatorium adenophorum	50	4	3.50±0.28^{b} (6.33±0.33)	3.25±0.25^{b} (6.00±0.57)	2.50±0.28^{b} (5.33±0.33)	1.25±0.25^{c} (5.33±0.33)	0.00±0.00^{d} (5.00±0.00)	0.00±0.00^{d} (4.66±0.33)
	100	3	3.33±0.33^{b} (6.33±0.33)	2.33±0.33^{b} (6.00±0.57)	1.66±0.33^{c} (5.33±0.33)	0.66±0.33^{c} (5.33±0.33)	0.00±0.00^{c} (5.00±0.00)	0.00±0.00^{c} (4.66±0.33)
	200	4	2.75±0.25^{c} (6.33±0.33)	2.25±0.25^{c} (6.00±0.57)	0.75±0.25^{d} (5.33±0.33)	0.00±0.00^{d} (5.33±0.33)	0.00±0.00^{d} (5.00±0.00)	0.00±0.00^{d} (4.66±0.33)
Eupatorium riparium	50	10	3.40±0.16^{d} (9.00±0.57)	2.70±0.26^{d} (8.66±0.33)	1.90±0.23^{d} (8.33±0.66)	1.20±0.13^{d} (7.66±0.33)	0.70±0.21^{d} (7.66±0.33)	0.10±0.10^{d} (7.00±0.57)
	100	10	2.30±0.39^{d} (9.00±0.33)	1.90±0.34^{d} (8.66±0.33)	1.70±0.42^{d} (8.10±0.33)	1.10±0.35^{d} (7.66±0.33)	0.60±0.26^{d} (7.10±0.18)	0.30±0.21^{d} (6.50±0.22)
	200	12	1.83±0.27^{d} (8.75±0.25)	1.16±0.27^{d} (8.50±0.19)	0.58±0.23^{d} (7.66±0.33)	0.16±0.16^{d} (7.50±0.15)	0.00±0.00^{d} (7.00±0.17)	0.00±0.00^{d} (6.41±0.19)
Lantana camara	50	4	4.00±0.00^{c} (9.00±0.57)	3.25±0.25^{d} (8.66±0.33)	3.00±0.00^{d} (8.33±0.33)	2.50±0.50^{c} (8.00±0.00)	1.50±0.28^{c} (7.33±0.33)	0.75±0.25^{c} (6.66±0.33)
	100	6	3.83±0.40^{d} (8.33±0.33)	3.16±0.16^{d} (8.00±0.57)	2.66±0.21^{d} (8.00±0.57)	2.16±0.16^{d} (7.33±0.88)	1.66±0.33^{d} (7.00±0.57)	0.83±0.31^{d} (6.66±0.33)
	200	6	3.83±0.16^{d} (8.33±0.33)	2.50±0.34^{d} (7.66±0.33)	1.50±0.22^{d} (7.33±0.33)	1.16±0.16^{d} (6.66±0.33)	0.16±0.16^{d} (6.33±0.33)	0.00±0.00^{d} (6.00±0.57)

[a] Means (± SE) were analyzed using Parametric, One-way ANOVA. Figures in parentheses represent the control; [b, c & d] Values are significantly different at $P<$ *0.05,0.01 & 0.001 respectively. N: Number of observations.*

Table 1.7 Effect of methanol extracts of selected plants on the behavioral inactivity of adult *Oxya hyla* [a]

Plants	Conc mgml^{-1}	N	Days of observation 1	2	3	4	5	6
Ageratum conyzoides	50	5	3.00±0.70[b] (0.00±0.00)	6.00±1.41[b] (0.33±0.33)	8.00±1.37[c] (1.33±0.33)	9.20±0.80 (1.33±0.33)	10.00±0.00[d] (1.33±0.33)	10.00±0.00[d] (2.33±0.33)
	100	4	3.75±0.85[b] (0.00±0.00)	7.25±0.85[c] (0.33±0.33)	10.00±0.00[d] (1.33±0.33)	10.00±0.00[d] (2.33±0.66)	10.00±0.00[c] (2.66±0.88)	10.00±0.00[d] (3.00±0.57)
	200	4	10.00±0.00[d] (0.25±0.25)	10.00±0.00[d] (0.25±0.25)	10.00±0.00[d] (0.75±0.47)	10.00±0.00[d] (1.25±0.47)	10.00±0.00[d] (1.75±0.47)	10.00±0.00[d] (2.25±0.47)
Artemisia nilagarica	50	3	4.66±0.33[c] (0.00±0.00)	8.66±0.88[b] (0.00±0.00)	9.33±0.33[c] (0.00±0.00)	10.00±0.00[c] (0.66±0.33)	10.00±0.00[c] (1.33±0.33)	10.00±0.00[c] (1.66±0.33)
	100	3	3.00±0.57 (1.00±0.57)	6.33±0.88 (1.66±0.88)	8.33±0.88[b] (1.66±0.88)	10.00±0.00[b] (1.66±0.88)	10.00±0.00[c] (2.33±0.33)	10.00±0.00[c] (2.33±0.33)
	200	3	5.00±0.00[c] (0.33±0.33)	8.33±0.33[c] (0.33±0.33)	10.00±0.00[c] (0.33±0.33)	10.00±0.00[c] (1.33±0.33)	10.00±0.00[c] (1.66±0.33)	10.00±0.00[c] (2.66±0.33)
Eupatorium adenophorum	50	3	4.33±0.33[c] (0.00±0.00)	7.66±0.33[c] (0.66±0.33)	9.66±0.33[c] (1.66±0.33)	10.00±0.00[c] (1.66±0.33)	10.00±0.00[c] (2.66±0.33)	10.00±0.00[c] (2.66±0.33)
	100	3	3.66±0.33[c] (0.00±0.00)	7.33±0.33[c] (0.00±0.00)	9.66±0.33[b] (1.00±0.57)	10.00±0.00[c] (1.66±0.33)	10.00±0.00[c] (2.00±0.00)	10.00±0.00[c] (2.66±0.33)
	200	3	3.00±0.57[b] (0.00±0.00)	8.00±0.57[b] (1.00±0.57)	10.00±0.00[c] (1.66±0.33)	10.00±0.00[c] (1.66±0.33)	10.00±0.00[c] (1.66±0.33)	10.00±0.00[c] (2.33±0.33)
Eupatorium riparium	50	3	2.66±0.66 (0.00±0.00)	6.33±0.66[b] (0.00±0.00)	9.00±0.57[c] (0.00±0.00)	9.66±0.33[c] (0.00±0.00)	10.00±0.00[c] (0.33±0.33)	10.00±0.00[c] (0.66±0.33)
	100	3	3.66±0.33[c] (0.00±0.00)	7.33±0.66[c] (0.00±0.00)	9.66±0.33[c] (0.33±0.33)	10.00±0.00[c] (0.33±0.33)	10.00±0.00[c] (1.00±0.00)	10.00±0.00[c] (1.66±0.33)
	200	3	4.33±0.88[b] (0.00±0.00)	7.00±1.00[b] (0.00±0.00)	10.00±0.00[c] (0.33±0.33)	10.00±0.00[c] (0.66±0.33)	10.00±0.00[c] (1.00±0.57)	10.00±0.00[c] (1.33±0.33)
Lantana camara	50	3	4.00±0.00[c] (0.66±0.33)	6.66±0.88[b] (1.66±0.88)	8.00±0.00[c] (2.00±0.88)	9.00±0.00[c] (2.33±1.15)	10.00±0.00[c] (3.33±1.20)	10.00±0.00[c] (3.66±1.00)
	100	3	3.66±0.33[b] (0.66±0.33)	6.66±0.33[b] (1.66±0.88)	8.00±0.57[c] (2.00±0.88)	10.00±0.00[c] (2.33±1.15)	10.00±0.00[c] (3.33±1.20)	10.00±0.00[c] (3.66±1.00)
	200	3	4.66±0.66[b] (0.66±0.33)	7.66±0.88[c] (1.66±0.88)	10.00±0.00[c] (2.00±0.88)	10.00±0.00[c] (2.33±1.15)	10.00±0.00[c] (3.33±1.20)	10.00±0.00[c] (3.66±1.00)

[a] Means (± SE) were analyzed using Parametric, One-way ANOVA . Figures in parentheses represent the control; [b, c & d] Values are significantly different at $P< 0.05, 0.01$ & 0.001 respectively, N: Number of observation.

Table 1.8 Effect of aqueous extracts of selected plants on the behavioral inactivity of adult *Oxya hyla* [a]

Plants	Conc mgml^{-1}	N	Days of observation 1	2	3	4	5	6
Ageratum conyzoides	50	3	1.66±0.33[b]	2.66±0.33[b]	2.66±0.33[b]	3.33±0.33[b]	3.33±0.33[b]	3.66±0.33[b]
			(0.00±0.00)	(0.00±0.00)	(0.33±0.33)	(0.66±0.33)	(1.00±0.00)	(1.33±0.33)
	100	3	1.33±0.33	2.66±0.33[b]	3.00±0.57	3.00±0.57	4.00±0.57	4.66±0.33[b]
			(0.00±0.00)	(0.33±0.33)	(0.66±0.33)	(1.33±0.33)	(1.66±0.33)	(2.33±0.33)
	200	3	1.66±0.33[b]	2.00±0.57[b]	2.33±0.33[b]	3.66±0.66	4.66±0.33	5.33±0.33[b]
			(0.00±0.00)	(0.33±0.33)	(0.66±0.33)	(1.66±0.33)	(2.33±0.33)	(2.66±0.33)
Artemisia nilagarica	50	3	2.33±0.33[b]	2.33±0.33[b]	3.00±0.57[b]	3.33±0.66[b]	4.33±0.66[b]	5.33±0.66[b]
			(0.00±0.00)	(0.00±0.00)	(0.00±0.00)	(0.33±0.33)	(0.33±0.33)	(1.00±0.57)
	100	3	1.66±0.33[b]	3.00±0.00[b]	3.66±0.66[b]	3.66±0.66[c]	4.00±1.00[b]	4.66±1.20[b]
			(0.00±0.00)	(0.00±0.00)	(0.00±0.00)	(0.33±0.33)	(0.33±0.33)	(1.00±0.57)
	200	3	2.66±0.33[b]	3.33±0.88	4.33±0.66[b]	4.66±0.88	5.33±1.20	6.66±0.88[b]
			(0.00±0.00)	(0.00±0.00)	(0.00±0.00)	(0.66±0.33)	(0.66±0.33)	(1.33±0.33)
Eupatorium adenophorum	50	5	2.20±0.37[c]	2.60±0.24[d]	3.20±0.48[c]	3.80±0.37[c]	4.20±0.37[c]	4.80±0.37[d]
			(0.00±0.00)	(0.00±0.00)	(0.00±0.00)	(0.66±0.33)	(1.00±0.00)	(1.66±0.33)
	100	3	1.66±0.33[b]	1.66±0.33[b]	2.33±0.33[b]	3.33±0.33[b]	4.00±0.57[b]	4.33±0.33[b]
			(0.00±0.00)	(0.00±0.00)	(0.00±0.00)	(0.66±0.33)	(1.00±0.00)	(1.66±0.33)
	200	3	2.33±0.33[b]	2.66±0.33[b]	3.00±0.00[b]	4.66±0.33[b]	5.33±0.33[c]	6.00±0.57[b]
			(0.00±0.00)	(0.00±0.00)	(0.00±0.00)	(0.66±0.33)	(1.00±0.00)	(1.66±0.33)
Eupatorium riparium	50	3	2.66±0.33[b]	3.33±0.33[b]	3.66±0.33	4.33±0.33[b]	6.00±0.57[c]	6.66±0.33[c]
			(0.00±0.00)	(0.66±0.33)	(1.33±0.33)	(1.66±0.33)	(2.33±0.33)	(3.33±0.33)
	100	3	2.33±0.33[b]	3.33±0.33[b]	3.66±0.33[b]	4.33±0.33[b]	6.00±0.57	6.33±0.33[b]
			(0.00±0.00)	(0.33±0.33)	(0.66±0.33)	(1.66±0.33)	(2.66±0.33)	(3.66±0.33)
	200	3	2.33±0.33[b]	3.00±0.57[b]	4.66±0.33[b]	5.66±0.33[b]	6.33±0.33[b]	7.33±0.33[d]
			(0.00±0.00)	(0.33±0.33)	(0.66±0.33)	(1.66±0.33)	(2.66±0.33)	(3.33±0.33)
Lantana camara	50	3	1.66±0.33[b]	1.66±0.33	3.00±0.00[b]	3.00±0.00	3.33±0.33	3.66±0.33[b]
			(0.00±0.00)	(0.33±0.33)	(1.33±0.33)	(1.66±0.66)	(2.00±0.57)	(2.00±0.57)
	100	3	1.66±0.33[b]	2.33±0.33	3.66±0.33[b]	4.00±0.57[b]	5.33±0.33[c]	5.66±0.33[b]
			(0.00±0.00)	(0.33±0.33)	(0.33±0.33)	(1.00±0.00)	(1.00±0.00)	(1.33±0.33)
	200	3	3.33±0.33[b]	3.66±0.33[b]	3.66±0.33[b]	5.33±0.33[b]	5.66±0.33	6.66±0.33[b]
			(0.33±0.33)	(0.66±0.33)	(0.66±0.33)	(1.33±0.33)	(2.00±0.57)	(2.66±0.33)

[a] Means (± SE) were analyzed using Parametric, One-way ANOVA . Figures in parentheses represent the control; [b, c & d] Values are significantly different at P< 0.05,0.01 & 0.001 respectively, N: Number of observation.

Table 1.9 Effect of 1% methanol extracts of selected plants on the behavioral inactivity of adult *Oxya hyla* [a]

Plants	Conc mgml^{-1}	N	Days of observation 1	2	3	4	5	6
Ageratum conyzoides	50	3	2.33±0.33^{b} (0.00±0.00)	4.66±0.33^{b} (0.66±0.33)	7.66±0.33^{c} (1.00±0.57)	8.66±0.33^{d} (1.66±0.33)	9.33±0.33^{c} (2.33±0.33)	10.00±0.00^{c} (3.33±0.33)
	100	3	2.66±0.33^{b} (0.00±0.00)	5.33±0.66^{b} (1.00±0.57)	7.33±0.33^{c} (1.66±0.33)	9.33±0.33^{c} (1.66±0.33)	10.00±0.00^{c} (2.33±0.33)	10.00±0.00^{c} (3.33±0.33)
	200	3	2.33±0.33 (0.33±0.33)	4.33±0.88 (0.33±0.33)	9.33±0.33^{c} (1.00±0.57)	10.00±0.00^{c} (1.66±0.33)	10.00±0.00^{c} (2.33±0.33)	10.00±0.00^{c} (2.66±0.33)
Artemisia nilagarica	50	3	2.33±0.33^{b} (0.00±0.00)	5.33±0.88^{b} (0.33±0.33)	8.00±0.57^{c} (0.33±0.33)	8.66±0.33^{b} (1.00±0.57)	9.33±0.33^{c} (1.66±0.33)	10.00±0.00^{c} (2.33±0.33)
	100	3	2.00±0.57 (0.00±0.00)	4.66±0.88 (0.66±0.66)	7.66±0.66^{c} (1.66±0.33)	9.33±0.33^{c} (2.00±0.57)	10.00±0.00^{c} (2.00±0.57)	10.00±0.00^{c} (2.33±0.66)
	200	3	2.66±0.33^{b} (0.33±0.33)	5.66±0.33^{c} (0.33±0.33)	9.33±0.33^{c} (1.00±0.57)	10.00±0.00^{c} (1.66±0.33)	10.00±0.00^{c} (2.00±0.57)	10.00±0.00^{d} (2.33±0.66)
Eupatorium adenophorum	50	4	3.25±0.85^{b} (0.00±0.00)	4.50±1.04^{b} (0.00±0.00)	6.50±0.86^{b} (1.66±0.33)	7.75±0.63^{c} (2.33±0.33)	9.50±0.50^{d} (3.33±0.33)	10.00±0.00^{d} (3.33±0.33)
	100	4	3.75±0.63^{c} (0.00±0.00)	6.25±0.85^{c} (0.00±0.00)	8.00±0.91^{c} (1.66±0.33)	9.75±0.25^{d} (2.33±0.33)	10.00±0.00^{d} (3.33±0.33)	10.00±0.00^{d} (3.33±0.33)
	200	4	4.00±0.41^{c} (0.00±0.00)	7.75±0.75^{d} (0.00±0.00)	9.50±0.28^{d} (1.66±0.33)	10.00±0.00^{d} (2.33±0.33)	10.00±0.00^{d} (3.33±0.33)	10.00±0.00^{d} (3.33±0.33)
Eupatorium riparium	50	5	3.20±0.48^{c} (0.00±0.00)	3.60±0.51^{c} (0.40±0.24)	4.40±0.40^{c} (1.66±0.24)	4.80±0.20^{c} (1.66±0.24)	6.00±0.44^{c} (1.66±0.24)	6.40±0.24^{d} (2.66±0.24)
	100	5	3.00±0.54^{c} (0.00±0.00)	4.60±0.24^{d} (0.40±0.24)	5.00±0.31^{d} (1.66±0.24)	6.00±0.44^{d} (1.66±0.24)	7.20±0.37^{d} (1.66±0.24)	7.60±0.51^{c} (2.60±0.24)
	200	6	3.50±0.34^{d} (0.16±0.16)	5.33±0.76^{d} (0.83±0.30)	5.83±0.98^{c} (1.50±0.22)	6.83±1.25^{b} (2.16±0.16)	7.83±1.25^{c} (2.50±0.22)	8.16±1.33^{b} (3.50±0.22)
Lantana camara	50	3	2.33±0.33 (0.33±0.33)	2.66±0.33^{b} (0.33±0.33)	3.33±0.33^{b} (1.00±0.57)	3.66±0.33^{d} (1.66±0.33)	4.66±0.33 (2.00±0.57)	5.33±0.33 (2.33±0.66)
	100	3	2.33±0.33 (0.33±0.33)	3.33±0.33^{b} (0.33±0.33)	3.66±0.33 (1.33±0.33)	4.00±0.00^{b} (1.33±0.33)	4.33±0.33^{b} (1.33±0.33)	6.00±1.00 (2.00±0.57)
	200	3	2.33±0.33^{b} (0.00±0.00)	4.33±0.33^{c} (0.66±0.33)	4.33±0.33^{b} (1.33±0.33)	5.33±0.33 (1.66±0.66)	5.66±0.33^{b} (2.33±0.33)	7.00±0.57^{c} (3.33±0.33)

[a] Means (± SE) were analyzed using Parametric, One-way ANOVA. Figures in parentheses represent the control; [b, c & d] Values are significantly different at $P < 0.05, 0.01$ & 0.001 respectively. N: Number of observation.

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LIFE CYCLE STUDY OF THE SMALL RICE GRASSHOPPER,

OXYA HYLA

CHAPTER - 2

INTRODUCTION

Grasshoppers compete with humans for plant resources all over the world (Dempster, 1963; Farrow, 1990). They can cause damage to crops or rangeland (DeBrey et al. 1993). Several species can move long distances when triggered by unknown environmental cues (Pfadt, 1988) upto over 3500m in elevation, which is well outside of their typical habitat (Lockwood et al. 1994).

2.1. General description

Adult - The mature grasshoppers are green and pale brown in color, with a dark stripe running laterally from each eye through the thorax to the base of the wing; the femurs and tibiae are green in color. The color of the nymphs are yellowish green having two prominent dark stripes in the thorax, these stripes are not visible in the first three instars.

Egg - All grasshoppers begin their lives as eggs which occur in oval, elongated egg pods. Yet eggs represent the least known stage of the grasshopper life cycle. They are laid in a mass of froth (which hardens to form the protective 'pod') a few centimeters above the water level on the rice or grass foliage or just below the soil surface on the wet soil hidden from the view of humans in autumn.

Nymph – Newly hatched nymphs are white. However, after several hours of exposure to sunlight, they assume the distinctive colors and markings of adults.

2.2. Life History

Incubation of eggs begins immediately after females deposit them in the soil. The embryo, at first a tiny disc of cells laying on the ventral side of the yolk surface and at the posterior end of the eggs, grows rapidly, receiving nourishment from the nutrient stores in the yolk. One or more males often attend a female actively depositing eggs. Depending at least partly on clutch size, females take from 25 to 90 minutes to lay a full complement of eggs. After withdrawing her ovipositor a female will take a minute or two to cover the aperture of the hole with particles of soil and ground litter. The female uses either her ovipositor or her hind tarsi, depending on species, to do this. The act appears to be instinctive maternal care that provides some protection for the eggs from predation by birds, rodents, and insects.

There is only a single generation per year, eggs overwinter, hatch in late March or mid April or early May as soil temperatures rise and spring rains begin. The nymphs are semi aquatic. Young males generally pass through five instars, whereas females have six instars (Pfadt, 1988). They are alleged to swim quite well and can gain access to the rice plants in flooded fields in this way. Development proceeds more rapidly when the weather is warm and not too wet.

In spring the first nymph to leave the egg pod makes a tunnel from the pod to the soil surface through which the succeeding nymphs emerge, about five months having been spent in egg stage. The emergence of hatching grasshoppers may be readily observed. All embryos of a single pod usually wriggle out one after another. Once out, they immediately shed an embryonic membrane called the serosa. An individual hatchling, lying on its side or back and squirming, takes only a few minutes to free itself. During this time the hatchlings are susceptible to predation by ants. After the shedding of the membrane the young grasshoppers stand upright and are able to jump away and escape attacking predators. In spring young grasshoppers avail green and nutritious host plants in the surrounding. The majority of individuals in grasslands are grass feeders, but some individuals are mixed feeders, eating both grasses and forbs and also feed on broad-leaved plants (Pfadt and Lavigne, 1982). The broad-leaved plants are necessary for maximum growth. They prefer the lush growth around edges of streams, marshes and cultivated fields. Hosts include grasses and most crops, especially paddy, alfalfa and vegetables, and occasionally trees and shrubs (Mulkern et al. 1969).

For young grasshoppers to continue their growth and development and reach the adult stage, they must periodically molt or shed their outer skin changing structures and their form. This process is called metamorphosis. Depending on species and sex, they molt five to six times during their nymphal or immature life. The insect between molts is referred to as an instar; a species with five molts thus has five instars. After shedding the serosal skin, the newly hatched nymph is the first instar. After each molt the instar increases by one so that the nymph consecutively becomes a second, third, fourth, fifth and sixth instars. When the fifth instar molts, the grasshopper becomes an adult male or an imago and after sixth instar molts it becomes an adult female. A number of insects undergo hemimetabolic metamorphosis, such as grasshoppers. With this type of metamorphosis the insect that hatches looks like the adult except for its smaller size, lack of wings, fewer antennal segments, and rudimentary genitalia.

The new adult has fully functional wings but is not yet ready to reproduce. The female has a preoviposition period during which there is increase in weight and matures. Having mated with a male, the female digs a small hole in the soil with the ovipositor and deposits the first group of eggs or wrap around in the broad leaves of the plants and deposits the eggs (Pfadt 1988). Once egg laying begins, the female continues to deposit eggs regularly for the rest of her short life. Depending on the species, production may range from three pods per week to one pod every one to two weeks. The species that lay fewer eggs per pod oviposit more often than those that lay more eggs per pod.

2.3. Behavior

A grasshopper's day (and night) is linked closely to the abiotic factors, especially temperature, but also light, rain, wind, and soil. Stereotyped and instinctive behavior patterns serve grasshoppers remarkably well in making adjustments to wide fluctuations of physical factors that otherwise might be fatal. Grasshoppers effectively exploit the resources of their habitat and at the same time are able to tolerate or evade the extremes of physical factors. Their characteristic rapid jumping and flying responses help them escape numerous enemies that parasitize or prey upon them (Belovsky and Slade, 1995).

A grasshopper's day usually starts shortly after dawn. Since body temperatures have fallen during the night, a grasshopper on the ground crawls to an open spot, often on the east side of vegetation, that allows it to warm itself by basking in the radiant rays of the sun. A common orientation is to turn a side perpendicular to the rays and lower the associated hindleg, which exposes the abdomen. Those that have spent the night on a plant make adjustments in their positions to take advantage of the sun's rays or they may climb or jump down to the ground to bask. Although grasshoppers generally remain quiet while they bask, they occasionally stir, preen, and turn around to expose the opposite side, and sometimes crawl to a more favorable basking location. Grasshoppers may bask for a second time in the cool of late afternoon. Then as shadows begin to engulf the habitat, they retreat into their customary shelters.

After basking for one to two hours on sunny days, grasshoppers become active. They may walk about, seek mates, or feed. Since grasshoppers are cold-blooded creatures, their usual daily activities are interrupted when the weather turns cold, overcast, or rainy. During such times they generally remain sheltered and inactive.

During warm sunny weather of late spring and summer, grasshoppers take advantage of two foraging periods, one in the morning and one in the afternoon. Individuals of this species climb the host plant to feed on leaves, petals, buds, soft seeds, cut and fell a grass leaf and feed on it while sitting on the ground. Severed leaves dropped by the grasshoppers that feed on the host plant, are soon found and devoured by the ground foragers. In habitats infested by dense populations of grasshoppers, pellets of their excrement, rather than litter, accumulate in small conspicuous piles. Grasshoppers fastidiously select their food. By lowering their antennae to the leaf surface and drumming (tapping) it with their maxillary and labial palps, grasshoppers taste a potential food plant (Chapman and Sword, 1993). Gustatory sensilla located on the tips of these organs are stimulated by attractant and repellent properties of plant chemicals, allowing a grasshopper to choose a favorable host plant and reject an unfavorable one. A grasshopper may take an additional taste by biting into the leaf before it begins to feed freely. Phagostimulants are usually important ones nutritionally certain sugars, phospholipids, amino acids, and vitamins. Grasshoppers may even make choices among the leaves of a single host plant. They prefer young green leaves and discriminate against old yellowing ones. This feeding may be a means of restoring water balance - either losing or gaining moisture.

Amazingly, grasshoppers are able to communicate visually and acoustically among themselves (Bailey et al. 1993). They produce sounds with structural adaptations on hindlegs and wings and receive these signals with auditory organs (ears) located in the first abdominal segment. Using their colorful wings and hindlegs they also flash visual messages and receive these with their compound eyes. Intraspecific communication, that which occurs between members of the same species, is used to attract and recognize mates, to ward off an unwanted suitor, and to defend a territory or a morsel of food. Grasshoppers produce acoustical signals by rubbing the hindlegs against the tegmina or the sides of the abdomen. They may also communicate by rapidly flexing or snapping their hindwings in flight, a behavior called crepitation. Each species apparently produces its own unique sound and, in human terms, has its own language.

MATERIALS AND METHODS

2.4. Insect collection:

The freshly hatched nymphs were collected during late March or early April every year (1999 – 2001) with host plant leaves for feeding. The nymphs were kept in the stocking cage of 75cm x 30cm and 30cm height, which was covered with the special designed lid, allowing free air circulating inside at the average room temperature of 18-20°C and relative humidity 80-90 %.

2.5. Identification:

Identification of the adult insects, both males and females were sent to the Zoological Survey of India, Calcutta, India. The Identification Report No. 485, Z.S.I. Lot No. 46/2000, Dated 1.2.2001.

2.6. Insect rearing:

Groups of newly molted nymphs were separated from their original positions by mean of a soft hair brushes and forceps and transferred to rearing units, on which they will be reared till further molting. Fresh leaves of host plants were given daily. Their faecal matter and food remains from the rearing units were cleaned daily.

2.7. Nymphal development:

Nymphal duration as well as adult emergence was recorded. Morphological measurements of each nymphal stage and adult males and females were taken one or two days after emergence under a dissecting microscope. All experiments were conducted in the laboratory conditions but field observations were also made. Time taken in days for molting/ hatching and life duration of each stage was recorded (Kawano and Ando 1997). The longevity of the nymphs and adults were also studied after treatments with aqueous and methanol extracts of *Ageratum conyzoides*.

2.8. Statistical analysis: Means and standard error were analyzed using Parametric Test One-Way ANOVA.

RESULT

2.9. Insects emergence and occurrence

The insect species was identified as *Oxya hyla*, belonging to Orthoptera and family Acrididae. Emergence and occurrence of different instars of *Oxya hyla* was found to vary during the sampling years. The emergence of the I instar was recorded from the middle March each year after the rains and when atmospheric temperature increased. The population reaches a peak on May-June and disappeared totally on September-October every year. The II and III instars emerged on April-May reaching the peak on June-August and disappeared by October-November (Figure 2.1A,B and C). Furthermore, the IV, V and VI instars emerged on April-May, May-June and June-July with maximum number of individuals on July-August (IV & V instars) and September-October respectively.

Male and female adults emerged by June-July, attaining the maximum number on September-October. Females showed the maximum number on October-November every year (Figure 2.1A, B and C).

2.10. Morphometric features

Detail morphological features of the individuals of different nymphal stages of *Oxya hyla* was shown in Table 2.1. The measurements of total length of the insect, head width, wing length, femur length, tibia length, antenna length and pronotum were recorded.

2.11. Weights of individual of different stages

Table 2.2 depicted clearly the weights of eggs, egg pods and individuals of different stages in the life cycle of *Oxya hyla*. Average weight of a single egg was 1.33mg and an egg pod was 53.5mg. The initial wet weight of freshly hatched hoppers (I instar) averaged 8 mg and they attained a body weight of about 15, 29, 46 and 80 mg when they reached the II, III, IV and V instars respectively. The initial slow growth rate was however, succeeded by a period in which the growth rates was rapid and almost doubled. The average adult male attained the weight of 215 mg on the 150 days. The wet weights of the egg, egg pod and the first 5 instars of females was found to be similar with that of the males except for a slight increased in instar weights as shown in Table 2.2. Female had an extra instar, the VI instar having an average weight of 178 mg; the average adult female weighed about 304 mg. The larger body weight attained by a female was mainly due to the extension of the hopper period. Females showed variable body weights due to successive egg laying.

2.12. Normal life duration

Males *Oxya hyla* required 108 days and passed through 5 instars to become adults (Figure 2.2B). The first 2 instars lasted only about 15 days each, instars III, IV and V lasted for about 21, 23 and 32 days respectively (Table 2.3). The adult male lived for 48 days since the first day of molting from the V instar till death. Table 2.3 further explained clearly that the female nymphs required not only longer period of 141 days, but also passed through 6 instars to become adults (Figure 2.2A). The I and II instars took 16 days, II and IV instars lasted for 22 days and the V and VI instars lasted for 33 days respectively. Adult female lived for 55 days; the average life span of females from hatching to death was 196 days where as in males was 155 days at an average temperature of 18-20^{0}C and relative humidity of 80-90%.

2.13. Egg laying

Adult females laid their eggs during the months of September-November in the soil or leaves of the host plants. Most of the eggs laid overwinter. Females possessed a pre-oviposition period of 14-20 days and an oviposition period of one-week (4-6 days)

(Table 2.3). The average number of egg pod per female was about 6, and total number of egg per pod was about 15-17. Therefore, it was observed that each female adult *O. hyla* laid an average number of about 100 eggs on its life span (Table 2.2).

2.14. Effect of *Ageratum conyzoides* extracts on instar life duration

Table 2.4a & b showed the longevity of the individuals in each instar stage after treated with aqueous and methanol extracts of *A. conyzoides* in different concentrations. It clearly explained that the aqueous extracts were found less effective in disturbing normal life duration of the nymphs in each instar stage compared to the control individuals (Table 2.3).

Methanol extracts of *A. conyzoides* was more effective in inhibiting normal life duration of *O. hyla*. No individuals of any instar stage can live beyond the 6^{th} day of experiment, instead all died within 3-4 days (Table 2.4b) in concentrations tested. Table 2.5 also explained clearly the parallel activity of *A. conyzoides* with Precocene I and II the two active principles isolated from this plant on life duration of III instars of *O. hyla*. Further, it was observed that Precocene I had higher insecticidal activity than Precocene II within 6 days of assaying, which was very significant, compared to the control.

2.15. Effect of *A. conyzoides* extracts, Precocene I and Precocene II on molting of nymphs

Table 2.6a & b showed molting percentage of different instar nymphs after the sixth day of assaying with aqueous and methanol extracts of *A. conyzoides*. The aqueous extracts of *A. conyzoides* showed a slight stimulating effect on molting. It was seen that the methanol extracts showed a very strong insecticidal activity that no insects from any instar stage could live and molt to the next after treatment. Precocene I and II, were also observed to stimulate molting at lower concentrations, but at higher concentrations they are toxic and killed the insects totally as was shown in Table 2.7.

DISCUSSION

It is observed that in more than half of the surveyed areas and hence concluded that *O. hyla* will emerge widely in the paddy fields throughout North-East India within a few years. *O. hyla* is abundant in the fallow fields, where food plants are available (Ando and Yamashiro, 1993). Sparse populations of *Oxya hyla* surviving in damp grassy areas free from insecticides may have been invading abandoned paddy fields and increasing in density.

The nymphs hatched in August and later did not reach the adult stage and died during December. Few of the adult males and females survive during winter months, but they die off just in the beginning of spring (March-April). The life duration of the instars and adults is found to disturb mainly by the presence and absence of natural enemies, physical factors, and chemical insecticides, pollution and other human activity.

In the low lying fields it was found that during summer, due to heavy rainfall, many of the young nymphs die of drowning. Similarly due to freezing cold in winter, all the nymphs as well as most of the adult insects die due to cold. The normal development of the species is disturbed if they are treated with the extracts of *A. conyzoides*. Aqueous extracts are found to have lesser insecticidal activity as compared to methanol extracts. In methanol extract the insects get inactivated immediately after applying the extracts which leads to death after few hours. The same observations were obtained when insects were treated with Precocene I and II.

CONCLUSION

Grasshopper life history is a seasonal cycle – the timing of the period of egg hatch, nymphal growth and development, emergence of the adults and acquisition of functional wings (fledging), and the deposition of eggs or reproduction. The occurrence of these periods is greatly influenced by environment. An early spring hastens these events and a late one delays them. Latitude also influences the dates of occurrence. The lower temperatures of higher altitudes, especially those of mountain meadows, are responsible for retarded seasonal cycles of grasshoppers. Grasshoppers pass the winter as eggs overwintering in the soil. The eggs hatch at different times from early spring until late summer. The variety of seasonal cycles (Newton et al. 1954) allows actively feeding and developing hoppers to spread out over the entire growing season. The species has its own time to hatch, develop and reproduce but with much overlapping cycles.

Past observations of hoppers in their natural habitat have revealed various behavioral responses. Each appears to have its own way of reacting to a battery of environmental factors. Since a relatively few species have been investigated, much remains to be discovered. The whole subject of grasshopper behavior provides a fertile area for research both in the field and in the laboratory. Acquiring sufficient information on the various aspects of grasshopper behavior will not only serve to improve integrated management of grasshopper pest species and the protection of beneficial ones, but will also advance the science of insect behavior.

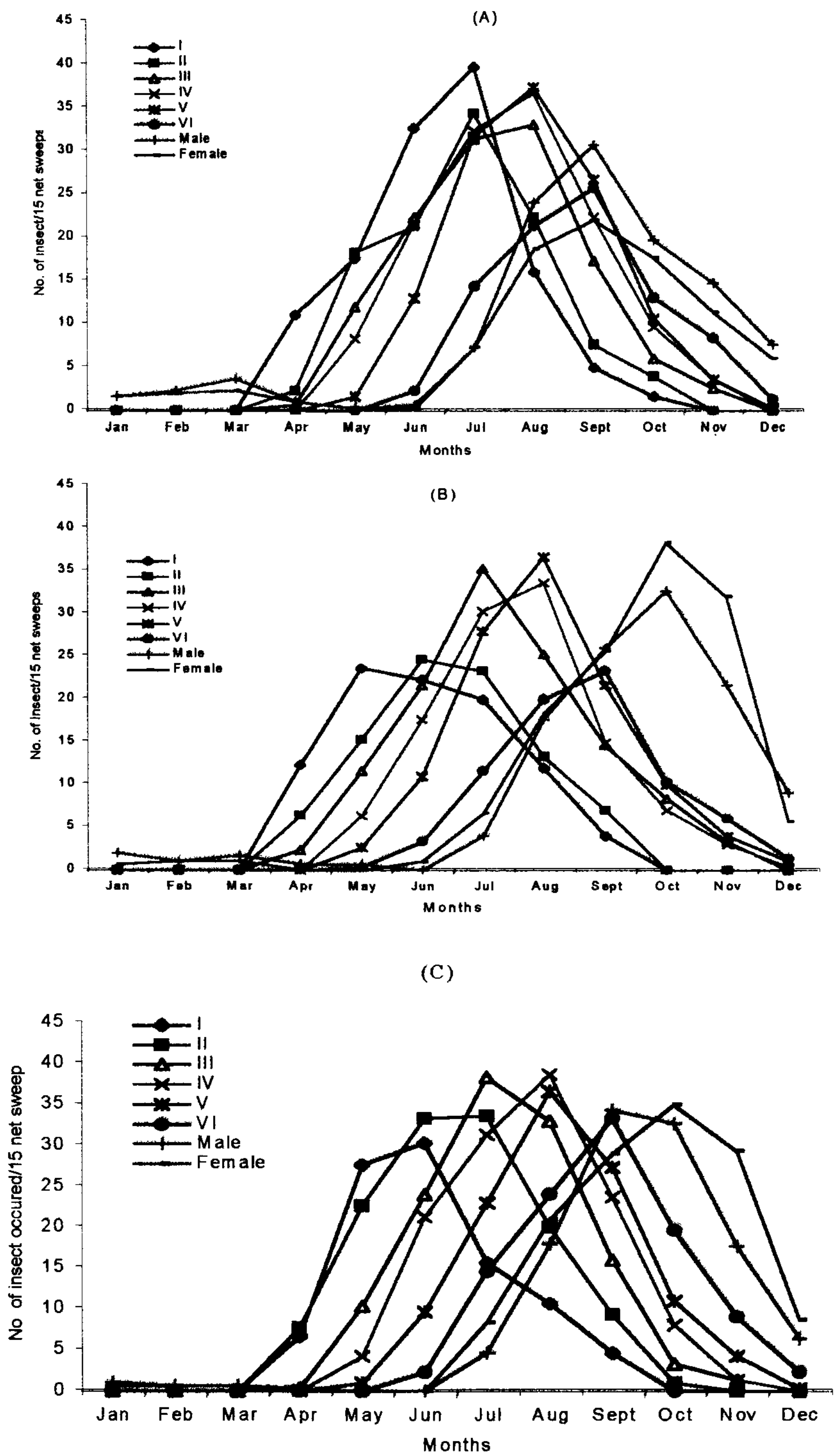

Figure 2.1 Occurrence of different stages of *Oxya hyla* in different months of the year (A) 1999, (B) 2000 and (C) 2001 respectively.

Table 2.1 Morphometric features of different stages of *Oxya hyla* (Serv) [a].

Instar	Total length (mm)	Head width (mm)	Wing length (mm)	Femur length (mm)	Tibia length (mm)	Antenna length (mm)	Pronotum (mm)	N
I	5.54±0.20	1.00±0.00	-	3.00±0.00	2.50±0.11	1.00±0.00	1.00±0.00	(11)
II	8.43±0.14	1.68±0.05	-	4.31±0.09	4.00±0.00	1.50±0.00	1.57±0.04	(8)
III	12.33±0.55	2.50±0.00	-	6.33±0.55	6.00±0.44	2.41±0.20	2.33±0.10	(6)
IV	14.25±0.25	3.00±0.00	1.12±0.12	7.87±0.12	7.12±0.12	3.25±0.14	3.12±0.12	(3)
V	20.50±0.28	3.37±0.07	4.62±0.24	11.25±0.47	9.25±0.47	5.50±0.28	3.50±0.20	(4)
VI	23.37±0.24	4.12±0.12	6.87±0.12	13.75±0.25	10.87±0.31	6.75±0.25	4.62±0.24	(3)
Male	22.33±0.42	3.25±0.11	18.50±0.50	13.33±0.21	10.50±0.22	8.66±0.21	3.83±0.10	(6)
Female	28.16±0.74	4.41±0.05	20.66±0.66	16.50±0.22	14.66±0.71	8.50±0.34	5.16±0.16	(6)

[a] Mean (± SE) are calculated using Parametric T-test One – Way ANOVA, N: Number of observation.

Table 2.2 Weights (mg) of individual stages of *Oxya hyla* and total number of eggs laid by female [a].

Egg	Egg pod	Instar I	Instar II	Instar III	Instar IV	Instar V	male	
1.33±0.21	53.50±6.00	8.71±0.70	15.16±1.85	29.00±2.59	46.58±3.59	80.35±3.66	215.95±5.14	
Egg	Egg pod	Instar I	Instar II	Instar III	Instar IV	Instar V	Instar VI	female
1.33±0.21	53.50±6.00	8.91±0.70	16.16±1.85	30.00±2.59	48.58±3.59	83.36±3.66	178.66±6.55	304.40±17.16

Total (Ave.) egg pod/female	Total (Ave.) egg/pod	(Ave) No. of egg laid/female
5.75±0.25	17.50±2.02	100.50±12.59

Table 2.3 The average normal life duration and total longevity (in days) of different instar stages of *Oxya hyla* in laboratory conditions [a].

Instar I	Instar II	Instar III	Instar IV	Instar V	Instar VI	Adult female	Egg
15.33±0.33	15.33±1.20	21.33±0.33	23.33±6.17	32.66±1.20	33.33±1.20	55.33±5.84	Over wintering
Instar I	Instar II	Instar III	Instar IV	Instar V	Adult male		
15.33±0.33	15.33±1.20	21.33±0.33	23.33±6.17	32.66±1.20	48.00±1.15		

Male nymphal period	Female nymphal period	Male adult	Female adult	Female pre-oviposition period	Female oviposition period
107.98±2.12	141.31±1.55	155.98±0.91	196.64±1.65	20.25±1.93	4.75±0.63

[a] Mean (± SE) are calculated using Parametric T-test One – Way ANOVA.

Figure 2.2 Stages of normal life cycle of female (A) and male (B) of *Oxya hyla*

Table 2.4 (a) Longevity (days) of the individual stages of *Oxya hyla* after treatment with different concentrations of aqueous extracts of *Ageratum conyzoides* [a].

Conc. $mgml^{-1}$	Instar I	Instar II	Instar IIII	Instar IV	Instar V	Instar VI	Male	Female
Control	15.33±0.33	15.33±1.20	21.33±0.33	23.33±6.17	32.66±1.20	33.33±1.20	48.00±1.15	55.33±5.84
50	11.50±0.28	12.75±0.47	13.00±0.41	14.25±0.85	21.25±1.60	21.75±1.79	23.00±1.77	25.50±1.04
100	11.75±0.25	13.75±1.18	14.00±0.81	14.50±1.50	20.25±1.11	20.75±1.70	24.25±1.11	30.25±2.53
200	11.40±0.51	12.00±0.63	13.80±0.86	14.80±1.15	19.00±0.54	19.40±1.40	20.40±1.63	26.20±4.81

(b) Longevity (days) of the individual stages of *Oxya hyla* after treatment with different concentrations of methanol extracts of *Ageratum conyzoides* [a].

Conc. $mgml^{-1}$	Instar I	Instar II	Instar III	Instar IV	Instar V	Instar VI	Male	Female
Control	12.50±0.86	12.75±1.11	13.25±0.85	13.50±1.04	14.75±0.63	14.25±0.85	21.75±2.65	29.00±3.02
50	-	-	-	-	-	-	-	-
100	-	-	-	-	-	-	-	-
200	-	-	-	-	-	-	-	-

[a] Mean (± SE) are calculated using Parametric T-test One – Way ANOVA.

Table 2.5. Longevity (days) of the III instar nymphs of *Oxya hyla* after treatment with different concentrations of Precocene I and Precocene II

Precocene I (dissolved in methanol)

Conc μgml^{-1}	Means (± SE)[a] longevity
Control	12.25±0.63
10	7.00±0.70
20	0.00±0.00

Precocene II (dissolved in methanol)

Conc $mgml^{-1}$	Means (± SE)[a] longevity
Control	12.75±0.63
1$mgml^{-1}$	8.00±0.41
2$mgml^{-1}$	0.00±0.00

[a] Mean (± SE) are calculated using Parametric T-test One – Way ANOVA.

Table 2.6 (a). Molting (%) in nymphal stages of *Oxya hyla* after treatment with aqueous extracts of *Ageratum conyzoides* [a].

Conc $mgml^{-1}$	Instar I	Instar II	Instar III	Instar IV	Instar V	Instar VI
Control	0.75±0.47	0.50±0.28	0.50±0.50	-	0.75±0.47	1.50±0.86
50	-	-	1.00±1.00	-	2.66±2.66	3.66±2.02
100	-	2.66±1.45	5.00±1.15	-	4.33±2.33	3.66±1.85
200	2.66±1.33	6.00±1.00	7.00±2.00	5.66±1.76	2.66±2.66	5.00±2.51

(b) Molting (%) in nymphal stages of *Oxya hyla* after treatment with methanol extracts of *Ageratum conyzoides* [a].

Conc $mgml^{-1}$	Instar I	Instar II	Instar III	Instar IV	Instar V	Instar VI
Control	0.75±0.47	0.50±0.28	0.50±0.50	-	0.75±0.47	1.50±0.86
50	-	-	-	-	-	-
100	-	-	-	-	-	-
200	-	-	-	-	-	-

Table 2.7 Molting (%) in the III nymphal stage of *Oxya hyla* after treatment with Precocene I and Precocene II [a].

Precocene I (in methanol)		Precocene II (in methanol)	
Conc μgml^{-1}	Means (± SE)	Conc $mgml^{-1}$	Means (± SE)
Control	2.00±0.00	Control	-
10	1.00±0.00	1.0	1.00±0.00
20	-	2.0	-

[a] Means (± SE) are calculated using Parametric T-test One – Way ANOVA.

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FURTHER SCREENING OF INSECTICIDAL ACTIVITY OF AGERATUM CONYZOIDES L. (COMPOSITAE) AND ITS TWO ACTIVE PRINCIPLES, PRECOCENE I AND II AGAINST DIFFERENT STAGES OF OXYA HYLA.

CHAPTER - 3

INTRODUCTION

Ageratum conyzoides L (Compositae) is a herbaceous plant, which is worldwide in distribution. The plant has a long history of traditional medicinal uses in several countries of the world in folk medicine including Asia, South America and Africa as a remedy for numerous diseases, it is also known for its insecticidal and nematocidal activity. This tropical species appears to be a valuable agricultural resource (Ming, 1999).

3.1 Botany

Ageratum is derived from the Greek "*a geras*," meaning non-aging, referring to the longevity of the flowers or the whole plant. The specific epithet "*conyzoides*" is derived from "*kónyz*," the Greek name of *Inula helenium,* which it resembles (Kissmann and Groth, 1993).

It has many synonyms and vernacular names (Jaccoud, 1961; Oliveira et al. 1993). *Ageratum* ranges from Southeastern North America to Central America, but the center of origin is in Central America and the Caribbean. Most taxa are found in Mexico, Central America, the Caribbean, and Florida. *Ageratum conyzoides* now is found in several countries in tropical and sub-tropical regions (Baker, 1965; Lorenzi, 1982; Correa, 1984; Cruz, 1985).

Ageratum conyzoides is an erect, herbaceous annual, 30 to 80 cm tall; stems are covered with fine white hairs, leaves are opposite, pubescent with long petioles and include glandular trichomes. The inflorescence contain 30 to 50 pink flowers arranged as a corymb and are self-incompatible (Jhansi and Ramanujam, 1987; Kaul and Neelangini, 1989; Ramanujam and Kalpana, 1992; Kleinschmidt, 1993). The fruit is an achene with an aristate pappus and is easily dispersed by wind. In some countries the species is considered a weed, and control is often difficult (Lorenzi, 1982; Scheffer, 1990; Kalia and Singh, 1993; Lam et al. 1993, Paradkar et al. 1993; Waterhouse, 1993; Kshatriya et al. 1994). Seeds are positively photoblastic, and viability is often lost within 12 months (Marlks and Nwachuku, 1986; Ladeira et al. 1987). The optimum germination temperature ranges from 20 to 25°C (Sauerborn and Koch, 1988). The species has great morphological variation, and appears highly adaptable to different ecological conditions.

3.2 Phytochemical characteristics

There is high variability in the secondary metabolites of *A. conyzoides, which* include flavonoids, alkaloids, cumarins, essential oils, and tannins. Many of these are biologically active. Essential oil yield varies from 0.02% to 0.16% (Jaccoud, 1961). Borthakur and Baruah (1987) identified precocene I and precocene II, in plants collected in India. These compounds have been shown to affect insect development, as antijuvenile hormones, resulting in sterile adults (Borthakur and Baruah, 1987). Ekundayo et al. (1988) identified 51 terpenoid compounds, including precocene I and precocene II. Gonzales et al. (1991) found 11 cromenes in essential oils, Vera (1993), found ageratocromene, other cromenes, and beta cariophyllene in its essential oil. Mensah et al. (1993) and Menut et al. (1993) reported similar yields of precocene I in the essential oil of plants collected in Ghana.

Vyas and Mulchandani (1986) identified flavones and Horrie et al. (1993) reported hexamethoxyflavone. Ladeira et al. (1987) in Brazil, reported three cumarinic compounds. The species contains alkaloids, mainly the pirrolizidinic group, which suggest that it may be a good candidate for pharmacological studies. Trigo et al. (1988) found several alkaloids, including 1,2- desifropirrolizidinic and licopsamine which can have hepatotoxic activity. Weindenfeld and Roder (1991) also found alkaloids in a hexane extract of *A. conyzoides* in Africa.

3.3 Folk Medicinal uses and pharmacological studies

A. conyzoides is widely utilized in traditional medicine by various cultures worldwide, although applications vary by region. In Central Africa it is used to treat pneumonia, but the most common use is to cure wounds and burns (Durodola, 1977). Traditional communities in India use this species as a bacteriocide, antidysenteric, and antihelminthic (Borthakur and Baruah, 1987), and in Asia, South America, and Africa, aqueous extract of this plant is used as a bacteriocide (Almagboul, 1985; Ekundayo et al. 1988). In Cameroon and Congo, traditional use is to treat fever, rheumatism, headache, and colic (Menut et al. 1993; Bioka et al. 1993). The whole plant is also used as an antidysenteric (Vera, 1993). The use of this species in traditional medicine is extensive in Brazil. Aqueous extracts of leaves or whole plants have been used to treat colic, colds and fevers, diarrhea, rheumatism, spasms, or as a tonic (Penna, 1921; Jaccoud, 1961; Correa, 1984; Cruz, 1985; Negrelle et al. 1988; Oliveira et al. 1993). *A. conyzoides* has quick and effective action in burn wounds and is recommended by Brazilian Drugs Central as an antirheumatic (Brasil, 1989).

Several pharmacological investigations have been conducted to determine efficacy. Duradola (1977) verified inhibitory activities of ether and chloroform extracts against in vitro development of *Staphylococus aureus*. Almagboul et al. (1985), using methanolic extract of the whole plant, verified inhibitory action in the development of *Staphylococcus aureus*, *Bacillus subtilis*, *Eschericichia coli*, and *Pseudomonas aeruginosa*. Bioka et al. (1993) reported effective analgesic action in rats using aqueous extract of *A. conyzoides* leaves (100 to 400 mg/kg). Assays realized in Kenya, with aqueous extract of the whole plant, demonstrated muscle relaxing activities, confirming its popular use as an antispasmodic (Achola et al. 1994).

3.4 Bioactivity of *A. conyzoides*

Ageratum conyzoides has biological activity that may have agricultural use, as shown by several research investigations in different countries. Jaccoud (1961), reported use of the leaves as an insect (moth) repellent. The insecticide activity may be the most important biological activity of this species. The terpenic compounds, mainly precocenes, with their antijuvenile hormonal activity are probably responsible for the insecticide effects.

Assays conducted in Colombia by Gonzalez et al. (1991) showed activity of this species against *Musca domestica* larvae, using whole plant hexane extract. Vyas and Mulchandani (1986) reported the action of cromenes (precocenes I and II), isolated from *Ageratum* plants, which accelerate larval metamorphosis, resulted in juvenile forms or weak and small adults. Ekundayo et al. (1988) also demonstrated the juvenilizing hormonal action of precocene I and II in insects, the most common effect being precocious metamorphosis and producing sterile adults. Raja et al. (1987), using *A. conyzoides* methanolic extract from fresh leaves (250 and 500 ppm) in the fourth instar of *Chilo partellus* (Lepidoptera: Pyralidae), a sorghum pest, observed the presence of a dark stain in the insects' cuticle and immature pupae formation, both symptoms of deficiency of juvenile hormone.

A. conyzoides also induces morphogenetic abnormalities in the development of mosquitoes larvae (*Culex quinquefasciatus*, *Aedes aegypt*, and *Anopheles stephensi*). This has been verified using petroleum ether extracts (5 and 10 mg/L) of the whole plants. The larvae showed intermediary stages between larvae–pupae, discolored and longer pupae, as well as incompletely developed adults (Sujatha et al. 1988). Extracts of the flowers of this species showed activity against mosquitoes (*Anopheles stephensi*), in the last instar, showing LD 50 with 138 ppm (Kamal and Mehra, 1991).

Acetonic extracts of the species produced significant effects against the mosquito, *Culex quinquefasciatus*, in India, when applied to fourth instar larvae and adult females. In larvae, the extracts produced altered individuals, intermediate between larvae and pupae, unmelaninized and with inhibition of development, as well as adults with deformed wing muscles. In female adults, there was loss of fecundity, lower eggs production, and production of defective eggs (Saxena et al. 1992). Similar results were observed in larvae *of Anopheles stephensi* and *Culex quinquefasciatus* in others essays, confirming the antijuvenile potential of *A. conyzoides* (Saxena and Saxena 1992; Saxena et al. 1994).

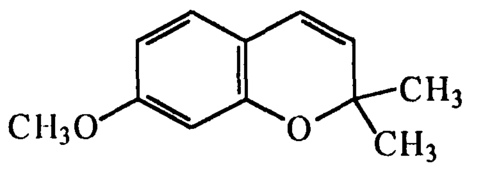
The species also has potential use in controlling other pests. Shabana et al. (1990), using aqueous extract of the whole plant, verified reduction of larvae emergence of *Meloidogyne incognita*. Pu et al. (1990) and Liang et al. (1994) verified that plants of *A. conyzoides* in *Citrus* orchards sheltered predators of the spider *Panonychus citri*, suggesting that its development in orchards is beneficial. Other *Citrus* spiders populations, *Phyllocoptruta oleivora* and *Brevipalpus phoenicis* were decreased with maintenance of *A. conyzoides* in the orchards and a reduction of leprosy virus was noted (Gravena et al. 1993)

The presence of *A. conyzoides* can also be used as germination inhibitor, decreasing development of several herbaceous plants. Jha and Dhakal (1990) in Nepal, reported that an aqueous extract of the aerial part or roots of this species (15 g of aerial part or 3 g of roots in 100 ml of water, during 24 h) inhibited germination of wheat and rice seeds while Prasad and Srivastava (1991) in India, reported a lower germination index in peanut seeds with aqueous extract.

3.5 Bioactivity of Precocene I and II

Given the voracity of insect larvae, it's amazing that any plant exists at all. However, despite their calm outward appearances, plants are vicious. Most of our poisons come from plants, and this is largely due to the plant's having to deal with animal predators through out their evolutionary history. One of the most fascinating levels of control by which plants can get rid of animal pests occurs at the level of juvenile hormones. Some plants poison predators with extra amount of it, while other plants destroy the ability of their predators to make it themselves. Of these compounds, Precocene I and Precocene II are the most important.

Precocene I or 7-methoxy-2,2-dimethyl-3-chromene



Precocene II or 6,7-dimethoxy-2,2-dimethyl-3-chromene

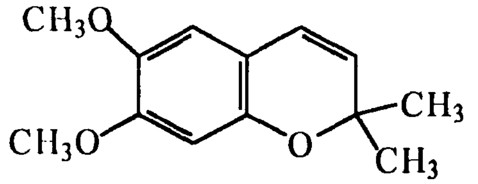


Figure 3.1 Chemical structure of Precocene I and Precocene II

MATERIALS AND METHODS

3.6 Plant species selected: - From all the plants tested, *Ageratum conyzoides* L (Compositae) was found to posses the maximum insecticidal activity on *Oxya hyla* after screening by previous experiments. Hence, it is required that this investigation be done in more detail.

3.7 Preparation of extracts

Fresh aerial parts of the plants were washed, cut into pieces and sundried for two weeks (average temp 18 - 20°C). The dried materials were grounded to powder in a homogenizer. The crude extracts were obtained by soaking the powdered samples in water and methanol for two weeks or more at room temperature. The extracts were filtered through a fine muslin cloth and the filtrates so obtained were distilled off, by a distilling apparatus. The final semi-dried samples were stored in a freezer at -20°C until (Harborne 1984 and Macedo et al. 1997).

3.8 Bioassay using topical application

Different concentrations of plant crude extract were prepared from the semi-dried sample of 50mgml^{-1} 100mgml^{-1} and 200mgml^{-1} for bioassays and stored in refrigerator at -4^{0} C. Freshly hatched and molted *Oxya hyla* nymphs were separated into different stages or age groups. Host plant leaves of *Oryza sativa* were also collected for the experiments. The fresh leaves were cut into smaller parts, dipped into different concentrations of crude extracts prepared. They were evaporated in the room temperature for 10 -15 minutes before introduce into the experimental chambers/flasks. 10-15 nymphs of separate nymphal stages and adults of *Oxya hyla* were first topically applied with the standardized amount (50,100 and 200mg/ml) of the concentration of extracts with the help of a fine hairbrush. They were then introduced into the experimental flasks, their activity was observed every day till the sixth day. Mortality, feeding, molting and behavioral activity were observed and recorded every day. Controls were setup by treating with the solvents used in the extract preparations (Macedo et al. 1997; Singh et al. 1998)

3.9 Bioassay with Precocene I and Precocene II

The two active principles of *Ageratum conyzoides* were obtained from Sigma – Aldrich Pharmaceutical Company, Bangalore, India. The standardized concentrations (10 and 20μgml^{-1} for Precocene I and 1mgml^{-1} and 2 mgml^{-1} for Precocene II) of these two compounds were prepared in methanol and then applied topically in the same manner as of the extracts against the III instar nymphs of *Oxya hyla*. Observations were recorded daily till the sixth day of assaying. Control insects were treated with methanol only.

3.10 Field Experimentation

3m^{2} plots were studied in the rice fields during the months of June – Nov of 2000 and 2001, when the rice crop had attained the height of 25cm - 75cm above the ground. The rice crops were sprayed with 100mgml^{-1} concentration of methanol and aqueous extracts of *Ageratum conyzoides* using a sprayer on sunny days in morning time at 8:00 am. Every 2 days after spraying the number of insects (*O. hyla*), nymphs adults (males and females) were sampled by insect net and by careful observation and recording the number of insect's occurrence and activity in each plot. To other plots of same size only methanol or water sprayings were done to serve as control for the same parameters of observations.

At the harvest time the fresh rice grains from the treated and control plots were weighed separately and yield compared statistically.

Observations on insect's occurrence and activity were studied in the fields by planting *Ageratum conyzoides* on the sides of every $4m^2$ plots of rice field. The study was conducted in the months of June – Nov of 2000 and 2001. Plots having the same sizes without *A. conyzoides* on the sides were kept as control.

3.11 Statistical evaluation

Mortality, feeding, molting and behavioral activity were analyzed using means and standard error and significance. Comparison were also analyzed and compared using Parametric Test of One-Way ANOVA and Parametric Two-Sided t-Test Paired Comparison.

RESULT

3.12 Effect of *A. conyzoides* extract on mortality of nymphal stages of *Oxya hyla*

Previous experiments had indicated the higher activity of methanol extracts over aqueous and it was also observed that methanol extract of *A. conyzoides* was far more effective against the nymphs of *Oxya hyla* than aqueous extracts. Figure 3.2 showed clearly the effect of the methanol extract concentrations against the insects. Figure 3.2 A, B and C explained the effects of the three extract concentrations (50, 100 and $200 mgml^{-1}$) against the mortality rate of instar nymphs I, II and III. It was obtained that all the three concentrations were very effective and showed an early total mortality of insects tested. Nymphs I were killed completely within 3 days at 50 and 100 $mgml^{-1}$, and 2 days at $200 mgml^{-1}$ (Figure 3.2A). Instar nymphs II and III were totally killed within 3 days by $50 mgml^{-1}$conc, 2 and 3 days by $100 mgml^{-1}$ and within 2 days by $200 mgml^{-1}$ conc (Figure 3.2B and C) respectively. Furthermore, Figure 3.3 D, E and F showed the mortality rate in instar nymphs IV, V and VI, where the nymphs were killed completely before the last day of the experiment. It was found that at 50 $mgml^{-1}$ nymphs IV and V were totally killed within 4 days and 6 days for VI instar nymphs. At 100 and 200 mgml^{-1} concs total mortality was found within 3 days in nymphs 4 and 3 days in nymphs V and within 5 days in VI instar nymphs.

In another observation with aqueous plant extract it was observed that the activity was far less effective compared to methanol extract. The mortality effect of aqueous extract against the nymphs was clearly explained in the Figure 3.4 (G, H and I) and Figure 3.5 (J, K and L) respectively. No total mortality was obtained in the insects at any instar stage within the period of observation. However, it was found that the extract showed significant increase in mortality against the insects treated.

3.13 Effect of Precocene I and II on mortality of III instar nymphs

When Precocene I and II, the two active principles of *A. conyzoides* were tested for insecticidal activity, it was found that these two compounds showed parallel results as methanol extracts. Precocene I in 10 and 20 μgml^{-1} concentrations was observed to posses high effect on mortality. 10μgml^{-1} showed 95 % mortality at the end of experimental period and 20μgml^{-1} showed 100% mortality in 5 days respectively as shown in Figure 3.6A. Precocene II at 1mgml^{-1} and 2mgml^{-1} concentrations showed high mortality. The highest mortality rate was 60% in 1mgml^{-1} in the last day of the observation and 100% on the same day with 2mgml^{-1} as shown in Figure 3.6B.

3.14 Effect of the *A. conyzoides* extract on feeding activity of nymphal stages of *Oxya hyla*

Tables 3.1- 3.4 showed the antifeeding activity of both methanol and aqueous extracts of *A. conyzoides* on instar nymphs of *O. hyla*. All the extract concentrations inhibited feeding completely within few days. 50 mgml^{-1} concentration methanol extract stopped insects feeding totally within 2 days in nymphs I to IV. However, in case of aqueous extract concentrations, no total feeding inhibition was observed, though a very significant effect was recorded (Table 3.1). Instar nymphs V and VI were stopped feeding by methanol extract within 3 and 6 days respectively as shown in Table 3.2. Further, Table 3.2 and Table 3.3 showed the effect of 100mgml^{-1} concentration, methanol extract inhibited feeding completely within 2 days in instars I to III and V, 3 days for instar IV and within 5 days for instar VI respectively. Aqueous extract again was observed to have no total feeding inhibition on the insects. Effect of 200mgml^{-1} was shown clearly in Table 3.3 and Table 3.4, where methanol extract inhibited feeding of the insects totally within 2 days for instars I, II, III, IV and V and within 3 days for instar VI respectively, but no complete inhibition was observed in aqueous extracts, however, the effect of the extract was very significant compared to the control.

3.15 Effect of Precocene I and II on feeding of III instar nymphs

Tables 3.5a and b showed the antifeeding activity of Precocene I and II. Precocene I showed total feeding inhibition within 4 days at 20μgml^{-1}, however there was no total feeding inhibition in the lower concentration of 10μgml^{-1} (Table 3.5a) but it significantly reduced the feeding activity of the nymphs. Similarly, Precocene II also showed high activity, where at 2 mgml^{-1} inhibited insect feeding totally on the sixth day and no total feeding inhibition was obtained in 1 mgml^{-1} (Table 3.5b), though a significant effect was observed.

3.16 Effect of *A. conyzoides* extract on behavioral activeness of the insects

Tables 3.6 –3.12 showed detail the effect of methanol and aqueous extracts on the activity of the *O. hyla*. Behavioral observations were based on movement, flight, feeding activity, hopping, beating of wings and legs and antennal movement. The methanol extracts were found to inhibit behavioral activeness in all instar stages. Instar nymphs I was found having been completely inhibited within 2 days (Table 3.6), II in 2-3 days (Table 3.7), III in 2 days (Table 3.8), IV in 2-3 days (Table 3.9), V in 3 days (Table 3.10) and VI in 3-4 days (Table 3.11) respectively. In adult insects both males and females it was found that methanol extract stopped activity completely within 3-5 days as it was shown in Table 3.12.

Aqueous extract showed less ability to inhibit the activeness of the insects at any instar stage of life cycle, however, they significantly reduced the behavioral activeness of the insects to a large extend.

3.17 Effect of *A. conyzoides* extract on behavioral inactivity of the insects

Inactivity was also studied on movement, flight, feeding activity, hopping, breathing, beating of wings and legs and antennal movement till partial paralysis occurred in the insects. These behavioral observations were explained in detail in Tables 3.13 – 3.19. Methanol extract showed the maximum activity and having capability to paralyze the insects totally within the time frame of experimental observation in all the concentrations applied. Methanol extracts inactivated the instar nymphs I totally (Table 3.13) within 2-3 days, 2 days for II (Table 3.14) and III (Table 3.15), 3 days for IV (Table 3.16), 3-4 days for V (Table 3.17) and in 4 days for the VI nymphal stage (Table 3.18) respectively. The inactivation was also high in adults (Table 3.19) having total inactivation within 5 days of assaying. Further, aqueous extract was found to have lesser activity in inactivation of behavioral patterns of the insects, and no complete inhibition on all the instar stages of insects was observed. However, aqueous extracts showed significant effect in some of the concentrations when they were compared with the control.

3.18 The effect of Precocene I and II on the Behavior of III instar nymphs of *Oxya hyla*

Tables 3.20 and 3.21 showed the effect of Precocene I and II on behavioral activity of the insects. All concentrations (10 and 20μgml^{-1}) of Precocene I was found to stop the activeness of the insects completely in 6 days and 5 days respectively (Table 3.20). Total inactivation of the III instar nymphs was obtained in 5 days and 4 days after treatment with precocene I at 10 and 20μgml^{-1} respectively (Table 3.20). Precocene II had similar effect but lesser potency, it was observed to inactivate insects behavior completely within 5 days at 2$mgml^{-1}$, but no complete inactivation was obtained in 1$mgml^{-1}$ (Table 3.21). Complete inhibition of activeness by precocene II was obtained within fourth day in 2$mgml^{-1}$ concentration and no complete inhibition of activeness was observed in 1$mgml^{-1}$, however it significantly affected the normal behavior of the nymphs as was shown in Table 3.21.

3.19 Effect of A. conyzoides extracts on molting of nymphs of *O. hyla*

Tables 3.22 – 3.24 showed the effects of methanol and aqueous extracts on molting of the instar nymphs. It was observed that molting was greatly reduced by methanol extracts as compared to aqueous extracts. In methanol extract, 3.33% molting was obtained after 1 day (Table 3.22) at 50 $mgml^{-1}$in nymphal stage I and 6.66% after 2 days in nymphs V (Table 3.24). 6.66% was recorded in 2 days (Table 3.24) in VI instar nymphs treated with 100$mgml^{-1}$, but no molting was obtained at 200 $mgml^{-1}$ concentration. Higher percentage of molting was obtained in aqueous extract. 16.66% within 3 days (Table 3.22) in instars I, 6.66% and 11% in instars II in 3-4 days (Table 3.22), 3.33% and 13.33% in instars III in 4-6 days (Table 3.23) and 3.33% in instars V in 1 day and 6 days (Table 3.24) after treatment with 50$mgml^{-1}$ concentration. At 100$mgml^{-1}$ concentration, 6.66% in instars III in 5-6 days (Table 3.23) and 10% in instars IV on fifth day (Table 3.23), and in 200$mgml^{-1}$, 6.66% and 13.33% molting occurred in III instars (Table 3.23) in 4-6 days, 6.66%, 10% and 13.33% in 2-6 days of IV instar nymphs (Table 3.23) and 3.33% on instars V on the fourth day (Table 3.24) of treatment respectively.

3.20 Effect of Precocene I and II on molting of III instar nymphs

10μgml^{-1} Precocene I showed 5% molting in day 5 and 6 and 2.5% in day 3 of experimental observation respectively. 5% occurred in day 1 at 20μgml^{-1} (Figure 3.7A). In 1$mgml^{-1}$ Precocene II, 5% molting occurred in day 5 and 6 (Figure 3.7B) and 2.5% each in day 2 and 5 with 2$mgml^{-1}$ respectively.

3.21 Field observations with *A. conyzoides* extracts

Field trial were conducted on the years 2000 and 2001 using both aqueous and methanol extracts (100$mgml^{-1}$) of *A. conyzoides* against *O. hyla* in the rice field (3 m^2). Methanol extracts showed higher activity and significantly reduced crop exploitation by insects (Table 3.25). Aqueous extract on the other hand, had moderately reduced crop exploitation. The effect of the extracts in the field was slow, insects were not killed

In both the sampling years similar results were obtained, which indicated that the effect of the plant extracts were positive in controlling this pest in the field. Of course few insects were able to attack, feed and mate on the treated plants but the majority were repelled.

3.22 Field observation in presence or absence of *A. conyzoides* on the sides of the field

Observations in the rice fields ($4m^2$) where *A. conyzoides* were planted on the periphery and the fields without *A. conyzoides* were observed in the months June-Dec. of the sampling years 2000 and 2001. It was found that the presence of *A. conyzoides* on the sides of the field significantly reduced insects occurrence and attack in the year 2000 (Table 3.26) and 2001 (Table 3.27). This showed that the plant harbored toxic and repellent compounds that repelled the insects from attacking the plants.

3.23 Grain production in treated and untreated rice plots

Grain produced in plots of rice field ($3m^2$) after spraying with the plant extracts in 2000 and 2001 was harvested and the total fresh grain obtained between the treated and control was compared. It was found that the grain production increased in the plots treated with methanol extract. However, the field treated by aqueous extract showed no significant effect (Table 3.28) although there was improvement the production of the rice. Methanol extract treated plots showed significant increased in rice production. This trial showed clearly the protective effect of *A. conyzoides* extracts against the exploitation of rice plants by *O. hyla*. The paddy grasshoppers were repelled from treated plots. It was observed that other pests were also repelled and even killed.

DISCUSSION

Methanol extract is always more effective than aqueous extract, this is because the secondary plant compounds are easily dissolved in methanol and not in water. These compounds may act as repellents and antifeedants etc. (Marngar and Kharbuli, 2001; Marngar et al. 2002). The effect of the extracts on mortality rate, antifeeding activity, activeness, inactiveness and molting of insects is found to be significant. Various groups of compounds present in the plant impart many disruptions on the normal functioning of the insect, leading to death of the treated individuals (Shabana et al. 1990; Gravena et al. 1993). These compounds of *A. conyzoides* extract affect the peripheral nervous system and disrupting cellular, biochemical and physiological processes of insects (Paine and Stephen, 1988; Bowers and Puttick, 1988). However, they mostly act by affecting the insect central nervous system (Levinson, 1976). They inhibit oviposition due to nutritional disruption (Murray et al. 1995; Saxena et al. 1992), induce morphogenetic defects in the insects (Unnithan et al. 1978; Schmutterer, 1990), alter the host selection and behavioral patterns and reduce growth and development of the insects (Gonzalez-Coloma et al. 1995; Bowers and Puttick, 1989; Wagner et al. 1983; Cole et al. 1990).

Precocene I and II, the active principles derived form this plant have been reported of having antijuvenile hormone and insecticidal activity. Similar results are obtained when these are tested against the III instar nymphs of *O. hyla*. They show similar effects with the extracts of the plant, having high mortality rate, feeding inhibition, physiological disorder, behavioral abnormalities, reduce growth and development.

It is also found that Precocene I and II fasten molting at low concentrations, but become toxic at higher concentrations. It is observed in the individuals that these compounds and *A. conyzoides* extracts induce metamorphosis in the insects (Bowers et al. 1976; Bowers 1991b), in which they undergo one more molt and then die. The cause of toxicity of Precocenes and the extracts of *A. conyzoides* is accomplished by causing selective death of corpus allatum cells of the insects (Schooneveld, 1979; Pratt et al. 1980) which in turn disrupts the whole regulatory mechanism of physiological activities in the body that leads to death of individuals.

Effect of the extracts in molting of the insects is observed to be higher in aqueous extract than in methanol. Aqueous extract induces molting because it contains less toxic compounds, instead giving more time for the insects for growth and development. However, methanol extract possessing more insecticidal compounds, hence giving no time to the insects to grow and develop, instead kill them before molting occurs.

Fields trial by spraying with *A. conyzoides* extracts and the plots having the same plant growing in the periphery are observed to have less number of insects (*O. hyla*) that attack, feed, oviposite and even mate when compare to the control plots. This shows the toxicity of the extracts to the insects, which repel them through various mechanisms. Similar observations are obtained when the crops in the plots are treated by the extracts. The occurrence, feeding, behavioural activity, ovipositing and mating are totally disrupted.

Crop production from the treated and control plots of the rice field when compared after harvest, it is found that in both the years 2000 and 2001, the production in the treated plots are more than the control, indicating the positive effects of the plant extracts in controlling the pests in the fields.

CONCLUSION

It is clear from the results above that there are a large number of applications of the plant extracts in the study of their biological activities. Extract activity is increasing with increasing concentrations and time duration, meaning that is dose and time dependent manner. Hence the secondary plant compounds present in the plant may play a major role in controlling this pest, the small rice grasshopper (*O. hyla*) which is the major pest of rice (*Oryza sativa*). It is possible that by using these secondary plant compounds, which are eco-friendly, safer, does not induce resistance to insect pest, and being biodegradable, the synthetic chemical insecticides would be probably replaced in the future.

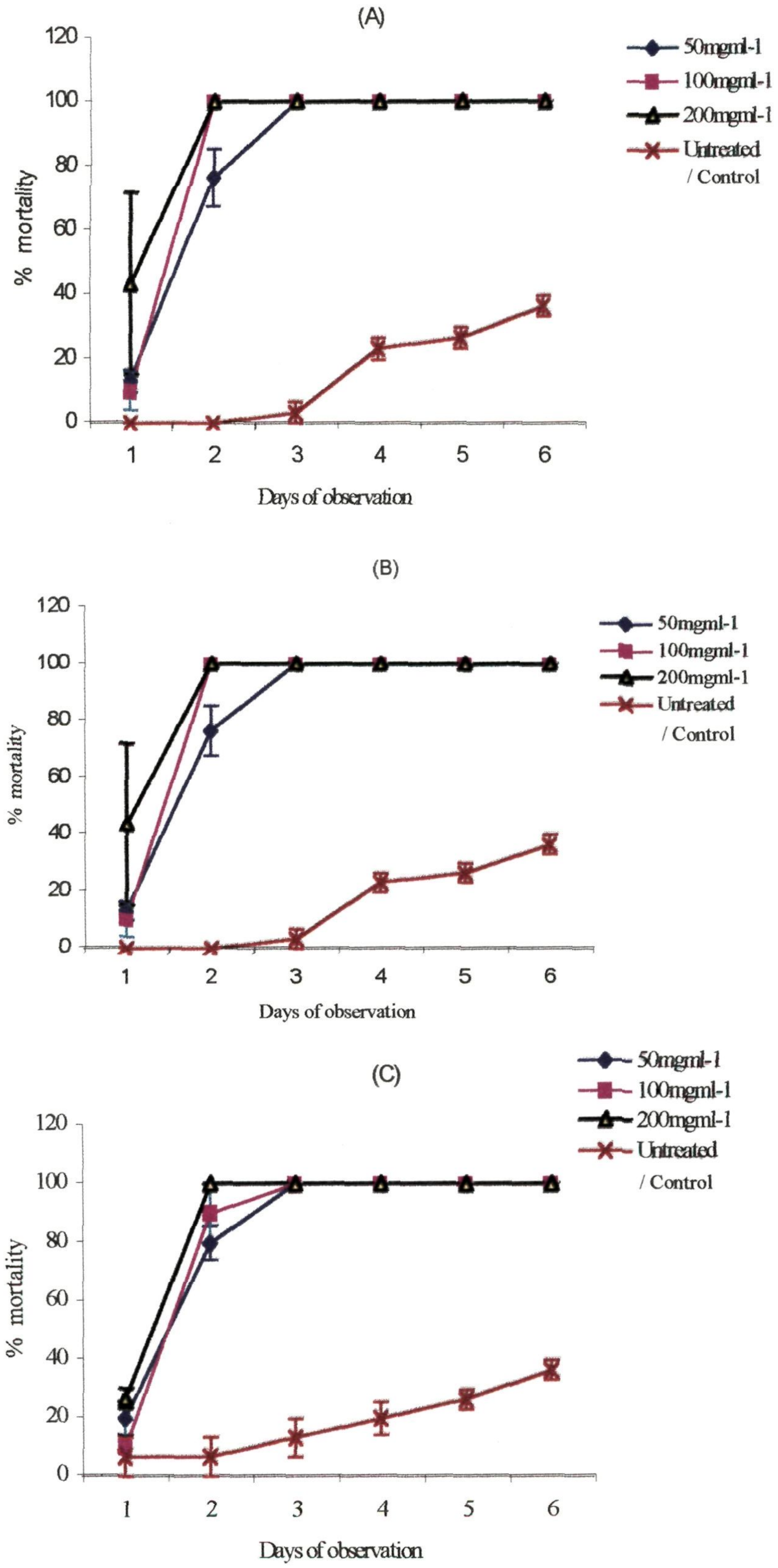


Figure 3.2 Effect of methanol extracts of *Ageratum conyzoides* on mortality of I (A), II (B) & III (C) instar nymphs of *Oxya hyla* respectively.

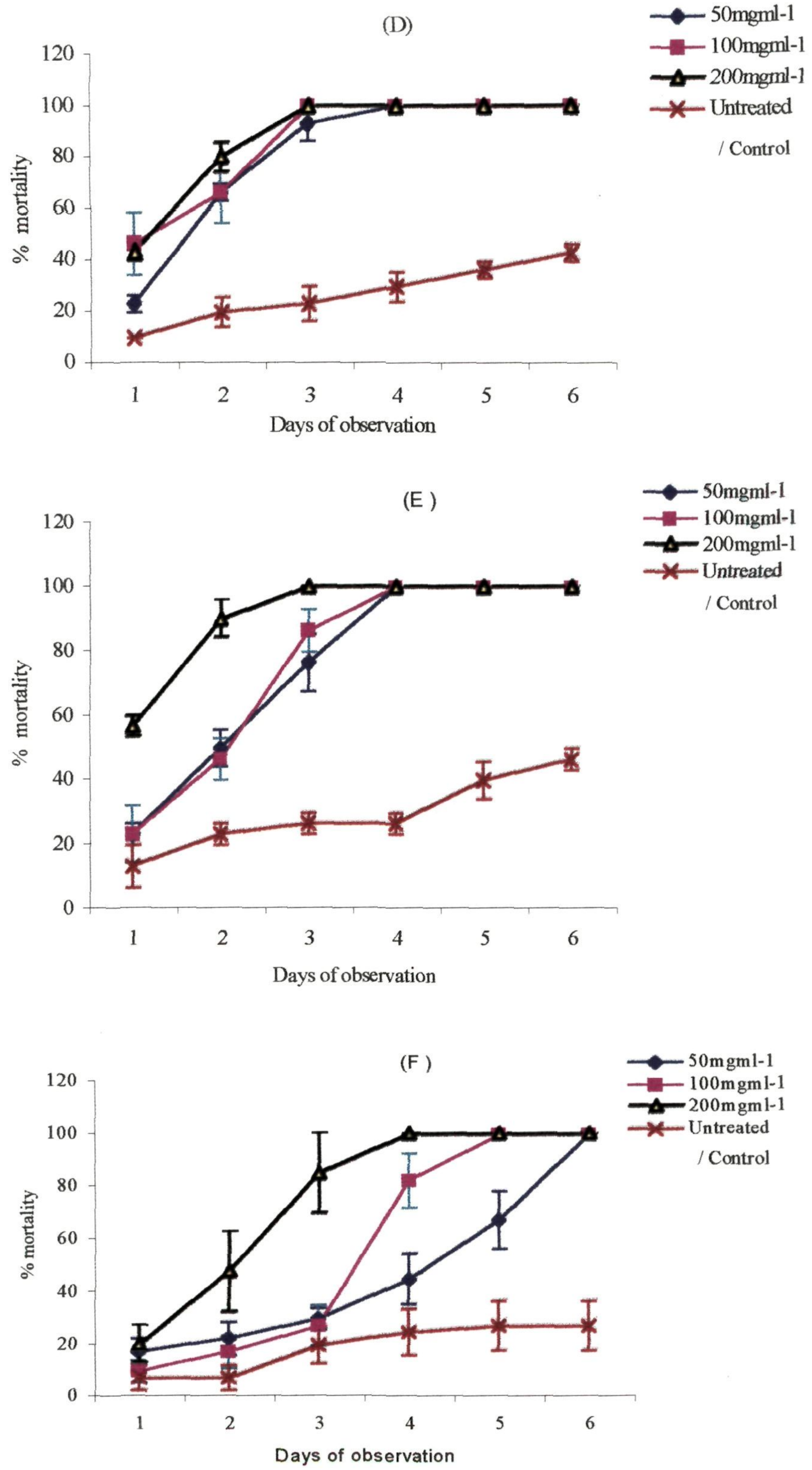


Figure 3.3 Effect of methanol extracts of *Ageratum conyzoides* on mortality of IV (D), V (E) & VI (F) instar nymphs of *Oxya hyla* respectively.

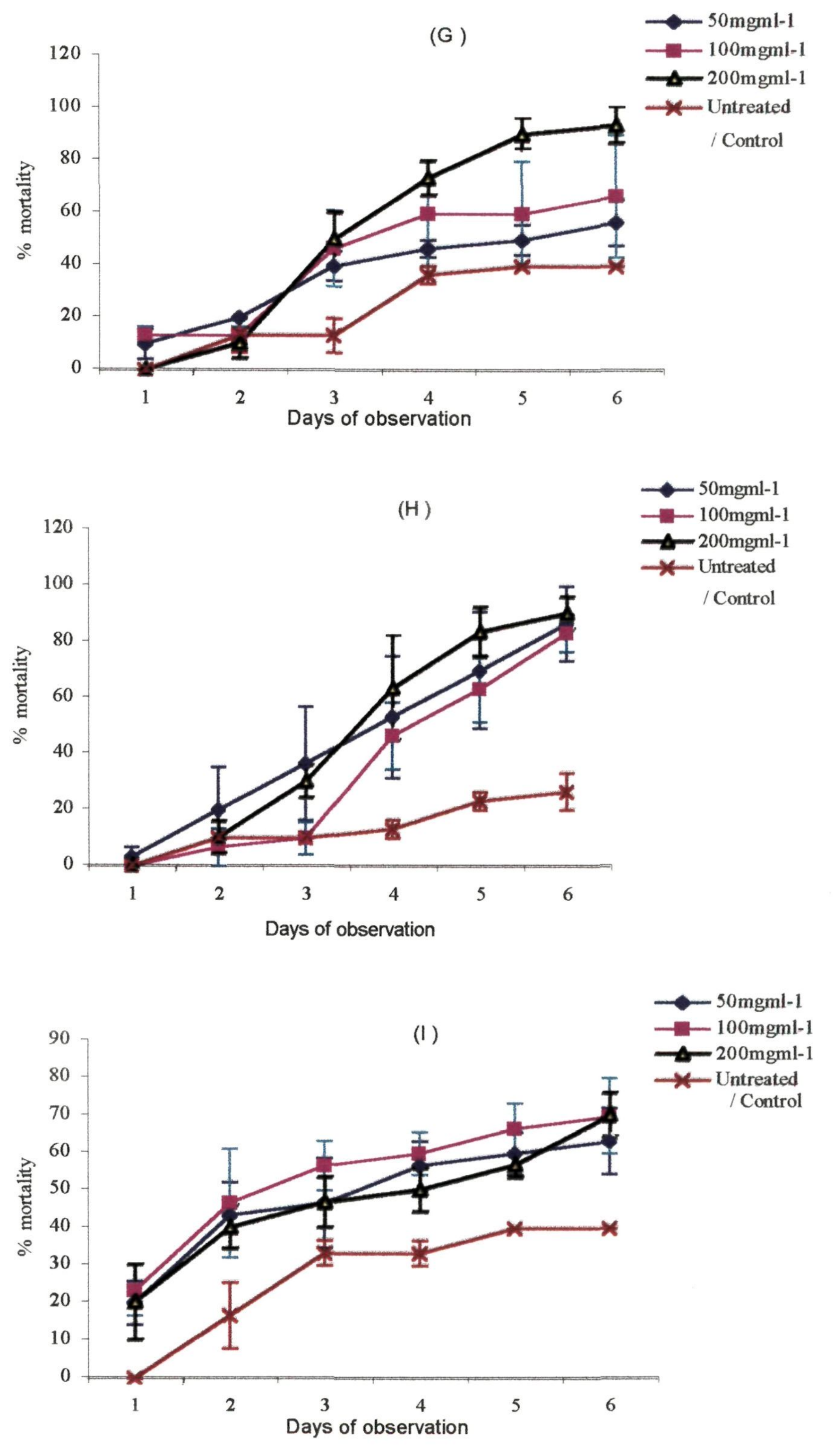
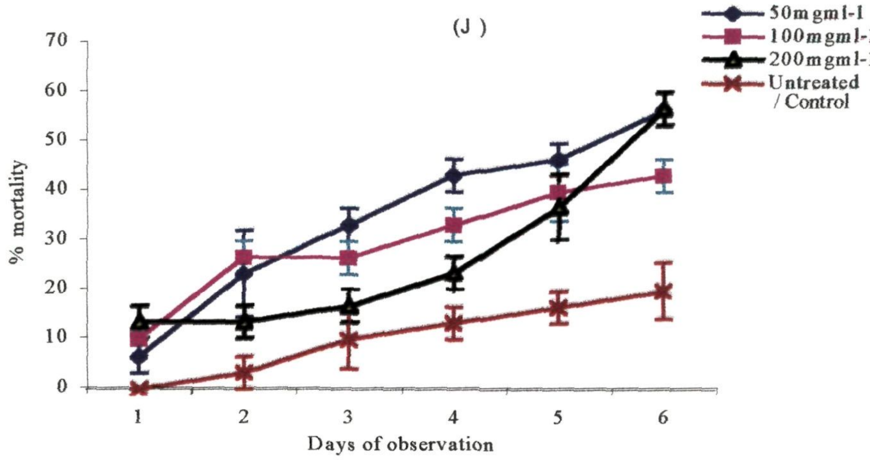
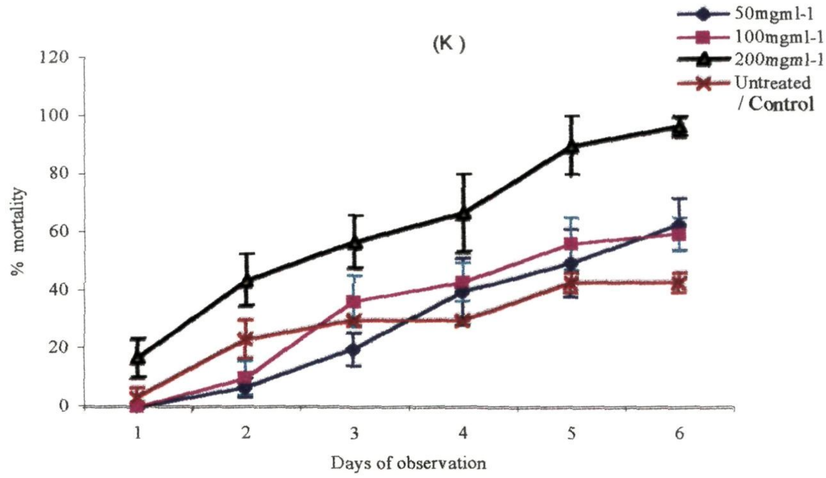


Figure 3.4 Effect of aqueous extracts of *Ageratum conyzoides* on mortality of instar nymphs I (G), II (H) & III (I) of *Oxya hyla* respectively.





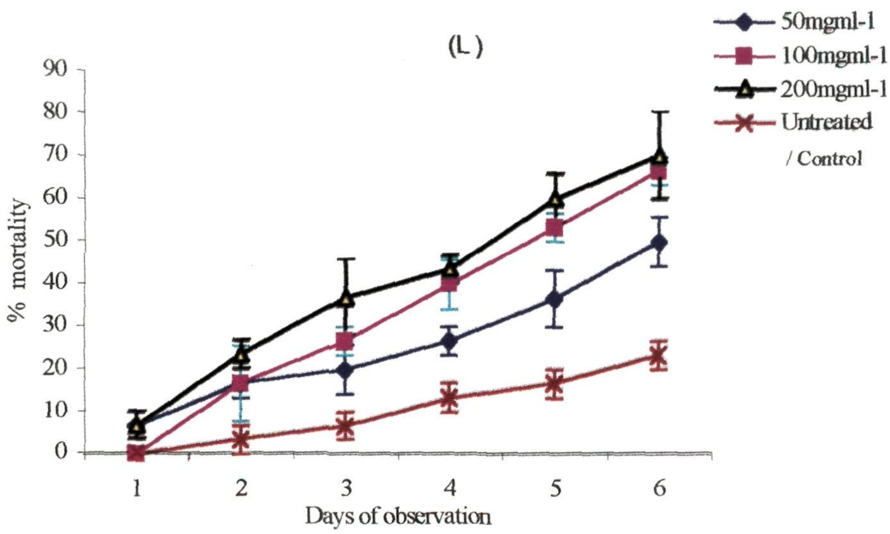
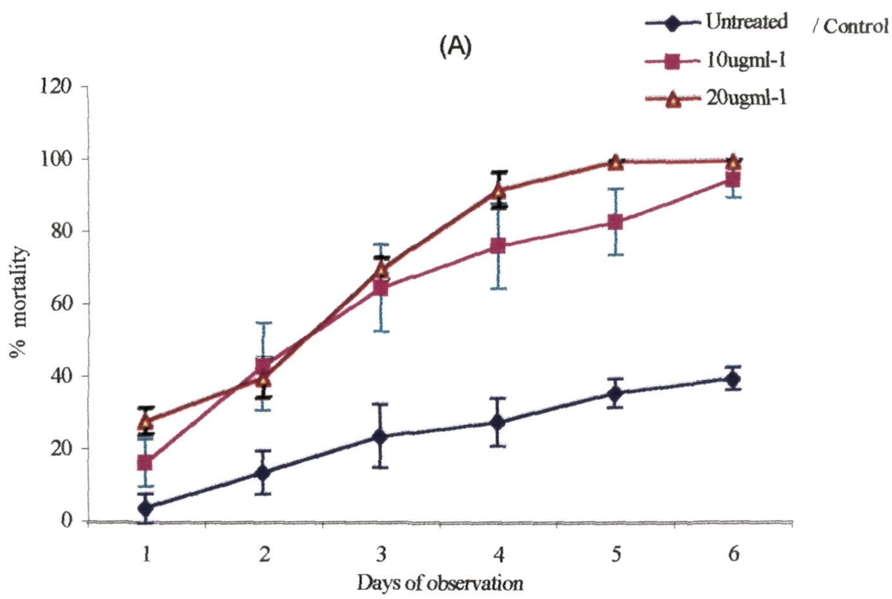


Figure 3.5 Effect of aqueous extracts of *Ageratum conyzoides* on mortality of instar nymphs IV (J), V (K) & VI (L) of *Oxya hyla* respectively.



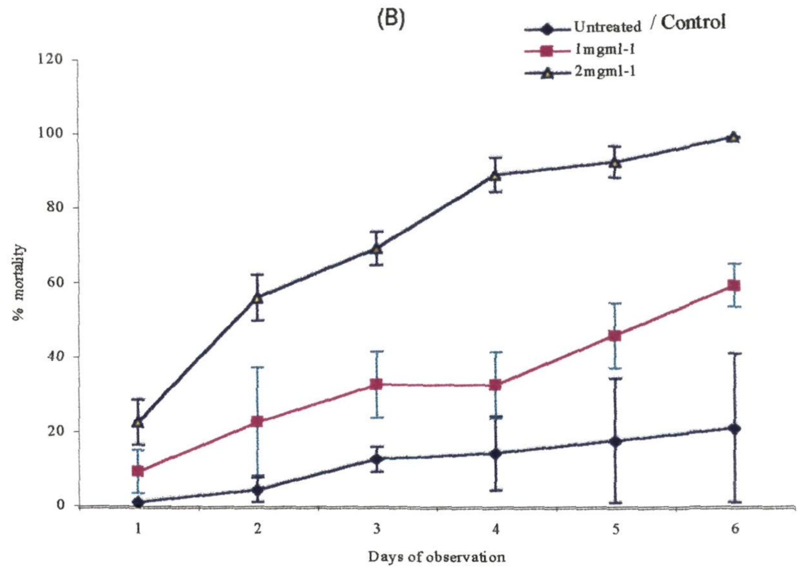


Figure 3.6 Effect of Precocene I (A) and Precocene II (B) on mortality of III instar nymphs of *Oxya hyla*.

Table 3.1 Effect of methanol and aqueous extracts of *Ageratum conyzoides* on feeding activity of nymphal stages of *Oxya hyla*.[a]

			Days of observation					
Extract	Instar	Conc. $mgml^{-1}$	1	2	3	4	5	6
MeOH	I	50	2.40 ± 0.24^c (6.33±0.33)	0.00 ± 0.00^c (5.33±0.33)	0.00 ± 0.00^c (5.33±0.33)	0.00 ± 0.00^c (4.33±0.33)	0.00 ± 0.00^c (4.00±0.00)	0.00 ± 0.00^c (3.33±0.33)
Aqueous	I	50	5.00±0.57 (6.33±0.33)	3.66±0.33 (5.33±0.33)	2.33±0.33 (5.33±0.33)	2.00 ± 0.00^b (4.33±0.33)	1.33 ± 0.33^b (4.00±0.00)	0.66 ± 0.66^b (3.33±0.33)
MeOH	II	50	1.66 ± 0.33^b (7.33±0.33)	0.00 ± 0.00^c (6.66±0.33)	0.00 ± 0.00^c (5.66±0.33)	0.00 ± 0.00^c (5.33±0.66)	0.00 ± 0.00^c (4.33±0.66)	0.00 ± 0.00^c (4.00±0.00)
Aqueous	II	50	6.00±0.57 (7.33±0.33)	4.00±0.00 (6.66±0.33)	2.66±1.45 (5.66±0.33)	1.33±1.33 (5.33±0.66)	1.00 ± 1.00^b (4.33±0.66)	0.33 ± 0.33^c (4.00±0.00)
MeOH	III	50	1.00 ± 0.00^c (5.33±0.33)	0.00 ± 0.00^c (4.66±0.88)	0.00 ± 0.00^c (4.00±0.57)	0.00 ± 0.00^c (3.66±0.88)	0.00 ± 0.00^c (3.33±0.66)	0.00 ± 0.00^c (2.66±0.33)
Aqueous	III	50	5.66 ± 0.33^b (5.33±0.33)	3.00±0.57 (4.66±0.88)	2.00±0.57 (4.00±0.57)	1.66±0.33 (3.66±0.88)	1.00±0.00 (3.33±0.66)	0.66±0.33 (2.66±0.33)
MeOH	IV	50	1.66 ± 0.33^b (7.00±0.00)	0.00 ± 0.00^c (6.00±0.57)	0.00 ± 0.00^c (5.66±0.88)	0.00 ± 0.00^c (5.33±0.66)	0.00 ± 0.00^b (5.00±0.57)	0.00 ± 0.00^b (4.33±0.66)
Aqueous	IV	50	4.66 ± 0.33^b (7.00±0.00)	2.66 ± 0.33^b (6.00±0.57)	2.66±0.33 (5.66±0.88)	2.00±0.57 (5.33±0.66)	2.00 ± 0.57^b (5.00±0.57)	1.33±0.66 (4.33±0.66)

[a] Means (±SE) were analyzed by Parametric test, One - Way ANOVA, [b & c] Values are significantly different at $P < .05$, .01 & .001 respectively. Figures in parentheses represent the control. Treated and control are calculated and compared using Parametric Two – Sides t-Test Paired Comparison.

Table 3.2 Effect of methanol and aqueous extracts of *Ageratum conyzoides* on feeding activity of nymphal stages of *Oxya hyla*[a]

			Days of observation					
Extract	Instar	Conc. $mgml^{-1}$	1	2	3	4	5	6
MeOH	V	50	2.33±0.33 (6.33±0.33)	1.00±0.57[b] (5.66±0.33)	0.00±0.00[c] (5.33±0.33)	0.00±0.00[b] (4.66±0.33)	0.00±0.00[b] (4.66±0.33)	0.00±0.00[b] (4.33±0.33)
Aqueous	V	50	6.33±0.33 (6.33±0.33)	5.33±0.33 (5.66±0.33)	3.66±0.33[b] (5.33±0.33)	2.66±0.33[c] (4.66±0.33)	2.00±0.00[c] (4.66±0.33)	1.00±0.57[b] (4.33±0.33)
MeOH	VI	50	3.50±0.50 (6.66±0.33)	2.25±0.25[c] (6.33±0.33)	1.75±0.25[c] (5.66±0.33)	1.00±0.41[c] (5.33±0.33)	0.25±0.25[c] (5.00±0.57)	0.00±0.00[c] (4.66±0.33)
Aqueous	VI	50	6.33±0.33 (6.66±0.33)	6.00±0.57 (6.33±0.33)	5.33±0.66 (5.66±0.33)	5.00±0.57 (5.33±0.33)	5.00±0.57 (5.00±0.57)	4.00±0.57 (4.66±0.33)
MeOH	I	100	0.80±0.48[c] (6.33±0.33)	0.00±0.00[d] (5.33±0.33)	0.00±0.00[d] (5.33±0.33)	0.00±0.00[d] (4.33±0.33)	0.00±0.00[d] (4.00±0.00)	0.00±0.00[d] (3.33±0.33)
Aqueous	I	100	5.33±0.33[b] (7.00±0.00)	4.00±0.57[b] (5.66±0.33)	2.00±1.00 (5.33±0.66)	1.33±1.33 (4.33±0.33)	1.00±1.00 (4.00±0.57)	0.66±0.66 (3.66±0.33)
MeOH	II	100	1.33±0.33[c] (6.66±0.33)	0.00±0.00[c] (5.33±0.33)	0.00±0.00[c] (5.00±0.00)	0.00±0.00[c] (4.33±0.33)	0.00±0.00[c] (4.00±0.00)	0.00±0.00[c] (3.33±0.33)
Aqueous	II	100	5.66±0.33 (6.66±0.33)	4.66±0.33 (6.00±0.00)	4.00±1.00 (6.00±0.00)	2.33±1.20 (5.00±0.00)	1.66±1.20 (4.33±0.33)	0.66±0.66[b] (4.00±0.00)
MeOH	III	100	1.00±0.00[c] (5.33±0.33)	0.00±0.00[c] (4.66±0.33)	0.00±0.00[c] (4.33±0.33)	0.00±0.00[c] (3.66±0.33)	0.00±0.00[c] (3.33±0.33)	0.00±0.00[c] (3.00±0.00)
Aqueous	III	100	4.33±0.33[d] (7.33±0.33)	2.33±0.88 (6.33±0.66)	1.66±0.33 (5.33±1.20)	1.33±0.33 (5.00±1.00)	1.33±0.33 (5.00±1.00)	1.00±0.57 (4.33±1.20)

[a] Means (±SE) were analyzed by Parametric test, One - Way ANOVA, [b, c & d] Values are significantly different at $P < .05, .01$ & $.001$ respectively. Treated and control are calculated and compared using Parametric Two – Sides t-Test Paired Comparison. Figures in parentheses represent the control.

Table 3.3 Effect of methanol and aqueous extracts of *Ageratum conyzoides* on feeding activity of nymphal stages of *Oxya hyla*.[a]

Extract	Instar	Conc. mgml^{-1}	1	2	3	4	5	6
			Days of observation					
MeOH	IV	100	1.33±0.33^c	0.33±0.33^b	0.00±0.00^c	0.00±0.00^c	0.00±0.00^b	0.00±0.00^b
			(4.66±0.33)	(4.33±0.33)	(3.66±0.33)	(3.33±0.33)	(3.00±0.00)	(2.33±0.57)
Aqueous	IV	100	3.66±0.33^c	2.33±0.33	2.33±0.33	2.00±0.00^b	1.00±1.00^b	0.66±0.33
			(7.00±0.00)	(6.00±0.57)	(5.66±0.88)	(5.33±0.66)	(5.00±0.57)	(4.33±0.66)
MeOH	V	100	1.66±0.33	0.00±0.00^c	0.00±0.00^c	0.00±0.00^b	0.00±0.00^b	0.00±0.00^b
			(3.66±0.33)	(3.33±0.33)	(3.33±0.33)	(2.66±0.33)	(2.33±0.33)	(2.00±0.00)
Aqueous	V	100	5.33±0.33^d	5.00±0.00^b	3.00±0.57	2.33±0.33^b	1.00±0.00^c	0.00±0.00^c
			(7.33±0.33)	(7.33±0.33)	(6.66±0.33)	(6.33±0.33)	(6.33±0.33)	(5.66±0.33)
MeOH	VI	100	3.00±0.44	1.80±0.37^b	1.60±0.24^c	0.20±0.20^c	0.00±0.00^d	0.00±0.00^c
			(4.50±0.28)	(4.50±0.28)	(4.25±0.25)	(3.50±0.28)	(3.25±0.25)	(3.00±0.00)
Aqueous	VI	100	5.33±0.66	4.33±0.33^b	4.00±0.57	3.66±0.66	3.00±0.57	2.66±0.88
			(8.33±0.33)	(7.66±0.33)	(7.33±0.33)	(7.33±0.33)	(6.66±0.33)	(6.33±0.33)
MeOH	I	200	1.80±0.58^c	0.00±0.00^d	0.00±0.00^d	0.00±0.00^d	0.00±0.00^d	0.00±0.00^d
			(6.40±0.40)	(5.23±0.20)	(4.66±0.24)	(4.00±0.31)	(3.40±0.24)	(2.66±0.24)
Aqueous	I	200	5.00±0.00^b	3.66±0.33	1.66±0.33	0.33±0.33^b	0.33±0.33	0.00±0.00^c
			(7.00±0.00)	(5.66±0.33)	(5.33±0.66)	(4.33±0.33)	(4.00±0.57)	(3.66±0.33)
MeOH	II	200	1.00±0.00^c	0.00±0.00^c	0.00±0.00^c	0.00±0.00^c	0.00±0.00^c	0.00±0.00^c
			(6.66±0.33)	(5.33±0.33)	(5.00±0.00)	(4.33±0.33)	(4.00±0.00)	(3.33±0.33)
Aqueous	II	200	5.33±0.33	5.00±0.00	3.00±0.57^b	1.33±0.88	0.66±0.33^b	0.00±0.00^c
			(6.66±0.33)	(6.00±0.00)	(6.00±0.00)	(5.00±0.00)	(4.33±0.33)	(4.00±0.00)

[a] Means (±SE) were analyzed by Parametric test, One - Way ANOVA, [b, c & d] Values are significantly different at P < .05, .01 & .001 respectively. Treated and control are calculated and compared using Parametric Two – Sides t-Test Paired Comparison. Figures in parentheses represent the control.

Table 3.4 Effect of methanol and aqueous extracts of *Ageratum conyzoides* on feeding activity of nymphal stages of *Oxya hyla*[a]

			Days of observation					
Extract	Instar	Conc. mgml^{-1}	1	2	3	4	5	6
MeOH	III	200	1.00±0.00^c (5.33±0.33)	0.00±0.00^c (4.66±0.33)	0.00±0.00^c (4.33±0.33)	0.00±0.00^c (3.66±0.33)	0.00±0.00^c (3.33±0.33)	0.00±0.00^c (3.00±0.00)
Aqueous	III	200	5.33±0.33^d (7.33±0.33)	2.66±0.33 (6.33±0.66)	2.66±0.33 (5.33±1.20)	2.66±0.33 (5.00±1.00)	2.33±0.33 (5.00±1.00)	1.66±0.33 (4.33±1.20)
MeOH	IV	200	1.33±0.33^c (4.66±0.33)	0.00±0.00^c (4.33±0.33)	0.00±0.00^c (3.66±0.33)	0.00±0.00^c (3.33±0.33)	0.00±0.00^b (3.00±0.00)	0.00±0.00^b (2.33±0.57)
Aqueous	IV	200	2.66±0.33^c (7.00±0.00)	2.33±0.33^c (6.00±0.57)	2.33±0.33^b (5.66±0.88)	1.66±0.33 (5.33±0.66)	1.66±0.33^b (5.00±0.57)	1.66±0.33 (4.33±0.66)
MeOH	V	200	0.66±0.33^b (3.66±0.33)	0.00±0.00^c (3.33±0.33)	0.00±0.00^c (3.33±0.33)	0.00±0.00^b (2.66±0.33)	0.00±0.00^b (2.33±0.33)	0.00±0.00^b (2.00±0.00)
Aqueous	V	200	3.66±0.33^c (7.33±0.33)	2.33±0.66^b (7.33±0.33)	1.33±0.33^c (6.66±0.33)	0.00±0.00^c (6.33±0.33)	0.00±0.00^c (6.33±0.33)	0.00±0.00^c (5.66±0.33)
MeOH	VI	200	1.75±0.25^c (4.50±0.28)	0.50±0.28^c (4.50±0.28)	0.00±0.00^d (4.25±0.25)	0.00±0.00^c (3.50±0.28)	0.00±0.00^d (3.25±0.25)	0.00±0.00^c (3.00±0.00)
Aqueous	VI	200	4.66±0.33^b (8.33±0.33)	4.33±0.33^b (7.66±0.33)	3.66±0.33^b (7.33±0.33)	3.33±0.33^b (7.33±0.33)	2.00±0.00^c (6.66±0.33)	1.33±0.33^d (6.33±0.33)

[a] Means (±SE) were analyzed by Parametric test, One - Way ANOVA, [b, c & d] Values are significantly different at P < .05, .01 & .001 respectively. Treated and control are calculated and compared using Parametric Two – Sides t-Test Paired Comparison. Figures in parentheses represent the control.

Table 3.5a Effect of Precocene I on feeding activity of the III instar nymphs of *Oxya hyla*. [a]

Conc μgml^{-1}	Days of observation 1	2	3	4	5	6
10	4.00±0.68[c]	2.33±0.84[c]	1.50±0.72[c]	0.66±0.42[d]	0.33±0.33[c]	0.16±0.16[c]
	(6.00±0.44)	(5.5±0.50)	(5.33±0.49)	(4.66±0.33)	(3.83±0.65)	(3.50±0.50)
20	3.60±0.24[c]	2.00±0.44[d]	0.20±0.20[d]	0.00±0.00[c]	0.00±0.00[d]	0.00±0.00[c]
	(5.80±0.58)	(5.80±0.58)	(5.00±0.54)	(4.80±0.58)	(4.40±0.40)	(4.00±0.54)

Table 3.5b Effect of Precocene II on feeding activity of the III instar nymphs of *Oxya hyla* [a]

Conc $mgml^{-1}$	Days of observation 1	2	3	4	5	6
1.0	4.00±0.31[c]	3.20±0.48[c]	2.20±0.37[c]	1.80±0.37[b]	1.20±0.37[b]	1.00±0.44[b]
	(7.20±0.37)	(6.80±0.37)	(6.00±0.44)	(5.00±0.70)	(4.40±0.40)	(4.00±0.44)
2.0	3.25±0.63[b]	2.50±0.64[b]	1.75±0.62[b]	1.00±0.41[b]	0.25±0.25[c]	0.00±0.00[c]
	(6.00±0.41)	(5.50±0.28)	(5.25±0.25)	(5.00±0.40)	(4.25±0.25)	(4.00±0.40)

[a] Means (±SE) were analyzed using Parametric Test, One-Way ANOVA . [b, c] & [d] Values are significantly different at $P< 0.05$, 0.01 & 0.001 from the control (Parametric Test of Two-sided t -Test Paired Comparison). Figures in parentheses represent the control.

Table 3.6 Effects of methanol and aqueous extracts of *Ageratum conyzoides* on behavioral activity of I instar nymphs of *Oxya hyla* [a]

Extract	Conc mgml^{-1}	Days of observation 1	2	3	4	5	6
MeOH	50	1.33±0.66	0.00±0.00^{c}	0.00±0.00^{b}	0.00±0.00^{b}	0.00±0.00^{b}	0.00±0.00^{b}
		(4.00±0.57)	(3.33±0.33)	(3.00±0.57)	(2.33±0.33)	(2.33±0.33)	(2.33±0.33)
	100	1.33±0.88	0.00±0.00^{c}	0.00±0.00^{b}	0.00±0.00^{b}	0.00±0.00^{b}	0.00±0.00^{b}
		(4.00±0.57)	(3.33±0.33)	(3.00±0.57)	(2.33±0.33)	(2.33±0.33)	(2.33±0.33)
	200	2.33±0.33	0.00±0.00^{c}	0.00±0.00^{b}	0.00±0.00^{b}	0.00±0.00^{b}	0.00±0.00^{b}
		(4.00±0.57)	(3.33±0.33)	(3.00±0.57)	(2.33±0.33)	(2.33±0.33)	(2.33±0.33)
Aqueous	50	4.00±0.57	3.33±0.33	2.66±0.33	2.33±0.33	1.66±0.33	1.00±0.57
		(6.00±0.57)	(5.66±0.66)	(5.33±0.33)	(4.33±0.88)	(4.00±1.00)	(3.66±0.66)
	100	3.66±0.33	3.33±0.33^{b}	2.00±0.57^{c}	1.33±0.88^{d}	1.33±0.88^{b}	0.66±0.66^{d}
		(6.00±0.57)	(5.66±0.66)	(5.33±0.33)	(4.33±0.88)	(4.00±1.00)	(3.66±0.66)
	200	4.33±0.33b	3.66±0.33	2.00±0.57	1.66±0.66	1.00±1.00	0.33±0.33
		(6.00±0.57)	(5.66±0.66)	(5.33±0.33)	(4.33±0.88)	(4.00±1.00)	(3.66±0.66)

[a] Means (±SE) were analyzed using Parametric Test. One-Way ANOVA ; [b, c] & [d] Values of the treated are significantly different at $P< 0.05$, 0.01 & 0.001 from the control (Parametric Test of Two-sided t -Test Paired Comparison) Figures in parentheses represent the control.

Table 3.7 Effects of methanol and aqueous extracts of *Ageratum conyzoides* on behavioral activity of II instar nymphs of *Oxya hyla* [a]

Extract	Conc $mgml^{-1}$	Days of observation 1	2	3	4	5	6
MeOH	50	1.66 ± 0.33^{b}	0.33 ± 0.33^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{b}	0.00 ± 0.00^{b}	0.00 ± 0.00^{b}
		(4.00 ± 0.00)	(4.00 ± 0.00)	(3.33 ± 0.33)	(3.00 ± 0.00)	(3.00 ± 0.00)	(2.66 ± 0.33)
	100	2.00 ± 0.00^{b}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{b}	0.00 ± 0.00^{b}	0.00 ± 0.00^{b}
		(4.00 ± 0.00)	(4.00 ± 0.00)	(3.33 ± 0.33)	(3.00 ± 0.00)	(3.00 ± 0.00)	(2.66 ± 0.33)
	200	1.66 ± 0.33^{b}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{b}	0.00 ± 0.00^{b}	0.00 ± 0.00^{b}
		(4.00 ± 0.00)	(4.00 ± 0.00)	(3.33 ± 0.33)	(3.00 ± 0.00)	(3.00 ± 0.00)	(2.66 ± 0.33)
Aqueous	50	4.66 ± 0.33	3.33 ± 0.66	2.00 ± 1.15	1.33 ± 1.33	1.00 ± 1.00	0.33 ± 0.33^{b}
		(5.33 ± 0.33)	(4.33 ± 0.33)	(3.66 ± 0.33)	(3.66 ± 0.33)	(3.00 ± 0.57)	(2.66 ± 0.33)
	100	5.00 ± 0.00	4.00 ± 0.00	3.66 ± 0.33	2.33 ± 0.66	1.33 ± 0.88	0.33 ± 0.33^{b}
		(5.33 ± 0.33)	(4.33 ± 0.33)	(3.66 ± 0.33)	(3.66 ± 0.33)	(3.00 ± 0.57)	(2.66 ± 0.33)
	200	4.66 ± 0.33	4.00 ± 0.57	2.66 ± 0.33	1.33 ± 0.66	0.66 ± 0.33	0.33 ± 0.33^{b}
		(5.33 ± 0.33)	(4.33 ± 0.33)	(3.66 ± 0.33)	(3.66 ± 0.33)	(3.00 ± 0.57)	(2.66 ± 0.33)

[a] Means (±SE) were analyzed using Parametric Test, One-Way ANOVA ; [b & c] values of the treated are significantly different at $P< 0.05$ & 0.01 from the control (Parametric Test of Two-sided t -Test Paired Comparison). Figures in parentheses represent the control.

Table 3.8 Effects of methanol and aqueous extracts of *Ageratum conyzoides* on behavioral activity of III instar nymphs of *Oxya hyla* [a]

Extract	Conc $mgml^{-1}$	Days of observation 1	2	3	4	5	6
MeOH	50	2.00 ± 0.57	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{b}	0.00 ± 0.00^{b}
		(4.66 ± 0.33)	(4.00 ± 0.00)	(3.66 ± 0.33)	(3.33 ± 0.33)	(3.00 ± 0.00)	(2.66 ± 0.33)
	100	2.00 ± 0.57	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{b}	0.00 ± 0.00^{b}
		(4.66 ± 0.33)	(4.00 ± 0.00)	(3.66 ± 0.33)	(3.33 ± 0.33)	(3.00 ± 0.00)	(2.66 ± 0.33)
	200	1.33 ± 0.33^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{b}	0.00 ± 0.00^{b}
		(4.66 ± 0.33)	(4.00 ± 0.00)	(3.66 ± 0.33)	(3.33 ± 0.33)	(3.00 ± 0.00)	(2.66 ± 0.33)
Aqueous	50	3.66 ± 0.33^{b}	2.33 ± 0.66	2.00 ± 0.57	1.00 ± 0.00^{b}	1.00 ± 0.00^{b}	1.00 ± 0.00^{b}
		(6.00 ± 0.00)	(5.66 ± 0.33)	(4.66 ± 0.88)	(4.33 ± 0.66)	(3.66 ± 0.33)	(2.66 ± 0.33)
	100	3.66 ± 0.33^{b}	2.33 ± 0.33	1.66 ± 0.33	1.00 ± 0.00^{b}	1.00 ± 0.00^{b}	0.66 ± 0.33
		(6.00 ± 0.00)	(5.66 ± 0.33)	(4.66 ± 0.88)	(4.33 ± 0.66)	(3.66 ± 0.33)	(2.66 ± 0.33)
	200	3.66 ± 0.33^{b}	2.66 ± 0.33^{b}	2.33 ± 0.33	1.66 ± 0.33	1.66 ± 0.33	1.33 ± 0.33
		(6.00 ± 0.00)	(5.66 ± 0.33)	(4.66 ± 0.88)	(4.33 ± 0.66)	(3.66 ± 0.33)	(2.66 ± 0.33)

[a] Means ($\pm$SE) were analyzed using Parametric Test, One-Way ANOVA ; [b & c] Values of the treated are significantly different at $P < 0.05$ & 0.01 from the control (Parametric Test of Two-sided t -Test Paired Comparison). Figures in parentheses represent the control.

Table 3.9 Effects of methanol and aqueous extracts of *Ageratum conyzoides* on behavioral activity of IV instar nymphs of *Oxya hyla* [a]

Extract	Conc mgml^{-1}	Days of observation 1	2	3	4	5	6
MeOH	50	1.33±0.33^{b}	0.00±0.00^{c}	0.00±0.00^{b}	0.00±0.00^{b}	0.00±0.00	0.00±0.00
		(3.66±0.33)	(3.33±0.33)	(2.66±0.33)	(2.33±0.33)	(2.00±0.57)	(1.33±0.33)
	100	1.33±0.33	0.33±0.33^{b}	0.00±0.00^{b}	0.00±0.00^{b}	0.00±0.00	0.00±0.00
		(3.66±0.33)	(3.33±0.33)	(2.66±0.33)	(2.33±0.33)	(2.00±0.57)	(1.33±0.33)
	200	0.66±0.33^{b}	0.33±0.33^{b}	0.00±0.00^{b}	0.00±0.00^{b}	0.00±0.00	0.00±0.00
		(3.66±0.33)	(3.33±0.33)	(2.66±0.33)	(2.33±0.33)	(2.00±0.57)	(1.33±0.33)
Aqueous	50	3.33±0.33^{b}	3.33±0.33	3.33±0.33	2.66±0.33^{d}	2.33±0.33	1.33±0.33
		(5.00±0.00)	(4.33±0.33)	(4.00±0.57)	(3.66±0.33)	(3.00±0.00)	(2.66±0.33)
	100	3.33±0.33^{b}	3.00±0.00	3.00±0.00	2.66±0.33	2.00±0.57	1.66±0.33
		(5.00±0.00)	(4.33±0.33)	(4.00±0.57)	(3.66±0.33)	(3.00±0.00)	(2.66±0.33)
	200	3.00±0.00^{b}	3.00±0.00	2.33±0.33	2.00±0.00^{b}	1.66±0.33	1.33±0.33
		(5.00±0.00)	(4.33±0.33)	(4.00±0.57)	(3.66±0.33)	(3.00±0.00)	(2.66±0.33)

[a] Means (±SE) were analyzed using Parametric Test. One-Way ANOVA; $^{b, c}$ & ^{d} Means of the treated are significantly different at $P < 0.05$, 0.01 & 0.001 from the control (Parametric Test of Two-sided t -Test Paired Comparison). Figures in parentheses represent the control.

Table 3.10 Effects of methanol and aqueous extracts of *Ageratum conyzoides* on behavioral activity of V instar nymphs of *Oxya hyla* [a]

Extract	Conc $mgml^{-1}$	Days of observation 1	2	3	4	5	6
MeOH	50	2.33±0.33	1.66±0.33	0.00±0.00^{b}	0.00±0.00^{b}	0.00±0.00^{b}	0.00±0.00^{b}
		(4.00±0.57)	(3.66±0.33)	(3.00±0.57)	(3.00±0.57)	(2.66±0.33)	(2.33±0.33)
	100	2.33±0.33	0.66±0.33^{b}	0.00±0.00^{b}	0.00±0.00^{b}	0.00±0.00^{b}	0.00±0.00^{b}
		(4.00±0.57)	(3.66±0.33)	(3.00±0.57)	(3.00±0.57)	(2.66±0.33)	(2.33±0.33)
	200	1.00±0.00^{b}	0.33±0.33^{c}	0.00±0.00^{b}	0.00±0.00^{b}	0.00±0.00^{b}	0.00±0.00^{b}
		(4.00±0.57)	(3.66±0.33)	(3.00±0.57)	(3.00±0.57)	(2.66±0.33)	(2.33±0.33)
Aqueous	50	4.50±0.28	4.00±0.40	3.75±0.25	2.75±0.25	2.50±0.28	1.75±0.25
		(4.75±0.47)	(4.50±0.28)	(3.50±0.50)	(3.25±0.62)	(2.75±0.47)	(2.75±0.47)
	100	3.25±0.25	2.75±0.25^{b}	2.25±0.25	1.50±0.28	1.25±0.25	1.00±0.00^{b}
		(4.75±0.47)	(4.50±0.28)	(3.50±0.50)	(3.25±0.62)	(2.75±0.47)	(2.75±0.47)
	200	2.50±0.28^{b}	1.75±0.25^{c}	1.25±0.25^{b}	1.25±0.25	0.25±0.25^{b}	0.25±0.25^{b}
		(4.75±0.47)	(4.50±0.28)	(3.50±0.50)	(3.25±0.62)	(2.75±0.47)	(2.75±0.47)

[a] Means (±SE) were analyzed using Parametric Test, One-Way ANOVA; [b & c] Values of the treated are significantly different at $P< 0.05$ & 0.01 from the control (Parametric Test of Two-sided t -Test Paired Comparison). Figures in parentheses represent the control.

Table 3.11 Effects of methanol and aqueous extracts of *Ageratum conyzoides* on behavioral activity of VI instar nymphs of *Oxya hyla* [a]

Extract	Conc $mgml^{-1}$	Days of observation 1	2	3	4	5	6
MeOH	50	1.50±0.28	1.00±0.00^{b}	0.75±0.25^{b}	0.00±0.00^{c}	0.00±0.00^{b}	0.00±0.00^{b}
		(2.50±0.28)	(2.25±0.25)	(2.00±0.00)	(1.75±0.25)	(1.50±0.28)	(1.25±0.25)
	100	1.75±0.47	1.25±0.25	1.00±0.00^{b}	0.00±0.00^{c}	0.00±0.00^{b}	0.00±0.00^{b}
		(2.50±0.28)	(2.25±0.25)	(2.00±0.00)	(1.75±0.25)	(1.50±0.28)	(1.25±0.25)
	200	2.00±0.40^{b}	0.75±0.25^{b}	0.00±0.00^{c}	0.00±0.00^{c}	0.00±0.00^{b}	0.00±0.00^{b}
		(2.50±0.28)	(2.25±0.25)	(2.00±0.00)	(1.75±0.25)	(1.50±0.28)	(1.25±0.25)
Aqueous	50	3.66±0.33	3.33±0.33^{b}	3.00±0.00	2.00±0.00^{b}	1.66±0.33	1.33±0.33
		(5.66±0.33)	(5.00±0.57)	(4.33±0.33)	(4.00±0.00)	(3.66±0.33)	(3.33±0.33)
	100	4.00±0.57	3.33±0.33	2.66±0.33^{b}	2.00±0.00^{b}	1.33±0.33^{b}	1.00±0.00^{b}
		(5.66±0.33)	(5.00±0.57)	(4.33±0.33)	(4.00±0.00)	(3.66±0.33)	(3.33±0.33)
	200	3.33±0.33^{b}	2.33±0.33^{b}	1.33±0.33^{b}	1.33±0.33^{b}	0.66±0.33^{b}	0.33±0.33^{b}
		(5.66±0.33)	(5.00±0.57)	(4.33±0.33)	(4.00±0.00)	(3.66±0.33)	(3.33±0.33)

[a] Means (±SE) were analyzed using Parametric Test, One-Way ANOVA; [b & c] Values of the treated are significantly different at $P < 0.05$ & 0.01 from the control (Parametric Test of Two-sided t -Test Paired Comparison). Figures in parentheses represent the control.

Table 3.12 Effects of methanol and aqueous extracts of *Ageratum conyzoides* on behavioral activity of Adults of *Oxya hyla* [a]

Extract	Conc $mgml^{-1}$	Days of observation 1	2	3	4	5	6
MeOH	50	2.00 ± 0.25^{d}	1.40 ± 0.26^{d}	0.40 ± 0.16^{d}	0.10 ± 0.10^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}
		(8.40±0.16)	(7.80±0.20)	(7.30±0.15)	(7.10±0.23)	(6.40±0.24)	(6.00±0.31)
	100	1.70 ± 0.15^{d}	1.00 ± 0.25^{d}	0.10 ± 0.10^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}
		(8.40±0.16)	(7.80±0.20)	(7.30±0.15)	(7.00±0.57)	(6.66±0.33)	(6.20±0.20)
	200	1.50 ± 0.40^{d}	0.40 ± 0.22^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}
		(8.33±0.66)	(7.80±0.57)	(7.66±0.33)	(7.00±0.57)	(6.66±0.33)	(6.33±0.33)
Aqueous	50	4.16 ± 0.87^{c}	3.83 ± 0.47^{d}	3.66 ± 0.33^{d}	3.16 ± 0.16^{d}	2.66 ± 0.21^{d}	2.50 ± 0.22^{d}
		(9.33±0.33)	(9.00±0.57)	(9.00±0.57)	(8.33±0.33)	(8.33±0.33)	(8.00±0.57)
	100	4.33 ± 0.61^{d}	3.50 ± 0.34^{d}	3.33 ± 0.42^{d}	2.83 ± 0.30^{d}	2.16 ± 0.16^{d}	1.83 ± 0.16^{d}
		(9.66±0.33)	(9.33±0.33)	(9.33±0.33)	(8.66±0.33)	(8.33±0.33)	(8.33±0.33)
	200	4.16 ± 0.87^{c}	3.66 ± 0.66^{d}	3.50 ± 0.56^{d}	2.50 ± 0.56^{d}	1.83 ± 0.40^{d}	1.66 ± 0.30^{d}
		(9.66±0.33)	(9.33±0.33)	(9.00±0.57)	(8.33±0.33)	(8.00±0.57)	(7.66±0.66)

[a] Means (±SE) were analyzed using Parametric Test. One-Way ANOVA; [c & d] Values of the treated are significantly different at P< 0.01 & 0.001 from the control (Parametric Test of Two-sided t -Test Paired Comparison). Figures in parentheses represent the control.

Table 3.13 Effects of methanol and aqueous extracts of *Ageratum conyzoides* on behavioral inactivity of I instar nymphs of *Oxya hyla* [a]

Extract	Conc mgml^{-1}	Days of observation 1	2	3	4	5	6
MeOH	50	5.50±0.64^{b} (0.75±0.47)	9.50±0.50^{c} (0.75±0.47)	10.00±0.00^{d} (1.25±0.25)	10.00±0.00^{d} (1.75±0.47)	10.00±0.00^{d} (2.25±0.25)	10.00±0.00^{d} (2.25±0.25)
	100	3.75±0.85 (0.75±0.47)	9.25±0.75^{c} (0.75±0.47)	10.00±0.00^{d} (1.25±0.25)	10.00±0.00^{d} (1.75±0.47)	10.00±0.00^{d} (2.25±0.25)	10.00±0.00^{d} (2.25±0.25)
	200	4.50±0.64^{b} (0.75±0.47)	10.00±0.00^{d} (0.75±0.47)	10.00±0.00^{d} (1.25±0.25)	10.00±0.00^{d} (1.75±0.47)	10.00±0.00^{d} (2.25±0.25)	10.00±0.00^{d} (2.25±0.25)
Aqueous	50	1.33±0.33 (0.00±0.00)	1.66±0.33^{b} (0.00±0.00)	3.00±0.57^{b} (0.00±0.00)	4.66±0.66^{b} (0.00±0.00)	5.66±0.33^{c} (0.33±0.33)	7.00±0.57^{c} (0.66±0.66)
	100	1.66±0.66 (0.00±0.00)	2.66±1.20 (0.00±0.00)	3.66±1.45 (0.00±0.00)	5.33±1.76 (0.00±0.00)	6.33±1.20 (0.33±0.33)	8.33±0.66^{b} (0.66±0.66)
	200	2.33±0.33^{b} (0.00±0.00)	3.00±0.57^{b} (0.00±0.00)	3.33±0.66^{b} (0.00±0.00)	5.00±0.57^{b} (0.00±0.00)	8.33±0.33^{c} (0.33±0.33)	9.66±0.33^{c} (0.66±0.66)

[a] Means (±SE) were analyzed using Parametric Test, One-Way ANOVA ; [b, c & d] Values of the treated are significantly different at P< 0.05, 0.01 & 0.001 from the control (Parametric Test of Two-sided t -Test Paired Comparison). Figures in Parentheses represent the control.

Table 3.14 Effects of methanol and aqueous extracts of *Ageratum conyzoides* on behavioral inactivity of II instar nymphs of *Oxya hyla* [a]

Extract	Conc mgml^{-1}	Days of observation 1	2	3	4	5	6
MeOH	50	5.66±0.33^{b} (2.00±0.57)	10.00±0.00^{c} (2.00±0.57)	10.00±0.00^{c} (2.33±0.33)	10.00±0.00^{b} (3.33±0.88)	10.00±0.00^{b} (3.66±0.66)	10.00±0.00^{b} (3.66±0.66)
	100	6.66±0.33^{c} (2.00±0.57)	10.00±0.00^{c} (2.00±0.57)	10.00±0.00^{c} (2.33±0.33)	10.00±0.00^{b} (3.33±0.88)	10.00±0.00^{b} (3.66±0.66)	10.00±0.00^{b} (3.66±0.66)
	200	5.33±0.33^{c} (2.00±0.57)	10.00±0.00^{c} (2.00±0.57)	10.00±0.00^{c} (2.33±0.33)	10.00±0.00^{b} (3.33±0.88)	10.00±0.00^{b} (3.66±0.66)	10.00±0.00^{b} (3.66±0.66)
Aqueous	50	2.00±0.00 (1.00±0.00)	2.66±0.66 (1.00±0.00)	4.00±1.00 (1.33±0.33)	4.66±0.88 (1.66±0.33)	5.66±0.66^{c} (2.33±0.33)	7.33±0.33^{c} (2.66±0.33)
	100	1.33±0.33 (1.00±0.00)	2.33±0.33 (1.00±0.00)	4.66±0.88^{b} (1.33±0.33)	7.00±1.00^{b} (1.66±0.33)	7.66±0.33^{b} (2.33±0.33)	8.33±0.33^{b} (2.66±0.33)
	200	2.33±0.33 (1.00±0.00)	2.66±0.66 (1.00±0.00)	3.66±0.88 (1.33±0.33)	6.66±0.88^{b} (1.66±0.33)	8.33±0.33^{c} (2.33±0.33)	9.33±0.33^{c} (2.66±0.33)

[a] Means (±SE) were analyzed using Parametric Test, One-Way ANOVA ; [b & c] Values of the treated are significantly different at $P< 0.05$ & 0.01 from the control (Parametric Test of Two-sided t -Test Paired Comparison). Figures in Parentheses represent the control.

Table 3.15 Effects of methanol and aqueous extracts of *Ageratum conyzoides* on behavioral inactivity of III instar nymphs of *Oxya hyla* [a]

Extract	Conc $mgml^{-1}$	Days of observation 1	2	3	4	5	6
MeOH	50	4.66 ± 0.33^{b}	10.00 ± 0.00^{c}	10.00 ± 0.00^{c}	10.00 ± 0.00^{c}	10.00 ± 0.00^{c}	10.00 ± 0.00^{c}
		(1.66±0.33)	(2.00±0.00)	(2.00±0.00)	(2.33±0.33)	(3.33±0.33)	(3.33±0.33)
	100	6.33 ± 0.33^{c}	10.00 ± 0.00^{c}	10.00 ± 0.00^{c}	10.00 ± 0.00^{c}	10.00 ± 0.00^{c}	10.00 ± 0.00^{c}
		(1.66±0.33)	(2.00±0.00)	(2.00±0.00)	(2.33±0.33)	(3.33±0.33)	(3.33±0.33)
	200	5.33 ± 0.33^{c}	10.00 ± 0.00^{c}	10.00 ± 0.00^{c}	10.00 ± 0.00^{c}	10.00 ± 0.00^{c}	10.00 ± 0.00^{c}
		(1.66±0.33)	(2.00±0.00)	(2.00±0.00)	(2.33±0.33)	(3.33±0.33)	(3.33±0.33)
Aqueous	50	1.33±0.33	2.00±0.00	2.66±0.33	5.00±0.57	5.66±0.66	7.00 ± 0.57^{b}
		(0.33±0.33)	(0.66±0.33)	(1.66±0.33)	(2.00±0.57)	(2.33±0.33)	(2.66±0.33)
	100	1.33±0.33	1.66±0.33	2.33±0.88	3.66±0.66	6.00 ± 0.57^{c}	8.00 ± 0.57^{c}
		(0.33±0.33)	(0.66±0.33)	(1.66±0.33)	(2.00±0.57)	(2.33±0.33)	(2.66±0.33)
	200	2.33±0.33	2.33 ± 0.33^{b}	3.00±0.00	4.00±0.57	5.33 ± 0.33^{b}	7.66 ± 0.33^{b}
		(0.33±0.33)	(0.66±0.33)	(1.66±0.33)	(2.00±0.57)	(2.33±0.33)	(2.66±0.33)

[a] Means (±SE) were analyzed using Parametric Test, One-Way ANOVA ; [b & c] Values of the treated are significantly different at $P < 0.05$ & 0.01 from the control (Parametric Test of Two-sided t -Test Paired Comparison). Figures in Parentheses represent the control.

Table 3.16 Effects of methanol and aqueous extracts of *Ageratum conyzoides* on behavioral inactivity of IV instar nymphs of *Oxya hyla* [a]

Extract	Conc mgml^{-1}	Days of observation 1	2	3	4	5	6
MeOH	50	4.00±0.57^{b}	9.00±1.00^{b}	10.00±0.00^{c}	10.00±0.00^{c}	10.00±0.00^{c}	10.00±0.00^{c}
		(0.00±0.00)	(0.00±0.00)	(0.66±0.33)	(1.33±0.33)	(1.66±0.33)	(2.66±0.33)
	100	4.66±1.20	9.00±0.57^{c}	10.00±0.00^{c}	10.00±0.00^{c}	10.00±0.00^{c}	10.00±0.00^{c}
		(0.00±0.00)	(0.00±0.00)	(0.66±0.33)	(1.33±0.33)	(1.66±0.33)	(2.66±0.33)
	200	6.33±1.20^{b}	9.66±0.33^{c}	10.00±0.00^{c}	10.00±0.00^{c}	10.00±0.00^{c}	10.00±0.00^{c}
		(0.00±0.00)	(0.00±0.00)	(0.66±0.33)	(1.33±0.33)	(1.66±0.33)	(2.66±0.33)
Aqueous	50	2.33±0.33^{b}	2.66±0.66	3.33±0.33^{b}	4.66±0.33^{c}	5.66±0.33^{b}	6.66±0.33^{c}
		(0.00±0.00)	(0.33±0.33)	(0.66±0.33)	(1.00±0.57)	(1.66±0.33)	(2.00±0.00)
	100	2.00±0.00^{b}	2.33±0.33	3.66±0.66	4.66±0.33	4.66±0.33^{b}	5.66±0.33^{c}
		(0.00±0.00)	(0.33±0.33)	(0.66±0.33)	(1.00±0.57)	(1.66±0.33)	(2.00±0.00)
	200	3.33±0.33^{c}	3.66±0.33^{c}	4.66±0.33^{b}	6.00±0.57^{b}	7.00±0.57^{b}	7.33±0.33^{c}
		(0.00±0.00)	(0.33±0.33)	(0.66±0.33)	(1.00±0.57)	(1.66±0.33)	(2.00±0.00)

[a] Means (±SE) were analyzed using Parametric Test. One-Way ANOVA ; [b & c] Values of the treated are significantly different at $P < 0.05$ & 0.01 from the control (Parametric Test of Two-sided t -Test Paired Comparison). Figures in Parentheses represent the control.

Table 3.17 Effects of methanol and aqueous extracts of *Ageratum conyzoides* on behavioral inactivity of V instar nymphs of *Oxya hyla* [a]

Extract	Conc mgml^{-1}	Days of observation 1	2	3	4	5	6
MeOH	50	3.66±0.33[c]	7.00±0.57[b]	9.66±0.33[c]	10.00±0.00[c]	10.00±0.00[c]	10.00±0.00[c]
		(0.00±0.00)	(0.33±0.33)	(0.66±0.33)	(1.33±0.33)	(1.66±0.33)	(2.33±0.33)
	100	4.33±0.33[c]	7.66±0.66[b]	9.66±0.33[c]	10.00±0.00[c]	10.00±0.00[c]	10.00±0.00[c]
		(0.00±0.00)	(0.33±0.33)	(0.66±0.33)	(1.33±0.33)	(1.66±0.33)	(2.33±0.33)
	200	4.33±0.88[b]	8.66±0.88[b]	10.00±0.00[c]	10.00±0.00[c]	10.00±0.00[c]	10.00±0.00[c]
		(0.00±0.00)	(0.33±0.33)	(0.66±0.33)	(1.33±0.33)	(1.66±0.33)	(2.33±0.33)
Aqueous	50	2.25±0.25[c]	2.25±0.25[c]	3.50±0.28[c]	5.00±0.57[c]	6.25±0.62[b]	6.75±0.47[c]
		(0.00±0.00)	(0.00±0.00)	(0.00±0.00)	(0.50±0.28)	(1.50±0.28)	(1.50±0.28)
	100	2.75±0.25[c]	2.50±0.28[c]	4.25±0.25[d]	5.00±0.40[d]	6.00±0.57[c]	7.50±0.28[d]
		(0.00±0.00)	(0.00±0.00)	(0.00±0.00)	(0.50±0.28)	(1.50±0.28)	(1.50±0.28)
	200	3.25±0.25[d]	4.75±0.62[c]	6.50±0.28[d]	7.75±0.47[d]	9.00±0.70[c]	9.75±0.25[d]
		(0.00±0.00)	(0.00±0.00)	(0.00±0.00)	(0.50±0.28)	(1.50±0.28)	(1.50±0.28)

[a] Means (±SE) were analyzed using Parametric Test, One-Way ANOVA ; [b, c & d] Values of the treated are significantly different at $P < 0.05$, 0.01 & 0.001 from the control (Parametric Test of Two-sided t -Test Paired Comparison). Figures in Parentheses represent the control.

Table 3.18 Effects of methanol and aqueous extracts of *Ageratum conyzoides* on behavioral inactivity of VI instar nymphs of *Oxya hyla* [a]

Extract	Conc $mgml^{-1}$	Days of observation 1	2	3	4	5	6
MeOH	50	2.75 ± 0.25^{b}	5.50 ± 0.28^{c}	7.50 ± 0.50^{c}	10.00 ± 0.00^{d}	10.00 ± 0.00^{d}	10.00 ± 0.00^{d}
		(0.75±0.25)	(1.25±0.25)	(1.75±0.25)	(2.25±0.25)	(3.00±0.41)	(3.25±0.47)
	100	5.00 ± 0.40^{c}	7.75 ± 0.25^{d}	8.25 ± 0.62^{c}	10.00 ± 0.00^{d}	10.00 ± 0.00^{d}	10.00 ± 0.00^{d}
		(0.75±0.25)	(1.25±0.25)	(1.75±0.25)	(2.25±0.25)	(3.00±0.41)	(3.25±0.47)
	200	3.75±0.25c	6.50 ± 0.64^{b}	9.75 ± 0.25^{c}	10.00 ± 0.00^{d}	10.00 ± 0.00^{d}	10.00 ± 0.00^{d}
		(0.75±0.25)	(1.25±0.25)	(1.75±0.25)	(2.25±0.25)	(3.00±0.41)	(3.25±0.47)
Aqueous	50	1.66 ± 0.33^{b}	3.00±0.57	4.66 ± 0.66^{b}	7.00 ± 0.57^{b}	7.66 ± 0.33^{c}	8.00 ± 0.57^{c}
		(0.00±0.00)	(1.00±0.57)	(1.66±0.33)	(2.00±0.57)	(2.33±0.33)	(2.66±0.33)
	100	2.33 ± 0.33^{b}	4.33±0.33	5.33 ± 0.33^{c}	7.66 ± 0.33^{b}	8.66 ± 0.33^{c}	8.66 ± 0.33^{c}
		(0.00±0.00)	(1.00±0.57)	(1.66±0.33)	(2.00±0.57)	(2.33±0.33)	(2.66±0.33)
	200	2.66 ± 0.33^{b}	4.33 ± 0.33^{c}	7.00 ± 0.57^{c}	9.00 ± 0.57^{c}	9.66 ± 0.33^{c}	10.00 ± 0.00^{c}
		(0.00±0.00)	(1.00±0.57)	(1.66±0.33)	(2.00±0.57)	(2.33±0.33)	(2.66±0.33)

[a] Means (±SE) were analyzed using Parametric Test, One-Way ANOVA ; [b, c & d] Values of the treated are significantly different at $P < 0.05$, 0.01 & 0.001 from the control (Parametric Test of Two-sided t -Test Paired Comparison). Figures in Parentheses represent the control.

Table 3.19 Effects of methanol and aqueous extracts of *Ageratum conyzoides* on behavioral inactivity of Adults of *Oxya hyla* [a]

Extract	Conc $mgml^{-1}$	Days of observation 1	2	3	4	5	6
MeOH	50	3.00 ± 0.70^{b} (0.00±0.00)	6.00 ± 1.41^{b} (0.33±0.33)	8.00 ± 1.37^{c} (1.33±0.33)	9.20 ± 0.80^{d} (1.33±0.33)	10.00 ± 0.00^{d} (1.33±0.33)	10.00 ± 0.00^{d} (2.33±0.33)
	100	3.75 ± 0.85^{b} (0.00±0.00)	7.25 ± 0.85^{c} (0.33±0.33)	10.00 ± 0.00^{d} (1.33±0.33)	10.00 ± 0.00^{d} (2.33±0.66)	10.00 ± 0.00^{c} (2.66±0.88)	10.00 ± 0.00^{d} (3.00±0.57)
	200	10.00 ± 0.00^{d} (0.25±0.25)	10.00 ± 0.00^{d} (0.25±0.25)	10.00 ± 0.00^{d} (0.75±0.75)	10.00 ± 0.00^{d} (1.25±0.47)	10.00 ± 0.00^{c} (1.75±0.47)	10.00 ± 0.00^{d} (2.25±0.47)
Aqueous	50	1.66 ± 0.33^{b} (0.00±0.00)	2.66 ± 0.33^{b} (0.00±0.00)	2.66 ± 0.33^{b} (0.33±0.33)	3.33 ± 0.33^{b} (0.66±0.33)	3.33 ± 0.33^{b} (1.00±0.00)	3.66 ± 0.33^{b} (1.33±0.33)
	100	1.33±0.33 (0.00±0.00)	2.66 ± 0.33^{b} (0.33±0.33)	3.00±0.57 (0.66±0.33)	3.00±0.57 (1.33±0.33)	4.00±0.57 (1.66±0.33)	4.66 ± 0.33^{b} (2.33±0.33)
	200	1.66 ± 0.33^{b} (0.00±0.00)	2.00 ± 0.57^{b} (0.33±0.33)	2.33 ± 0.33^{b} (0.66±0.33)	3.66±0.66 (1.66±0.33)	4.66±0.33 (2.33±0.33)	5.33 ± 0.33^{b} (2.66±0.33)

[a] Means (±SE) were analyzed using Parametric Test, One-Way ANOVA ; [b, c & d] Values of the treated are significantly different at $P< 0.05$, 0.01 & 0.001 from the control (Parametric Test of Two-sided t -Test Paired Comparison). Figures in Parentheses represent the control.

Table 3.20 Effect of Precocene I on the behavioral activity of III instar nymphs of *Oxya hyla* [a]

Activity	Conc $\mu g ml^{-1}$	Days of observation 1	2	3	4	5	6
Active	10	3.66 ± 0.21^b	2.83 ± 0.30^b	2.00 ± 0.25^c	1.00 ± 0.25^b	0.50 ± 0.22^b	0.00 ± 0.00^c
		(5.16±0.47)	(5.00±0.36)	(4.50±0.42)	(3.66±0.49)	(3.33±0.66)	(2.66±0.49)
	20	4.00 ± 0.31^b	2.20 ± 0.20^c	0.80±0.37c	0.20 ± 0.20^c	0.00 ± 0.00^d	0.00 ± 0.00^c
		(6.00±0.54)	(5.80±0.48)	(5.40±0.40)	(4.80±0.48)	(4.40±0.40)	(4.00±0.54)
Inactive	10	3.83 ± 0.47^d	6.83 ± 0.47^d	8.66 ± 0.33^d	9.66 ± 0.21^d	10.00 ± 0.00^d	10.00 ± 0.00^d
		(0.00±0.00)	(0.00±0.00)	(0.83±0.16)	(1.33±0.21)	(2.16±0.30)	2.83±0.31)
	20	4.75 ± 0.47^c	8.00 ± 0.70^c	9.50 ± 0.28^d	10.00 ± 0.00^d	10.00 ± 0.00^d	10.00 ± 0.00^d
		(0.00±0.00)	(0.00±0.00)	(1.25±0.62)	(2.50±0.28)	(2.50±0.28)	(2.75±0.25)

[a] Means (±SE) were analyzed using Parametric Test, One-Way ANOVA [b, c & d] Values of the treated are significantly different at P< 0.05, 0.01 & 0.001 from the control (Parametric Test of Two-sided t -Test Paired Comparison). Figures in Parentheses represent the control.

Table 3.21 Effect of Precocene II on the behavioral activity of III instar nymphs of *Oxya hyla* [a]

Activity	Conc $mgml^{-1}$	Days of observation 1	2	3	4	5	6
Active	1.0	3.33±0.66 (7.00±0.57)	2.33 ± 0.66^{b} (6.00±0.00)	2.00 ± 0.57^{c} (5.33±0.66)	1.33±0.66 (4.66±0.33)	1.33 ± 0.66^{b} (4.33±0.33)	0.66 ± 0.33^{b} (3.33±0.33)
	2.0	3.00 ± 0.44^{d} (6.00±0.31)	1.60 ± 0.24^{c} (5.40±0.40)	0.60 ± 0.24^{d} (5.20±0.48)	0.00 ± 0.00^{d} (4.40±0.40)	0.00 ± 0.00^{c} (3.60±0.51)	0.00 ± 0.00^{c} (3.20±0.37)
Inactive	1.0	4.33 ± 0.88^{b} (0.00±0.00)	6.00±1.52 (0.00±0.00)	6.33±1.76 (0.66±0.33)	6.33±1.76 (1.66±0.33)	7.00 ± 1.15^{b} (1.66±0.33)	8.33 ± 0.66^{c} (2.33±0.33)
	2.0	4.50 ± 0.50^{c} (0.00±0.00)	6.25 ± 0.25^{d} (0.00±0.00)	7.75 ± 0.25^{d} (1.25±0.47)	9.25 ± 0.47^{c} (2.00±0.41)	10.00 ± 0.00^{d} (2.50±0.28)	10.00 ± 0.00^{d} (2.50±0.28)

[a] Means (±SE) were analyzed using Parametric Test, One-Way ANOVA, [b, c & d] Values of the treated are significantly different at $P < 0.05$, 0.01 & 0.001 from the control (Parametric Test of Two-sided t -Test Paired Comparison). Figures in Parentheses represent the control.

Table 3.22 Effect of methanol and aqueous extracts of *Ageratum conyzoides* on molting (%) of I and II instars of *Oxya hyla* [a]

Extract	Instar	Conc $mgml^{-1}$	Days of observation 1	2	3	4	5	6
MeOH	I	50	3.33±3.33	-	-	-	-	-
		100, 200	-	-	-	-	-	-
		Control	-	-	-	-	-	-
Aqueous	I	50	-	-	16.66±8.81	-	-	-
		100 & 200	-	-	-	-	-	-
MeOH	II	50,100,200	-	-	-	-	-	-
		Control	-	-	-	-	-	
Aqueous	II	50	-	-	6.66±6.66	11.00±11.00	-	-
		100,200	-	-	-	-	-	-
		Control	-	-	-	-	-	

[a] Means (±SE) were analyzed using Parametric Test, One – Way ANOVA.

Table 3.23 Effects of methanol and aqueous extracts of *Ageratum conyzoides* on molting (%) of III & IV instar nymphs of *Oxya hyla* [a]

Extract	Instar	Conc $mgml^{-1}$	Days of observation: 1	2	3	4	5	6
MeOH	III	50,100,200	-	-	-	-	-	-
		Control	-	-	-	-	-	
Aqueous	III	50	-	-	-	3.33±3.33	13.33±3.33	13.33±3.33
		100	-	-	-	-	6.66±3.33	6.66±3.33
		200	-	-	-	6.66±3.33	13.33±3.33	13.33±3.33
MeOH	IV	50,100,200	-	-	-	-	-	-
		Control	-	-	-	-	-	
Aqueous	IV	50	-	-	-	-	-	-
		100	-	-	-	-	10.00±10.00	-
		200	-	6.66±3.33	10.00±5.77	13.33±6.66	13.33±6.66	13.33±6.66
		Control	-	-	-	-	-	-

[a] Means (±SE) were analyzed using Parametric Test, One – Way ANOVA.

Table 3.24 Effects of methanol and aqueous extracts of *Ageratum conyzoides* on molting (%) of V & VI instar nymphs of *Oxya hyla* [a]

Extract	Instar	Conc $mgml^{-1}$	Days of observation 1	2	3	4	5	6
MeOH	V	50	-	6.66±3.33	-	-	-	-
		100 & 200	-	-	-	-	-	-
		Control	6.66±6.66	3.33±3.33	3.33±3.33	-	-	-
Aqueous	V	50	3.33±3.33	-	-	-	-	3.33±3.33
		100	-	-	-	-	-	-
		200	-	-	-	3.33±3.33	-	-
		Control	-	-	-	-	-	-
MeOH	VI	50	-	-	-	-	-	-
		100	-	6.66±3.33	-	-	-	-
		200	-	-	-	-	-	-
		Control	-	3.33±3.33	-	-	-	-
Aqueous	VI	50,100,200	-	-	-	-	-	-
		Control	-	-	-	-	-	

[a] Means (±SE) were analyzed using Parametric Test, One – Way ANOVA.

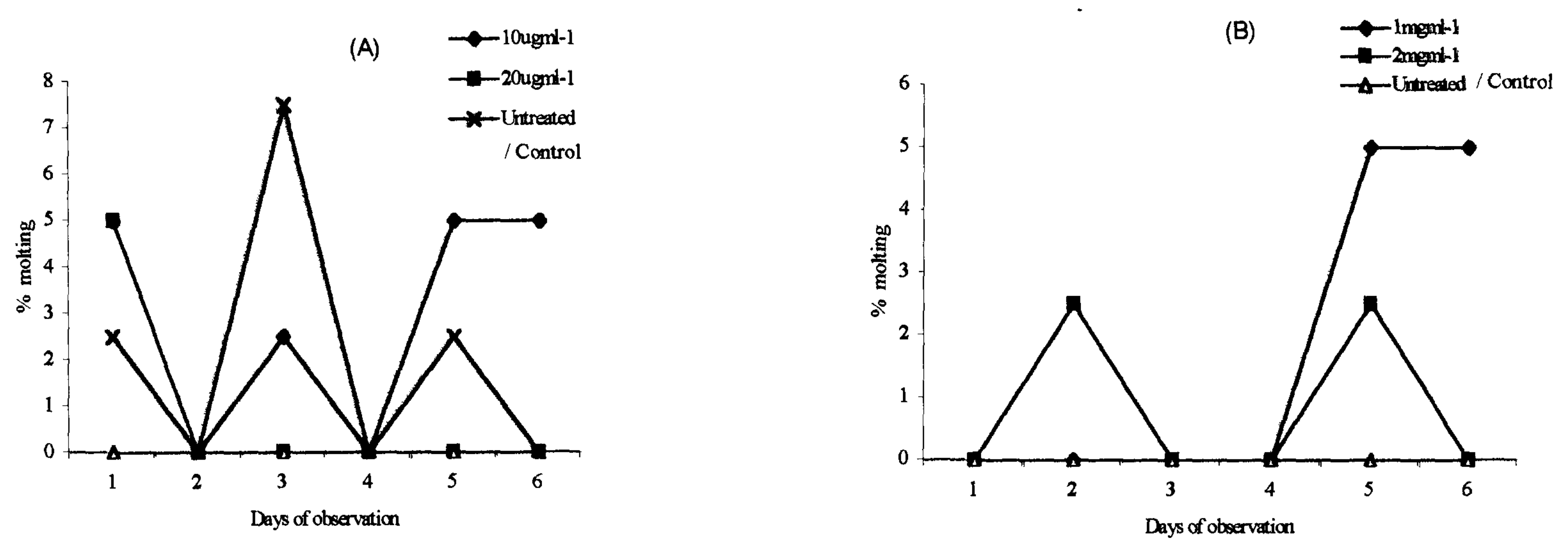


Figure 3.7 Effect of Precocene I (A) and II (B) on molting of the III instar nymphs of *Oxya hyla*.

Table 3.25 Field assays with aqueous and methanol extracts of *Ageratum conyzoides* in the rice plots in the year 2000 [a].

Area	Extract	Conc	Insect occurrence			Insect activity		
(m^2)		$mgml^{-1}$	Male	Female	Nymph	attacking	feeding	mating
3	Aqueous	100	8.14±2.26	8.00±2.54	2.42±0.36	13.42±2.78	7.14±1.90	1.00±0.48
			(12.42±2.06)	(9.71±1.79)	(4.14±1.40)	(23.14±4.33)	(18.42±3.57)	(1.28±0.56)
3	Methanol	50	$4.71±1.35^b$	$2.71±1.10^b$	1.00±0.30	$7.71±2.18^b$	$3.28±1.41^b$	0.14±0.14
			(12.42±2.06)	(9.71±1.79)	(4.14±1.40)	(23.14±4.33)	(18.42±3.57)	(1.28±0.56)

Field experiments with the aqueous and methanol extracts of *Ageratum conyzoides* in the rice plots in the year 2001 [a].

Area	Extract	Conc	Insect occurrence			Insect activity		
(m^2)		$mgml^{-1}$	Male	Female	Nymph	attacking	feeding	mating
3	Aqueous	100	6.55±1.37	5.00±1.02	1.33±0.37	$9.33±2.26^b$	$6.00±1.31^b$	$1.00±0.37^b$
			(12.42±2.06)	(9.71±1.79)	(4.14±1.40)	(23.14±4.33)	(18.42±3.57)	(1.28±0.56)
3	Methanol	100	$4.11±1.01^c$	$3.22±0.75^c$	$0.88±0.26^b$	$7.44±1.82^d$	$2.44±0.97^d$	$0.00±0.00^b$
			(12.42±2.06)	(9.71±1.79)	(4.14±1.40)	(23.14±4.33)	(18.42±3.57)	(1.28±0.56)

[a] Means (± SE) were statistically analyzed using Parametric Test One-Way ANOVA, [b, c & d] Values are significantly different from the control at (Parametric t-Test of Two Sided Paired Comparison) $P< 0.05, 0.01$ & 0.001. Figures in parentheses represent the control.

Table 3.26 Observations of the occurrence of *O. hyla* in the rice plots planted with *Ageratum conyzoides* on the sides in the year 2000 [a].

	Area size	Field	Insect occurrence			Insect activity		
Month	(m^2)	Condition	Male	Female	Nymph	attacking	feeding	mating
June	4	+A.c.	1.00±0.57 (2.00±0.57)	0.33±0.33 (0.66±0.33)	7.33±1.20[b] (17.33±1.85)	4.66±1.33 (12.00±1.15)	4.66±1.20 (5.66±0.66)	- -
July	4	+A.c.	1.66±0.88 (3.00±0.57)	0.33±0.33 (0.66±0.33)	22.00±2.08[c] (39.66±1.20)	16.33±2.02 (21.00±1.15)	14.66±2.02 (18.66±2.18)	- -
August	4	+A.c.	3.33±0.33 (6.33±0.88)	1.66±0.33[b] (4.33±0.33)	36.00±2.08[b] 49.33±1.45)	25.33±2.40 (22.66±2.02)	21.66±2.02 (26.33±2.84)	- -
Sept	4	+A.c.	5.66±1.45 (10.00±1.15)	3.33±0.88 (4.330.66)	27.66±2.02 (33.00±2.64)	18.66±1.4 (27.66±1.76)	12.00±1.15 (19.66±1.45)	- -
Oct	4	+A.c.	10.33±1.45 (12.66±0.88)	7.66±0.88 (9.00±0.57)	18.66±1.45[c] (23.33±1.20)	16.00±1.52 (19.33±0.88)	13.66±1.20 (17.00±0.57)	- -
Nov	4	+A.c.	15.66±1.45[c] (21.33±1.76)	12.33±0.88 (16.33±1.76)	0.00±0.00 (0.00±0.00)	13.33±0.88[b] (18.66±1.76)	10.66±1.20[c] (16.66±1.66)	1.00±0.57 (2.33±0.33)
Dec	4	+A.c.	6.00±2.08 (10.66±4.41)	5.00±1.00 (7.33±1.76)	0.00±0.00 (0.00±0.00)	6.00±3.46 (2.66±2.66)	2.66±2.66 (2.00±2.00)	0.00±0.00 (0.33±0.33)

[a] Means (± SE) were statistically analyzed using Parametric Test One-Way ANOVA, [b & c] Values are significantly different from the control at (Parametric t-Test of Two Sided Paired Comparison) P< 0.05 &0.01. Figures in parentheses represent the control. +A.c. - indicates the presence of *Ageratum conyzoides* on the sides of rice plots.

Table 3.27 Observations of the occurrence of *O. hyla* in rice plots planted with *Ageratum conyzoides* on the sides in the year 2001 [a].

			Insect occurrence			Insect activity		
Month	Area size (m^2)	Field Condition	Male	Female	Nymph	attacking	feeding	mating
June	4	+*A. c.*	4.50±2.50 (9.50±0.50)	3.50±1.50 (6.00±1.00)	5.00±2.00 (29.50±3.50)	7.00±2.00[b] (40.00±3.00)	4.00±1.00 (23.50±2.50)	0.00±0.00 (0.00±0.00)
July	4	+A.c.	3.00±0.00 (6.00±2.00)	2.50±0.50 (5.00±1.00)	4.00±0.00 (27.50±2.50)	8.00±0.00[b] (33.50±1.50)	3.50±0.50 (26.00±0.00)	0.00±0.00 (0.00±0.00)
August	4	+A.c.	4.50±0.50[b] (12.00±1.00)	3.50±0.50 (8.50±0.50)	5.50±0.50 (26.00±3.00)	10.50±0.50[b] (41.00±0.00)	7.00±2.00[b] (39.50±0.50)	0.00±0.00 (0.00±0.00)
Sept	4	+A.c.	6.00±2.00 (11.50±3.50)	4.00±1.00 (8.50±2.50)	5.50±0.50 (18.00±7.00)	6.50±0.50 (32.50±16.50)	6.00±0.00 (25.50±14.50)	0.00±0.00 (0.00±0.00)
Oct	4	+A.c.	9.00±1.15[b] (17.66±1.45)	7.00±0.57[b] (12.66±1.45)	1.33±0.66 (4.33±2.33)	11.33±3.17[b] (29.00±5.13)	8.33±1.66[b] (24.00±5.00)	2.00±0.57[b] (5.33±0.88)
Nov	4	+A.c.	12.33±1.45[b] (21.66±1.20)	10.66±0.33[c] (19.66±0.88)	0.00±0.00 (0.00±0.00)	10.00±1.15[d] (25.33±1.45)	8.00±1.15[c] (16.00±0.57)	1.00±0.57 (2.33±0.33)
Dec	4	+A.c.	6.33±3.75 (17.66±0.88)	5.00±2.88[b] (16.33±1.20)	0.00±0.00 (0.00±0.00)	1.33±1.33 (7.00±4.32)	1.00±1.00[c] (14.33±1.20)	0.00±0.00 (1.00±1.00)

[a] Means (± SE) were statistically analyzed using Parametric Test One-Way ANOVA, [b, c & d] Values are significantly different from the control at (Parametric t-Test of Two Sided Paired Comparison) $P < 0.05$, 0.01 & 0.001. Figures in parentheses represent the control. +A.c. - indicates the presence of Ageratum conyzoides on the sides of rice plots.

Table 3.28 The effects of extracts of *A. conyzoides* on rice production during 2000-2001[a].

Year	Extract	Conc ($mgml^{-1}$)	Rice grain production (Kg)
2000	Aqueous	100	1.135 ± 0.07 (1.005 ± 0.06)
	Methanol	100	1.36 ± 0.05^b (1.005 ± 0.06)
2001	Aqueous	100	1.435 ± 0.21 (0.88 ± 0.06)
	Methanol	100	1.56 ± 0.14^b (0.88 ± 0.06)

[a] Means ($\pm$ SE) were statistically analyzed using Parametric Test One-Way ANOVA
[b] Values are significantly different from the control at (Parametric t-Test of Two Sided Paired Comparison) $P < 0.05$. Figures in parentheses represent the control.

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EFFECT OF EXTRACTS OF AGERATUM CONYZOIDES AND PRECOCENE I AND II ON HOST SELECTION, CONSUMPTION AND GROWTH INDICES, FOOD CONVERSION EFFICIENCIES, AMYLASE ACTICITY, GASTROINTESTINAL HISTOLOGY AND TESTICULAR CELL CYCLE OF OXYA HYLA.

CHAPTER – 4

INTRODUCTION

Dethier (1982) described green plants as synthesizers and bankers of biochemical wealth and herbivores as the pillagers of this wealth and noted that this pillaging is not indiscriminate. Over the course of evolutionary history, each herbivore has become associated with a particular plant or group of plants to the exclusion of others. The large number of herbivores indicates that the plants with which each has become associated are nutritionally and ecologically adequate. The maintenance of such associations is achieved by recognition of the host plant through successive generations. Recognition is possible because any given plant possess a set of qualities that characterize it, including form, color, texture, water content, and chemical compounds. The herbivore's sensory system (its detecting and coding abilities) is the underlying mechanism that allows for the recognition of given plant characteristics (Dethier, 1982).

Knowledge of the nutritional requirements of insects and their interaction with food sources are basic for an understanding of their biology, since the amount and quality of food affect the growth rate at the immature stage and subsequent adult body size (Scriber and Slansky, 1981, Farrar et al. 1989). In completely favorable environments the performance of each individual is genetically determined, which in turn determines its maximal fitness in nutritional terms (Slansky and Rodriguez, 1987). Nevertheless, factors including density may be responsible for constraints on the consumption, utilization and allocation of food (Nicholson, 1954; Rodriguez, 1988; Travis, 1990), with consequences or the dynamic behaviour of populations (Mueller, 1988).

The location and selection of host plants by phytophagous insects has been depicted historically as a simple, uniform behavioral sequence (Thorsteinson, 1960). In particular response to the secondary and nutrient chemical constituents of plants have been considered generally as result of innate releasing mechanisms (Tinbergen, 1969), stereotyped and nearly resistant to environmental factors. However, currently there is sufficient evidence for learning of host preference in herbivorous insects (Stanton, 1984; Papaj, 1986).

The relative rate of consumption is a parameter commonly employed for quantifying the behavioural response of insects with respect to the food source (Waldbauer, 1968), although in certain cases the outcome of larval competition for food is perhaps more closely approximated to larval assimilation than to true consumption (Putman, 1977). Essential for studies of nutritional ecology are research techniques that employ biochemistry, physiology, genetics and behavior of organisms (Slansky and Rodriguez, 1987).

Some studies have explicitly investigated the habituation to feeding deterrents while ensuring that feeding status of insects was not involved. Gill (1972) was the first one to demonstrate this in feeding behavior of insects like *Scistocerca gregaria* which consumed successively more of a diet containing low levels of azadirachtin when they were allowed to feed on it for longer period.

The basic principles of the discipline of nutritional ecology, which, in short, addresses what insects eat, why they eat what they do, and how efficient they are in doing it. Insects, like all living organisms, require energy and nutrients to survive, grow and reproduce. The nutritional components (e.g., protein, carbohydrates, fats, vitamins, minerals) of ingested food may or may not be digested and absorbed. The proportion of ingested food that is actually digested is denoted by AD, the assimilation efficiency (also called "approximate digestibility"). Of the nutrients absorbed, portions are expended in the processes of respiration and work. The proportion of digested food that is actually transformed into net insect biomass is denoted by ECD, the efficiency of conversion of digested food. A parallel parameter, ECI, indicates the efficiency of conversion of ingested food. In short, AD indicates how digestible a food is, whereas ECD and ECI indicate how efficient a herbivore is in converting that food into biomass. These efficiency values may be calculated for specific dietary nutrients as well as for the bulk diet. For instance, nitrogen use efficiencies are informative because levels of plant nitrogen (an index of protein) are often times limiting to insect performance.

Food conversion efficiencies may vary considerably within a species. One cause of such variation involves homeostatic adjustment of consumption rates and efficiency parameters such that an insect can approach its "ideal" growth rate even with foods of different quality in various environments.

4.1 The process of Host plant selection

Many insects, including flies, beetles, butterflies, and moths, lay their eggs on an appropriate host plant for larval development and the insect is never presented with the challenge of finding a suitable host plant. However, some females do not always select the most appropriate host and newly hatched larvae must find and recognize a suitable host plant. Even when the female choice has been appropriate, insects are often required to move to new plants as their food supply is diminished or they enter reproductive maturity (Bernays and Chapman, 1994). Selection of a suitable host plant poses two main challenges for insects: (1) detecting and locating the host from a distance, and (2) confirming the appropriateness of the plant in terms of its species and quality (Bernays and Chapman, 1994; Schoonhoven et al. 1998).

4.2 Search Behavior

Since plants are stationary organisms, insects must move to find them. The sequence of behavioral steps passed through during searching is dependent on the development phase of the searching insect and on the cues available (Schoonhoven et al. 1998). Two primary modes of search behavior exist among insects, random and directed (Prokopy, 1986; Schoonhoven et al. 1998). **Random** searching has been described for various insects, including the squash bug, *Anasa tristis* (Cook and Neal, 1999), immature and mature locusts (Aikman and Hewitt, 1972), and polyphagous caterpillars (Dethier, 1982). During the search, scanning movements may be performed by the functioning of the 'central motor programs' located in the central nervous system (Miller and Strickler, 1984; Schoonhoven et al. 1998) to increase the probability that a resource is detected along the path. This searching type may be the best possible option when environmental cues provide no directionality or when the sensory capacity of the insect is insufficient to obtain the required stimuli (Schoonhoven et al. 1998).

Directed searching is possible when the host plant emits signals that, either alone or in combination with a second cue, allows direction to be perceived by the sensory system of the searching insect. Movement is directed by sensory information on external cues but may still be under the influence of central motor programs (Schoonhoven et al.

1998). This is achieved by one of two ways: (1) insects make temporal comparisons of information coming from the olfactory receptors, or (2) they compare sensory input coming simultaneously from a bilateral pair of olfactory receptors (Miller and Strickler, 1984; Schoonhoven et al, 1998).

Host finding by the important pests, *Dendroctonus brevicornis*, *Ips paraconfusus*, and *Scolytus quadripinosus* has been observed to be a random process (Byers, 1995). Other species, such as *Ips typographus*, locate host trees by orienting over several meters to volatile chemicals released by damaged or diseased trees. Diamondback moth, *Plutella xylostella*, employs a form of searching that uses both random and directed search movements (Pivnick et al.1994).

4.3 Chemical Cues

Attraction from a distance may involve smell, vision, or both. Smell (olfaction) is a powerful cue and has been argued as being the most important stimuli during host plant finding (Dicke, 2000; Finch and Collier, 2000). Air coming from an odor source contains pockets of odor-carrying air, carried in a meandering plume (Bernays and Chapman, 1994; Schoonhoven et al. 1998). These pockets are carried downwind from the plant so that an insect some distance from the source perceives a series of bursts of odor separated by periods of no odor. For example, in a female tobacco hornworm, *Manduca sexta,* the host plant odor acts as an activator for flight to occur, inducing the moth to take off from a resting or walking condition. Once in flight, the female moth picks up an odor plum and her flight path is determined by trying to prevent loss of the odor plume by moving in a zigzag pattern (Hildebrand and Montague, 1986).

In some species of insects, orientation to the wind using mechanical stimuli takes place while still on the ground. In a wind tunnel experiment, the apple maggot fly (*Rhagoletis pomonella*), aroused by apple volatiles, was observed turning into the wind and then walking steadily or taking 'short hopping flights' towards the source of the volatiles (Fein et al. 1982). In a field study, Aluja and Prokopy (1992) reported results similar to those of Fein et al. (1982). Using the same synthetic apple volatiles used by Fein et al (1982), *R. pomenella* was observed to alight on the ground and then move upwind to a point source of odor.

Nymphs of the desert locust, *Schistocerca gregaria*, and wingless females of the aphid *Cryptomyzus korschelti* and *Trirhabda canadensis* have been observed to move towards the upwind odor of their host plant (Bell, 1984; Visser and Taanman, 1987; Puttick et al. 1988). The potato beetle *L. decemlineata* has a strong odor preference for the cultivated potato (*Solanum tuberosum)* which it locates by walking. Visser (1986) found that when clean air was blown over it displayed a menotactic response to the wind, maintaining a constant angle to the wind direction. The observed response is thought to be the result of its attraction to green leaf chemicals produced by potato which include *trans*-2-hexenal, *cis*-3-hexanyl acetate, *cis*-3-hexanol and *trans*-2-hexenol (Jermy et al. 1988; Bernays and Chapman, 1994).

4.4 Visual Cues

Visual attraction to a host plant results from responding to the color or the form of the plant. Visual responses often occur only in conjunction with an appropriate olfactory stimulus. However, vision is of great importance in the final stages of host plant finding because the lack of odor gradients makes it unlikely that odor would lead an insect directly to a plant. Additionally, flying insects rely upon vision when landing on a potential host plant.

Three optical characteristics of plants influence host plant selection behavior: reflectance (color), dimensions (size), and pattern (shape) (Prokopy and Owens, 1983). The spectral sensitivity of insects ranges from 350-650 nm (near ultraviolet to red). The importance of leaf reflectance properties was demonstrated in an eloquent experiment by Prokopy and Owens (1983), in which the use of visual discrimination in the cabbage root flies, *D. radicum* was observed.

The yellow and green colors initially attract the watercress beetle, *Phaedon cochleariae* to the cruciferous host plant and then the odor of mustard oil provokes feeding (Bernays and Chapman, 1994; Jolivet, 1998). The importance of color also is apparent in many aphid species (Jolivet, 1998). Finally, the size and shape of plant leaves plays a critical role in host plant finding for some insects (Prokopy and Owens, 1983; Harris et al. 1993; Rojas and Wyatt, 1999)

4.5 The process of Host plant acceptance

When a herbivorous insect arrives at a plant and touches it, the insect enters what is commonly called the **'contact phase'** of host-plant finding (Schoonhoven et al. 1998). The contact phase consists of a series of behavioral elements that serve to evaluate physical and chemical traits of a plant. Upon encountering the plant, locomotion is stopped and the insect restricts movement to a small area on the plant surface; this is referred to as arrestment. In the arrestment phase, plant structures, e.g. leaf edges, veins, or stems, guide walking movements. For example, a walking insect may climb along the stem and then start moving in small circles over the plant surface. The insect will then evaluate the plant by repetitive contacting of legs, antennae, mouthparts, or the ovipositor with the plant surface. The movements allow the insect to perceive physical and chemical cues offered by the plant. Surface morphology, texture, and other physical structures are all characteristics evaluated by the insect during this phase.

4.6 Plant Physical Characteristics

The leaves of many plants are covered with hairs, or trichomes, that may deter or attract insects (Van Duyn et al. 1972). In small, phytophagous insects, heavy pubescence can prevent the insect from penetrating the epidermis (Southwood, 1986). On the leaf surface of the wild potato, *Solanum berthaultii*, are glandular trichomes that have been shown to produce a feeding deterrent to the Colorado potato beetle, *L. decemlineata.* Gregory et al. (1986) found that when the trichomes were removed from *S. berthaultii*, the leaf material was equally acceptable to *L. decemlineata*. While pubescence may have negative effects on host plant acceptance for some insects, it can increase acceptance in others. *Helicoverpa zea* females are better able to grip the upper pubescent surface than the glabrous underside of corn leaves, laying more eggs on the upper surface of the plant (Bernays and Chapman, 1994).

Insects at the plant surface also are exposed to lipid components of the epicuticular wax layer, and the composition of this layer plays an important role in mediating host plant selection (Eigenbrode et al. 1991; Powell et al. 1999).

4.7 Internal Plant Characteristics

After the insect has evaluated the physical characteristics of the plant, the next step in the evaluation phase is **test biting** of the plant tissue. A test bite is typically smaller than a regular bite and the plant material may be held in the pre-oral cavity for a longer period of time than during regular food intake (Schoonhoven et al. 1998). The plant cell contains large numbers of different chemicals and some may serve, as phagostimulants while others may be deterrents to feeding.

The key phagostimulants detected during the test bite are nutrients, and sugars (Bernays and Chapman, 1994). Plant secondary compounds also may act as phagostimulants. In general, secondary compounds only serve a phagostimulants when present in low concentrations. Additionally, many secondary compounds are present in one or a small number of plant taxa. In such cases, the secondary compounds provide indicators to monophagous or oligophagous insects that they have indeed located the correct host. For example, Bowers (1984) found that the iridoid glycosides, would characterize the host plant of the buckeye butterfly, *Junonia coenia,* and act as phago- and oviposition stimulants.

The stimulatory and inhibitory effects of plant chemicals, including primary and secondary compounds, counteract each other and determine the outcome of the decision making process, to accept or reject the plant as a host.

4.8 Food Aversion learning

Studies with the polyphagous grasshopper, *Schistocerca americana,* have clearly shown the ability of these insects to associate toxic effects with the tastes of particular foods. Bernays and Lee (1988) examined the food-aversion learning in a *S. americana* using an injected aversive stimulus after different foods. It was observed that grasshoppers show differences in their inclination to associate foods of different palatability with an aversive stimulus. Plant feeding insects in several genera are known to exhibit learning behavior including *Colias, Heliconius, Battus,* and *Peiris* butterfly adults; *Acrolepiopsis* leek moths; *Dacus, Ceratitis,* and *Rhagoletis* fruit fly adults; *Schistocerca* and *Locusta*; locust and *Melanoplus* grasshopper nymphs; *Callosobruchus,* *Deloyala, Haltica,* and *Leptinotarsa* beetles; and many species of lepidopterous larvae (Jermy, 1987; Papaj and Prokopy, 1989; Szentesi and Jermy, 1990).

MATERIALS AND METHODS

4.9 Host - plant selection and Host specificity

Fresh host plants were collected from the field and brought to the laboratory. Leaves of different plants, of uniform sizes were cut out from healthy growing plants, the initial weight of each leaf was taken. Choice tests were conducted in glass petridishes (15cm dia x 2cm high). Humidity inside was maintained by wet filter paper lining with pencil mark at the center and the peripheral sites to indicate the position of the leaf to be tested, the position of the leaves were randomized following the method of Chew (1980). The leaves were dipped in different concentrations of methanol and aqueous extracts of *A. conyzoides* and kept in the periphery of the arena. 10 adult or nymphs were starved for 24 hours, they were then introduced in the glass petridishes and allowed to feed for 24 hours, after which the fed leaves were again weighed to record the fed area of different leaves. Each experiment was repeated 3 times. Feeding leaves without treatment were used as control.

4.10 Consumption Rate, Growth Rate and Conversion Efficiencies

Specimens of *Oxya hyla* preferably of the same stage were selected. They were starved for a period of 24 hrs. The initial weight of each insect was recorded before introducing into separate experimental flasks containing treated leaves of different concentrations of methanol and aqueous extracts of *A.conyzoides.*

Feeding leaf was divided into two halves and weighed separately. The two halves after dipping in the concentrations of the extracts, the initial weights were recorded and one half was used for consumption, the other was kept for recording of the moisture loss. Such feeding leaves were inserted in the experimental flasks containing experimental insects. The part left over, excreta and final weight of insects were weighed after 24hrs of assaying. Leaves treated with methanol and water were set up as control.

Consumption rate, conversion efficiencies, growth rate were calculated using the method of Waldbauer (1964).

The consumption index (C.I) which is the amount of feeding relative to time and to the mean weight of the insect during the feeding period, was calculated as:

Conversion index (CI) = **F / TA**

Where F = wt of food eaten (mg)
A = mean wt of insect during feeding period (mg)
T = Duration of feeding period (days)

The relative growth rate (G.R), which is the rate at which digested matter becomes available to the insect, was calculated as:

Growth rate (GR) = **G / TA**

Where G = Weight gained by insect during feeding period (mg)
T = Duration of feeding period (days)
A = Mean weight of insect during feeding period (mg)

The amount of ingested food that is digested (Approximate Digestibility or AD) was calculated as;

AD = Wt of food ingested (mg) - wt of faeces (mg) / Wt of food ingested (mg) x 100

The efficiency of conversion of ingested food to body matter (E.C.I.), which is a measure of overall efficiency of an insect to grow on a given food, was calculated as;

Efficiency of Conversion of Digested food (ECI)

ECI = Wt gained by insect (mg) / wt of food ingested (mg) x 100

Or **ECI = GR / CI**

The E.C.I. will vary with the digestibility of the food, its nutritional value and the level of nutrient intake.

The efficiency with which digested food is converted to body matter (E.C.D.) was calculated as:

ECD = Wt gained by the insect (mg) / Wt of food ingested-wt of feces (mg) x 100

Amount of food digested = wt of food ingested (mg) - wt of feces (mg)

4.11 Histological study of the gastrointestinal tract and determination of Amylase activity

Oryza sativa leaves treated with 100mgml^{-1} concentration of methanol extract of *A. conyzoides* were fed to adults of same stage. The gastrointestinal tract was dissected out from the live insects after feeding for 24 hours and fixed in 10% formalin till use. Control insects were fed only with leaves treated with methanol only. Histological preparation was carried out by routine paraffin embedding technique and 8μ thick sections were cut in the microtome for microscopic studies. The sections were stained in Mallory's Triple stain (Pantin, 1946).

Adult insects were fed on leaves treated with methanol and aqueous (100mgml^{-1}) extract of *A. conyzoides* as well as Precocene I (10μgml^{-1}) and II (2mgml^{-1}) dissolved in methanol and were allowed to feed for 24hrs. The alimentary canals of the insects were dissected out in an ice-cold petridish. The tissues were weighed and 10% homogenate was prepared with acetate buffer (0.05M at pH 5.7). The homogenate was centrifuged for 15 minutes at 2500g. The supernatant was used as amylase enzyme source.

Assay of amylase activity was based on the method of Noelting and Bernfeld (1948), using a modified 3, 5 - dinitrosalicylic acid reagent. The reaction mixture consisted of 50 μl of acetate buffer (0.05M), 100 μl 1% starch in buffer, and 50 μl of enzyme solution that made the final volume to 200 μl. After every 5 minutes of incubation at 37^{0}C, enzyme activity was terminated by the addition of 0.8ml of the above reagent. The reaction mixture was heated for 5 minutes at 100^{0}C, cooled in tap water and diluted with 0.4 ml distilled water. The amylolytic activity was determined as OD units x 10^3 at 550 nm using Beckman DU® 640 Spectrophotometer in three replicates.

4.12 Testicular cell cycle development

Glass slides were cleaned and made grease free, a thin film of Mayer's albumin was applied and dried. 3-4 loops of testes from grasshoppers fed with leaves of host plant treated with the 100 $mgml^{-1}$ extracts of *Ageratum conyzoides* were taken on the slides and few drops of 45% acetic acid was dropped on the materials and left to fix for 5-15 minutes. The slides were then stained by acetocarmine for 15-30 minutes. The materials were covered by cover slips and hand thumb squashed. The squashed materials were observed under light microscope for different stages of the cell cycle.

RESULT

4.13 Host plant selection

Oxya hyla possessed a wide range of host plants for food. It was found that plants of Poaceae (Gramineae) family were the most widely accepted. Table 4.1 showed the choice and host specificity by the insect. The poaceae plants were attacked and easily eaten by the insects in natural conditions. But in some weeds, touching only was observed but no attacking and feeding were observed. Among the chosen host plants, *Oryza sativa* was consumed in maximum, though others were also consumed in high amount but lesser than paddy leaves (*Oryza sativa*). The acceptance and rejection of food by insects was due to the chemical compositions present on them and physical characteristics which may either stimulate or disrupt the normal activity of the insect.

4.14 Nutritional selection and feeding indices

Nutritional selection and feeding indices of nymphal stages IV, V, VI, male and female adults of *Oxya hyla* had greatly reduced their efficiency after treatment of the food plants with the extracts of *A. conyzoides* as was shown in the Tables 4.2-4.9. Significant effect was observed in all the concentrations (50, 100 & 200 $mgml^{-1}$) used. Leaves of *Arundina khasiana* (Table 4.2) treated with aqueous extract, showed a significant reduction in consumption rate, growth rate, digestibility and conversion efficiencies of ingested and digested food to body substance by the insects. Similar results were obtained with *Imperata cylindrica* (Table 4.4), *Ipomoea batatas* (Table 4.6) and *O. sativa* (Table 4.8) that significantly disrupted the normal functioning of food processing in insects. It was also found that high protection of *O. sativa* was observed though in fact it was the most favorable food plant in comparison to *A. khasiana, I. cylindrica and I. batatas*.

Indices of consumption, growth, approximate digestibility and conversion efficiencies of insects were much more affected by methanol extract of *A. conyzoides*. Some of the observations obtained were negative, which indicated that, the consumption and metabolic activity of insects were totally shut down by the plant compounds present in the extract. In *A. khasiana* (Table 4.3) negative values were obtained at higher concentrations of the extracts. The effect was very significant in all the concentrations applied when compared to the control values. Treated host plant *I. cylindrica* (Table 4.5), *I. batatas* (Table 4.7) and *O. sativa* (Table 4.9) showed similar results against the same parameters of the insects. At 200mgml^{-1} concentration it was shown that no consumption, digestion and conversion of ingested food to body substance as well as conversion of digested food to body substance in some host plant were observed in all the insects treated. The effects of the extracts were obtained to be very high and ultimately resulting into paralysis and death of the insects by disrupting the vital processes of insects.

Nutritional and feeding deterrence analyses of nymphal stage III of *Oxya hyla* showed that the compound Precocene I and II possessed feeding deterrence activity (Table 4.10a & b). These compounds significantly reduced consumption rate, growth rate (GR) and conversion efficiencies. Decrease in GR, CR, ECI and ECD values were in concentration dependent manner. In addition the values of GR, ECI and ECD were negative at concentration of 20 μgmml^{-1} of Precocene I (Table 4.10a). Precocene I and II decreased the growth rate at all the concentrations tested. There was obvious decrease in food utilization obtained (ECI and ECD) in the nymphs at the concentrations tested, although the decrease of CI, AD, ECI and ECD was not statistically significant in Precocene II (Table 4.10b).

4.15 Effect of the extracts on Amylase activity and histology of gastrointestinal epithelial cells

The extract was also found to affect the activity of amylase, the active enzyme of carbohydrate digestion. The effect was less significant on both the extracts applied at 100 $mgml^{-1}$ concentration (Figure 4.1A). No significant effect was obtained on amylase activity due to treatment with precocene I and II (Figure 4.1B).

Microtomy study showed the epithelial cells of the gut swelled up and finally burst into pieces in insects fed on leaves of *Oryza sativa* after treatment with the plant extracts. Figures 4.2 and 4.3 showed the epithelial cells of mid gut and crop (gizzard) increased in size and finally got damaged. Epithelial cells of the gut in the other hand were normal in control insects as shown in Figure 4.4.

4.16 Effect of *A. conyzoides* extract on testicular cell cycle development

The sub stages like Leptotene, Zygotene, Pachytene, Diplotene and Diakinesis and other stages like Metaphase I, Anaphase I, Metaphase II, Anaphase II and Telophase were examined against the effect of the extract. Methanol extract ($100mgml^{-1}$) was found to slow down and even stopped cell division and chromosomal separation (Table 4.11). In this study it was observed that after treatment testis development was disrupted. The division may proceed one or two more stages before stopping. Late stages of meiotic divisions were not recorded, in the study due to total inhibition of cell division by the extract. Only the existing divisional stage on the time of treatment can pass on to the next before it stops and no further division was observed. Cell division in controls was observed to be normal.

DISCUSSION

Selection of a host plant by *O. hyla* is random which involves both olfactory and visual elements of behaviour. Olfactory signal arouses the insect, causing it to move towards or away the source of odor, either by flying or walking. Visual cues are then used to enhance or initiate the accuracy of locating the host plant, as well as enabling the insect to land on the host target. Hence in natural environment the use of the two main sensory modalities, vision and olfaction, enhances their ability to find a host plant.

Finally, the size and shape of the plants play a critical role in host plant finding (Rojas and Wyatt, 1999; Harris et al. 1993). It is also observed the scavenging role that *O. hyla* play by feeding on dead insects or weaker ones.

Many factors are involved in the determination of food selection of *O. hyla*. Such factors include plant chemistry, predictability of the food plant in time and space, phylogenetic constraints, nutrient quality and distribution within plant (Bernays and Chapman, 1978). Secondary plant compounds have been shown to have a great influence over host plant selection through either deterrence or stimulation (Bernays and Chapman, 1978).

Consumption and food digestion rate depend on many parameters. It is observed that if the amount of excreta ejected is high, then the amount of digested food is very less. Further, if the food consumed is more, and the digested food is less, it resulted in less AD values. The high value of ECD is obtained because of very less amount of digested food this is to efficiently convert the existed digested food to body substance to compensate the body requirements of the insects. Less value of AD is due to low amount of food digested, however food consumption is high. If the amount of excreta ejected is more than the amount of food consumed, the AD value is zero or negative. Again if ECI value is high, there is high GR. GR is less because of the low value of ECI, but CI value is more, this is due to the amount of food consumed is ejected out as excreta in almost equal amount, which results to small values of digested food as well. The weight gain or growth of the insects depends on food consumption and amount of food digested. If food consumption and digestion increased then weight gain and growth of the insects are also increased and vice versa. The amount of food which get digested by the insects depends on amount of food consumed and ejected, if food consumption is high and food ejected is also high resulting to low growth rate and loss of weight. Further, when amount of food consumed is high but food ejected is less, this results in high growth rate and insect weight gain.

Food utilization efficiencies contribute to an understanding of nutritional ecology including consumers adaptations to different foods, that help in developing sound pest management strategies (Ferrar et al. 1989). To compare the performance rate among the individuals of different sizes and ages and to better assess the impact of food quality on individual performance, relative consumption rate (RCR/CI), relative growth rate (RGR/GR). In most insects, CR and GR tend to decline as the instars progress (Slansky and Scriber, 1985). The factors influencing food consumption and assimilation rate also influence energy allocation to respiration. An increase in respiration due to processing of the food in the alimentary canal would reduce the growth. A relative low growth despite highest consumption may be due to high expenditure of respiration energy. The high CR and GR are related to lower expenditure of metabolizable energy on respiration because of a lower concentration of the allochemics and comparatively good quality of basic nutrients (Mukhopadhyay and Saha, 1993).

Food intake might be offset by high digestibility or vice versa, poor digestibility might be offset by the efficient utilization of digested food or vice versa.

ECD will decrease as the proportion of digested food metabolizes for energy increases. Thus ECD is affected by factors which influence the amount of energy devoted to the maintenance of physiological functions. ECD is not directly dependent upon digestibility, but it does vary with the level of nutrient intake. The proportion of food available for growth will decrease as intake decreases, and ECD also varies with the nutritional values of the food.

Utilization varies quantitatively from instars to instars and within instars (Fewkes, 1960). The rate of food intake appears to increase with decreases in the nutrient level of the diet (House, 1965b; McGinnis and Kasting, 1966) and correspondingly increasing amount of water. Total fresh weight consumption increased with the dilution of the nutrients. The efficiency of food utilization by the early instars is certainly of interest. The nutritional adequacy of a food can be judged only by its ability to support the growth of successive generations (Gordon, 1959). Utilization efficiency also varies with temperature, relative humidity and other physical factors (Waldbauer, 1964; Soo Hoo and Fraenkel, 1966).

High AD is compensated by low ECD, thus the comparatively high ECD suggest specific adaptations to the nutrient balances offered by their natural foods, The low ECD suggests a less precise correspondence between its requirements and the nutrient balance and its diet. Perhaps the high AD is an adaptation, which compensates for a decrease in the efficiency of conversion resulting from moderate nutritional imbalances.

It is clear that among the phytophagous insects digestibility and efficiency of conversion vary widely with the species of food plant (Waldbauer, 1964; Soo Hoo and Fraenkel, 1966). The changes in the physical or biotic environment may have significant effect on consumption, digestibility or the efficiency of food conversion (Legay, 1957). The amount of food consumed and the efficiency of its utilization may vary with the degree of crowding, that means the consumption and even molting is higher in crowded condition than in isolated condition (Davey, 1954; Norris, 1961; Long, 1953).

The two compounds Precocene I and II are toxic to nymphs of *O. hyla*. The compounds as well as the extracts of *A. conyzoides* have strong insecticidal and antifeedant properties. They exhibit deterrent activities not only in consumption rate, growth rate, but efficiency of food conversion as well. When nymphs fed on the leaves treated with precocene I and II, they consumed less amount of food or stop feeding at once. Both less food consumption and lower efficiency of food utilization contributed to the growth inhibition. The phenomena mean that although the insects can take some treated food, they can hardly utilize it as nutrient for their bodies and population increase. To maintain their life, they have to use stored energy, which leads to the negative value of GR (Berenbaum and Rosenthal, 1992; Rosenthal and Berenbaum, 1991).

Insects that experience reduced ECD due to increased respiratory costs may be able to compensate by increasing consumption rates or digestion efficiencies (AD). Not all changes are homeostatic, however. For instance, many insects increase food consumption rates in response to low concentrations of critical nutrients such as protein. Increased consumption will accelerate passage of food through the gut and thereby reduce AD. Other nonhomeostatic changes in efficiency values may occur in response to plant allelochemicals. For example, compensatory feeding to increase intake of a limiting nutrient may simultaneously increase exposure to plant toxins, which in turn may reduce ECD. However, it can be quite difficult to ascertain "cause" and "effect" responses with efficiency parameters. Does the insect eat more because digestibility is low, or is digestibility low because the insect is eating more? Efficiency parameters are so closely physiologically related that determination of "cause" and "effect" is not a trivial matter.

Intraspecific variation in food conversion efficiencies may also be related to insect development. AD generally decreases, whereas ECD increases, from early to late instars. In other words older larvae digest their food less completely, but that which they do digest is more efficiently utilized for growth. Factors contributing to such changes are still largely unknown, but may include shifts in food selection, digestive physiology, metabolic rates, and body composition.

The amylase activity decreased gradually with the increase of extract concentration as observed by Ascher and Ishaaya, 1973. The effect on the digestive enzymes is most marked when starved insects are fed with treated leaves. A significant reduction in amylase activity is obtained this could be the main cause of antifeedant effect of the extract. The amylase activity recovers fully after the insects are transferred to control leaves (Ascher and Ishaaya, 1973).

The epithelial cells lining the gut wall or crop became swollen up gradually, ultimately resulting to bursting of the swollen cells, this may be because the compounds that are present in the extract are toxic to the cells of insects in the gut.

The testicular cell cycle in adults has been disturbed by the action of the plant extracts as seen in the sub stages of Prophase I of testis development, where development stopped at certain stages after treatment. Cell division in most of the treated insects stopped at Diakinesis stage where no further development is observed. The extracts may also affect chromosomal separation, pairing, crossing over and disrupt the microtubules condensation.

CONCLUSION

Plants like *Ageratum conyzoides* contain a virtually untapped reservoir of insecticides that can be used directly or as templates for synthetic insecticides. Numerous factors have increased the interest of the insecticides industry and the insecticides market in this source of natural products as insecticides. These include diminishing returns with traditional insecticide discovery methods, increased environmental and toxicological concerns with synthetic insecticides, and the high level of reliance of modern agriculture on natural insecticides. Despite the relatively small amount of previous effort in development of plant-derived compounds as insecticides, they have made a significant impact in the field of Integrated Pest Management. The number of options that must be considered in discovery and development of a natural product as an insecticide is larger than for a synthetic insecticide. Furthermore, the molecular complexity limited environmental stability, and low activity of many biocides from plants, compared to synthetic insecticides, is discouraging. However, advances in chemical and biotechnology are increasing the speed and ease with which man can discover and develop secondary compounds of plants as insecticides. These advances, combined with increasing need and environmental pressure, are greatly increasing the interest in plant products as insecticides.

More understanding as to how these compounds affect organisms on various ecological processes and the potential for eco-friendly products to control pest is enormous. Further research in this field should expand out of the laboratory into the real world. In this way these novel products can be evaluated as viable alternatives to the persistent, less environmentally friendly products.

Table 4.1 Choice of food by the III instar nymphs of *Oxya hyla* in normal laboratory conditions

Host plant	Touching	Attacking	Feeding
Arundina khasiana	++	++	++
Imperata cylindrica	++	++	++
Ipomoea batatas	+	+	+
Oryza sativa	+++	+++	+++
Ageratum conyzoides	+	-	-
Artemisia nilagarica	+	-	-
Eupatorium adenophorum	+	-	-
Eupatorium riparium	+	-	-
Lantana camara	+	-	-

+ : Less response
++ : High response
+++ : Highest response
- : No response

Table 4.2 Nutritional selection, feeding deterrence indices and conversion efficiencies of different instars of *Oxya hyla* on *Arundina khasiana* host plant treated with aqueous extract of *Ageratum conyzoides* measured on wet weight basis at 18-20°C temperature and 70-80% humidity. [a]

Stage	Conc $mgml^{-1}$	GR (mg/mg/day wet- wt)	CI (mg/mg/day wet- wt)	AD (%)	ECI (%)	ECD (%)	N
IV	50	6.56±1.81 (4.67±0.57)	44.40±1.27[b] (78.10±1.69)	67.11±1.78 (78.98±0.88)	14.77±3.65 (5.97±0.60)	22.02±6.05 (7.56±0.84)	(3)
V	50	4.07±1.88[b] (12.89±1.59)	40.87±9.09[b] (83.80±18.71)	63.47±1.12[c] (84.68±3.06)	9.95±4.01 (16.31±2.29)	24.78±13.05 (19.30±2.79)	(3)
VI	50	4.52±1.80 (10.18±2.89)	77.65±8.30 (63.97±12.75)	71.89±2.23 (76.12±5.69)	5.82±1.76[b] (20.02±7.38)	7.55±2.68[b] (28.34±11.58)	(3)
♂	50	7.37±3.56 (8.88±0.11)	50.60±5.22[d] (215.92±36.49)	52.68±2.45[c] (84.35±3.55)	14.56±5.72 (4.22±0.66)	26.00±12.07 (4.98±0.57)	(3)
♀	50	8.96±1.82 (12.56±4.70)	38.98±1.63[c] (85.89±32.21)	30.31±0.13[d] (62.64±5.35)	22.98±3.73 (14.62±0.57)	67.24±8.02 (23.44±1.46)	(3)
IV	100	9.33±0.25 (4.67±0.57)	42.69±3.67[b] (78.10±1.69)	47.24±4.99[b] (78.98±0.88)	21.85±2.30 (5.97±0.60)	47.48±4.55[b] (7.56±0.84)	(3)
V	100	9.08±3.02 (12.89±1.59)	69.14±12.04 (83.80±18.71)	60.77±14.24 (84.68±3.06)	13.13±5.84 (16.31±2.29)	32.88±20.66 (19.30±2.79)	(3)
VI	100	8.13±0.04[b] (10.18±2.89)	78.20±16.16 (63.97±12.75)	74.47±3.58 (76.12±5.69)	10.39±2.19 (20.02±7.38)	14.46±2.25 (28.34±11.58)	(3)
♂	100	6.99±0.24 (8.88±0.11)	65.98±2.41[b] (215.92±36.49)	48.12±2.97 (84.35±3.55)	10.59±0.75 (4.22±0.66)	22.25±2.93 (4.98±0.57)	(3)
♀	100	12.99±4.30 (12.56±4.70)	57.36±4.13 (85.89±32.21)	21.59±1.08[b] (62.64±5.35)	22.21±5.89 (14.62±0.57)	81.90±2.18 (23.44±1.46)	(3)
IV	200	3.93±0.58 (4.67±0.57)	41.54±22.67 (78.10±1.69)	63.90±16.30 (78.98±0.88)	17.54±7.75 (5.97±0.60)	36.32±18.46 (7.56±0.84)	(3)
V	200	4.27±1.57[b] (12.89±1.59)	27.71±8.57[b] (83.80±18.71)	60.00±15.23 (84.68±3.06)	28.99±14.63 (16.31±2.290	36.91±15.05 (19.30±2.79)	(3)
VI	200	7.19±0.37 (10.18±2.89)	52.83±5.99 (63.97±12.75)	71.29±5.98 (76.12±5.69)	13.70±0.85 (20.02±7.38)	19.26±0.42[b] (28.34±11.58)	(3)
♂	200	6.53±0.25 (8.88±0.11)	47.27±2.39[c] (215.92±36.49)	52.82±6.77 (84.35±3.55)	13.81±0.16 (4.22±0.66)	26.59±3.10 (4.98±0.57)	(3)
♀	200	7.71±3.20 (12.56±4.70)	36.30±3.09[c] (85.89±32.21)	40.83±2.73[b] (62.64±5.35)	21.24±10.86 (14.62±0.57)	54.26±22.96 (23.44±1.46)	(3)

[a] Means (± SE) are statistically analyzed using Parametric Test One-Way ANOVA, [b, c & d] Values are significantly different from the control (Parametric t-Test for Two sided Paired comparison) at $P<0.05$, 0.01& 0.001. Figures in parentheses represent the control. N: Number of observations.

Table 4.3 Nutritional selection, feeding deterrence indices and conversion efficiencies of different instars of *Oxya hyla* on *Arundina khasiana* host plant treated with methanol extract of *Ageratum conyzoides* measured on wet weight basis at 18-20°C temperature and 70-80% humidity. [a]

Stage	Conc mgml^{-1}	GR (mg/mg/day wet- wt)	CI (mg/mg/day wet- wt)	AD (%)	ECI (%)	ECD (%)	N
IV	50	5.38±1.73	14.53±1.48[d]	72.32±5.67	37.02±8.36	51.38±15.59	(3)
		(4.67±0.57)	(78.10±1.69)	(78.98±0.88)	(5.97±0.60)	(7.56±0.84)	
V	50	7.83±2.07	20.23±0.43[d]	63.10±1.19[c]	39.20±11.02	63.18±18.64	(3)
		(12.89±1.59)	(83.80±18.71)	(84.68±3.06)	(16.31±2.29)	(19.30±2.79)	
VI	50	7.34±1.17	19.53±3.70[c]	70.93±11.68	37.58±12.87	53.81±9.28	(3)
		(10.18±2.89)	(63.97±12.75)	(76.12±5.69)	(20.02±7.38)	(28.34±11.58)	
♂	50	4.44±1.45[b]	19.74±3.29[d]	39.10±4.71[d]	22.49±5.14[b]	58.72±18.51	(3)
		(8.88±0.11)	(215.92±36.49)	(84.35±3.55)	(4.22±0.66)	(4.98±0.57)	
♀	50	10.43±1.28	18.22±4.58[c]	66.67±13.23	57.24±17.26	82.27±7.81	(3)
		(12.56±4.70)	(85.89±32.21)	(62.64±5.35)	(14.62±0.57)	(23.44±1.46)	
IV	100	-3.45±0.01[d]	6.96±4.02[c]	29.45±17.00	-49.56±7.10	27.75±9.61	(3)
		(4.67±0.57)	(78.10±1.69)	(78.98±0.88)	(5.97±0.60)	(7.56±0.84)	
V	100	6.28±1.14[b]	12.70±0.43[d]	65.87±5.13	49.44±7.35	72.68±5.47	(3)
		(12.89±1.59)	(83.80±18.71)	(84.68±3.06)	(16.31±2.29)	(19.30±2.79)	
VI	100	2.17±2.60	10.60±3.29[c]	0.37±48.98	20.47±30.58	-37.84±26.65	(3)
		(10.18±2.89)	(63.97±12.75)	(76.12±5.69)	(20.02±7.38)	(28.34±11.58)	
♂	100	-4.72±1.21[c]	5.44±1.41[d]	-40.29±23.26[b]	-86.76±15.46	44.60±0.89	(3)
		(8.88±0.11)	(215.92±36.49)	(84.35±3.55)	(4.22±0.66)	(4.98±0.57)	
♀	100	-0.63±1.40[b]	4.57±0.60[d]	-76.33±6.75[c]	-13.78±12.99	13.32±9.45	(3)
		(12.56±4.70)	(85.89±32.21)	(62.64±5.35)	(14.62±0.57)	(23.44±1.46)	
IV	200	-1.46±1.99	76.35±36.55	18.83±10.87[b]	-1.91±3.74	31.56±1.73	(3)
		(4.67±0.57)	(78.10±1.69)	(78.98±0.88)	(5.97±0.60)	(7.56±0.84)	
V	200	0.30±1.63[b]	45.80±26.44	28.42±16.41	0.65±9.89	40.12±11.61	(3)
		(12.89±1.59)	(83.80±18.71)	(84.68±3.06)	(16.31±2.29)	(19.30±2.79)	
VI	200	-4.09±0.78[c]	-	-	-	-22.50±30.31	(3)
		(10.18±2.89)	(63.97±12.75)	(76.12±5.69)	(20.02±7.38)	(28.34±11.58)	
♂	200	-1.27±0.05[d]	-	-	-	34.61±11.10	(3)
		(8.88±0.11)	(215.92±36.49)	(84.35±3.55)	(4.22±0.66)	(4.98±0.57)	
♀	200	-8.14±0.91[c]	-	-	-	41.10±14.75	(3)
		(12.56±4.70)	(85.89±32.21)	(62.64±5.35)	(14.62±0.57)	(23.44±1.46)	

[a] Means (± SE) are statistically analyzed using Parametric Test One-Way ANOVA, [b, c & d] Values are significantly different from the control (Parametric t-Test for Two sided Paired comparison) at $P<0.05$, 0.01& 0.001 . Figures in parentheses represent the control. N: Number of observations.

Table 4.4 Nutritional selection, feeding deterrence indices and conversion efficiencies of different instars of *Oxya hyla* on *Imperata cylindrica* host plant treated with aqueous extract of *Ageratum conyzoides* measured on wet weight basis at 18-20°C temperature and 70-80% humidity. [a]

Stage	Conc mgml^{-1}	GR (mg/mg/day wet- wt)	CI (mg/mg/day wet- wt)	AD (%)	ECI (%)	ECD (%)	N
IV	50	2.02±0.08^b (6.33±3.18)	38.68±0.79^c (121.79±8.16)	67.83±1.24 (77.29±1.76)	5.22±0.31 (5.19±1.59)	7.71±0.32 (8.06±1.87)	(3)
V	50	5.70±2.42 (16.78±0.57)	38.62±15.37 (35.75±8.01)	67.36±0.41^c (97.65±0.39)	14.75±0.46^c (46.93±9.39)	21.98±0.89^b (38.25±21.35)	(3)
VI	50	2.91±0.83 (9.35±6.41)	64.16±11.18 (63.47±10.21)	90.56±1.40 (81.80±3.71)	4.53±0.51^b (14.73±15.66)	4.92±0.65^b (21.63±16.54)	(3)
♂	50	5.07±0.21^b (8.38±2.44)	59.83±3.19^b (214.60±39.70)	65.01±13.25 (80.24±1.23)	8.47±0.10 (3.90±0.43)	13.57±2.61 (4.77±0.60)	(3)
♀	50	1.45±0.98 (5.66±1.77)	28.52±2.35^b (94.49±15.05)	20.09±0.36^c (74.71±3.34)	5.08±3.90 (5.99±0.98)	37.21±29.44 (7.72±0.97)	(3)
IV	100	8.63±0.70 (6.33±3.18)	62.48±2.61^c (121.79±8.16)	64.14±4.33 (77.29±1.76)	13.92±1.54 (5.19±1.59)	21.66±1.82 (8.06±1.87)	(3)
V	100	8.34±2.48 (16.78±0.57)	78.98±12.86 (35.75±8.01)	66.90±5.14^b (97.65±0.39)	10.55±1.75^c (46.93±9.39)	15.45±3.47^b (38.25±21.35)	(3)
VI	100	7.10±0.94 (9.35±6.41)	43.80±5.86 (63.47±10.21)	39.11±8.74^b (81.80±3.71)	16.21±4.71 (14.73±15.66)	49.99±18.04 (21.63±16.54)	(3)
♂	100	4.09±0.03^c (8.38±2.44)	50.49±6.06^b (214.60±39.70)	49.05±1.49^b (80.24±1.23)	8.10±0.91 (3.90±0.43)	16.74±1.36 (4.77±0.60)	(3)
♀	100	2.92±2.12 (5.66±1.77)	45.26±16.36 (94.49±15.05)	64.87±4.68 (74.71±3.34)	5.47±2.70 (5.99±0.98)	8.78±4.80 (7.72±0.97)	(3)
IV	200	4.41±0.92 (6.33±3.18)	28.80±3.68^c (121.79±8.16)	80.33±3.17 (77.29±1.76)	15.31±1.62 (5.19±1.59)	18.84±2.63 (8.06±1.87)	(3)
V	200	6.50±1.90 (16.78±0.57)	43.00±3.20 (35.75±8.01)	56.34±0.08^c (97.65±0.39)	15.11±3.35 (46.93±9.39)	26.38±5.89 (38.25±21.35)	(3)
VI	200	3.10±0.06^c (9.35±6.41)	19.98±0.22^c (63.47±10.21)	34.60±6.56 (81.80±3.71)	15.51±0.15 (14.73±15.66)	46.47±8.38 (21.63±16.54)	(3)
♂	200	3.73±0.54^b (8.38±2.44)	44.60±3.83^d (214.60±39.70)	62.00±2.17^b (80.24±1.23)	8.36±0.66 (3.90±0.43)	13.48±1.58 (4.77±0.60)	(3)
♀	200	1.45±0.62^b (5.66±1.77)	27.94±5.37^c (94.49±15.05)	63.94±5.57 (74.71±3.34)	4.68±1.49 (5.99±0.98)	7.71±2.96 (7.72±0.97)	(3)

[a] Means (± SE) are statistically analyzed using Parametric Test One-Way ANOVA, [b,c&d] Values are significantly different from the control (Parametric t-Test for Two sided Paired comparison) at P<0.05, 0.01 & 0.001. Figures in parentheses represent the control. N: Number of observations.

Table 4.5 Nutritional selection, feeding deterrence indices and conversion efficiencies of different instars of *Oxya hyla* on *Imperata cylindrica* host plant treated with methanol extract of *Ageratum conyzoides* measured on wet weight basis at 18-20°C temperature and 70-80% humidity. [a]

Stage	Conc mgml^{-1}	GR (mg/mg/day wet- wt)	CI (mg/mg/day wet- wt)	AD (%)	ECI (%)	ECD (%)	N
IV	50	-5.40±0.51^b (6.33±3.18)	0.00±0.00 (121.79±8.16)	0.00±0.00^b (77.29±1.76)	0.00±0.00 (5.19±1.59)	85.18±6.92 (8.06±1.87)	(3)
V	50	-5.07±0.54^b (16.78±0.57)	6.97±0.23^c (35.75±8.01)	-78.49±1.50^c (97.65±0.39)	-72.74±5.39^b (46.93±9.39)	92.42±5.07 (38.25±21.35)	(3)
VI	50	-4.33±2.15 (9.35±6.41)	4.72±2.35 (63.47±10.21)	-4.89±84.89 (81.80±3.71)	-91.73±0.23^c (14.73±15.66)	-38.52±58.97 (21.63±16.54)	(3)
♂	50	3.14±11.67 (8.38±2.44)	3.69±1.35^c (214.60±39.70)	29.89±15.09 (80.24±1.23)	85.09±0.57 (3.90±0.43)	90.34±2.19 (4.77±0.60)	(3)
♀	50	6.55±2.42 (5.66±1.77)	7.27±2.38^d (94.49±15.05)	28.53±6.02^b (74.71±3.34)	90.09±6.08 (5.99±0.98)	40.69±9.09 (7.72±0.97)	(3)
IV	100	-5.46±0.36^b (6.33±3.18)	0.00±0.00 (121.79±8.16)	0.00±0.00 (77.29±1.76)	0.00±0.00 (5.19±1.59)	61.90±4.76 (8.06±1.87)	(3)
V	100	-2.20±0.69^b (16.78±0.57)	3.58±2.35^b (35.75±8.01)	-69.84±21.08 (97.65±0.39)	-61.45±9.53 (46.93±9.39)	4.16±2.49 (38.25±21.35)	(3)
VI	100	-0.36±0.09^d (9.35±6.41)	11.10±0.64^d (63.47±10.21)	33.72±19.46 (81.80±3.71)	-3.24±6.90^b (14.73±15.66)	-11.98±12.99 (21.63±16.54)	(3)
♂	100	-4.62±0.36^d (8.38±2.44)	8.97±1.71^c (214.60±39.70)	3.33±1.92^d (80.24±1.23)	-51.50±6.62 (3.90±0.43)	-65.89±5.25^c (4.77±0.60)	(3)
♀	100	-6.24±0.53^c (5.66±1.77)	14.80±0.82^d (94.49±15.05)	-39.36±22.72^b (74.71±3.34)	-42.16±18.9 (5.99±0.98)	50.44±21.16 (7.72±0.97)	(3)
IV	200	-1.57±0.77^c (6.33±3.18)	- (121.79±8.16)	- (77.29±1.76)	- (5.19±1.59)	50.87±10.13 (8.06±1.87)	(3)
V	200	-2.80±1.07^b (16.78±0.57)	- (35.75±8.01)	- (97.65±0.39)	- (46.93±9.39)	67.21±14.21 (38.25±21.35)	(3)
VI	200	-0.87±0.12^c (9.35±6.41)	1.25±0.09^d (63.47±10.21)	-78.90±13.68 (81.80±3.71)	-69.60±4.71^b (14.73±15.66)	86.66±6.66 (21.63±16.54)	(3)
♂	200	-3.32±0.73^c (8.38±2.44)	11.50±0.66^d (214.60±39.70)	41.12±23.74 (80.24±1.23)	-28.86±25.74 (3.90±0.43)	9.11±4.56 (4.77±0.60)	(3)
♀	200	-6.94±1.03^c (5.66±1.77)	9.29±1.89^d (94.49±15.05)	42.06±24.28 (74.71±3.34)	-74.70±9.17 (5.99±0.98)	8.26.33±4.34 (7.72±0.97)	(3)

[a] Means (± SE) are statistically analyzed using Parametric Test One-Way ANOVA, [b, c & d] Values are significantly different from the control (Parametric t-Test for Two sided Paired comparison) at P<0.05, 0.01& 0.001. Figures in parentheses represent the control. N: Number of observations.

Table 4.6 Nutritional selection, feeding deterrence indices and conversion efficiencies of different instars of *Oxya hyla* on *Ipomoea batatas* host plant treated with aqueous extract of *Ageratum conyzoides* measured on wet weight basis at 18-20°C temperature and 70-80% humidity. [a]

Stage	Conc mgml^{-1}	GR (mg/mg/day wet- wt)	CI (mg/mg/day wet- wt)	AD (%)	ECI (%)	ECD (%)	N
IV	50	-1.68±0.11[b] (0.30±0.07)	6.72±0.67 (11.57±1.12)	45.33±25.33 (95.83±0.83)	-25.00±6.65 (2.59±0.39)	9.31±4.02 (2.72±0.42)	(3)
V	50	-2.14±7.68 (0.24±0.06)	3.30±0.30 (26.80±2.32)	46.15±5.00 (52.75±5.25)	-64.84±3.44 (0.89±0.46)	34.16±7.50 (36.39±3.26)	(3)
VI	50	-1.27±1.79 (2.11±0.11)	4.96±4.45 (5.13±0.17)	47.22±27.28 (70.69±24.03)	-25.60±5.76 (41.13±18.11)	2.94±0.96 (34.36±29.92)	(3)
♂	50	-1.36±2.69 (3.23±0.02)	2.74±0.02 (5.32±0.63)	42.50±12.57 (65.38±3.84)	-49.63±22.59 (60.71±7.67)	16.91±8.08 (60.41±27.08)	(3)
♀	50	-8.86±0.88 (0.95±0.74)	8.96±5.65 (5.33±0.81)	44.23±17.23 (68.12±13.12)	-98.88±8.37 (17.82±16.98)	-19.42±32.75 (26.25±19.89)	(3)
IV	100	-7.53±1.94 (0.30±0.07)	8.89±6.19 (11.57±1.12)	71.91±0.49[b] (95.83±0.83)	-84.70±1.44 (2.59±0.39)	-14.75±1.90 (2.72±0.42)	(3)
V	100	-8.91±5.43 (0.24±0.06)	30.16±2.26 (26.80±2.32)	48.78±21.86 (52.75±5.25)	-29.54±7.46 (0.89±0.46)	-27.80±10.65 (36.39±3.26)	(3)
VI	100	-4.02±0.77 (2.11±0.11)	5.86±0.60 (5.13±0.17)	41.66±11.76 (70.69±24.03)	-68.60±20.54 (41.13±18.11)	-30.00±8.00 (34.36±29.92)	(3)
♂	100	-9.58±2.05 (3.23±0.02)	12.35±5.10 (5.32±0.63)	38.18±15.18 (65.38±3.84)	-77.57±6.47 (60.71±7.67)	0.59±9.40 (60.41±27.08)	(3)
♀	100	-2.43±1.16 (0.95±0.74)	3.95±3.90 (5.33±0.81)	41.13±9.93 (68.12±13.12)	-61.52±3.82 (17.82±16.98)	18.63±9.69 (26.25±19.89)	(3)
IV	200	-2.93±15.25 (0.30±0.07)	7.89±1.34 (11.57±1.12)	86.58±0.51[b] (95.83±0.83)	-37.13±13.33 (2.59±0.39)	-41.63±15.15 (2.72±0.42)	(3)
V	200	-2.48±3.04 (0.24±0.06)	5.28±3.79 (26.80±2.32)	70.38±16.41 (52.75±5.25)	-46.96±2.99[b] (0.89±0.46)	-56.83±9.01 (36.39±3.26)	(3)
VI	200	-10.30±10.30 (2.11±0.11)	13.90±0.75 (5.13±0.17)	31.25±6.25 (70.69±24.03)	-74.10±22.15 (41.13±18.11)	-16.66±6.36 (34.36±29.92)	(3)
♂	200	-4.69±3.43 (3.23±0.02)	22.84±2.63 (5.32±0.63)	50.22±14.22 (65.38±3.84)	-20.53±15.13 (60.71±7.67)	-92.39±4.16 (60.41±27.08)	(3)
♀	200	-19.95±0.65[b] (0.95±0.74)	29.49±0.60 (5.33±0.81)	92.23±0.15 (68.12±13.12)	-67.65±3.59[b] (17.82±16.98)	-73.41±4.00[b] (26.25±19.89)	(3)

[a] Means (± SE) are statistically analyzed using Parametric Test One-Way ANOVA, [b] Values are significantly different from the control (Parametric t-Test for Two sided Paired comparison) at $P<0.05$,. Figures in parentheses represent the control. **N**: Number of observations

Table 4.7 Nutritional selection, feeding deterrence indices and conversion efficiencies of different instars of *Oxya hyla* on *Ipomoea batatas* host plant treated with methanol extract of *Ageratum conyzoides* measured on wet weight basis at 18-20°C temperature and 70-80% humidity. [a]

Stage	Conc mgml^{-1}	GR (mg/mg/day wet- wt)	CI (mg/mg/day wet- wt)	AD (%)	ECI (%)	ECD (%)	N
IV	50	-6.32±0.89 (0.30±0.07)	8.46±4.70^{d} (11.57±1.12)	46.66±27.66 (95.83±0.83)	-74.70±0.5^{d} (2.59±0.39)	22.50±7.50 (2.72±0.42)	(3)
V	50	-2.14±0.59 (0.24±0.06)	3.40±0.34 (26.80±2.32)	35.71±5.71 (52.75±5.25)	-62.94±9.97 (0.89±0.46)	0.33±0.33 (36.39±3.26)	(3)
VI	50	-1.64±0.16^{c} (2.11±0.11)	7.13±3.56 (5.13±0.17)	46.15±23.07 (70.69±24.03)	-23.00±4.61^{b} (41.13±18.11)	8.88±2.88 (34.36±29.92)	(3)
♂	50	-1.39±0.40^{b} (3.23±0.02)	1.44±0.72^{b} (5.32±0.63)	26.66±13.33 (65.38±3.84)	-96.52±13.76 (60.71±7.67)	5.78±2.78 (60.41±27.08)	(3)
♀	50	-8.81±1.06 (0.95±0.74)	10.09±0.82 (5.33±0.81)	90.78±2.54 (68.12±13.12)	-87.31±12.42 (17.82±16.98)	-25.59±7.73 (26.25±19.89)	(3)
IV	100	-4.55±0.48 (0.30±0.07)	7.94±0.37 (11.57±1.12)	58.33±11.67 (95.83±0.83)	-57.30±8.73 (2.59±0.39)	-32.14±17.85 (2.72±0.42)	(3)
V	100	-3.54±1.96 (0.24±0.06)	- (26.80±2.32)	- (52.75±5.25)	- (0.89±0.46)	72.78±12.78 (36.39±3.26)	(3)
VI	100	-3.03±0.66 (2.11±0.11)	- (5.13±0.17)	- (70.69±24.03)	- (41.13±18.11)	14.44±8.89 (34.36±29.92)	(3)
♂	100	-2.58±0.13^{b} (3.23±0.02)	3.07±2.07 (5.32±0.63)	47.00±18.79 (65.38±3.84)	-84.04±23.47 (60.71±7.67)	7.98±2.58 (60.41±27.08)	(3)
♀	100	-2.98±2.55 (0.95±0.74)	3.45±1.63 (5.33±0.81)	38.75±15.68 (68.12±13.12)	-86.37±11.37 (17.82±16.98)	-7.48±3.48 (26.25±19.89)	(3)
IV	200	-4.60±0.77 (0.30±0.07)	- (11.57±1.12)	- (95.83±0.83)	- (2.59±0.39)	55.00±5.00 (2.72±0.42)	(3)
V	200	-1.10±0.06^{b} (0.24±0.06)	1.30±0.25^{b} (26.80±2.32)	25.00±5.00 (52.75±5.25)	-84.61±33.40 (0.89±0.46)	-4.48±0.85 (36.39±3.26)	(3)
VI	200	-2.07±0.68 (2.11±0.11)	- (5.13±0.17)	- (70.69±24.03)	- (41.13±18.11)	64.28±7.14 (34.36±29.92)	(3)
♂	200	-1.30±1.50^{b} (3.23±0.02)	6.10±4.10 (5.32±0.63)	8.33±5.36 (65.38±3.84)	-21.31±38.92 (60.71±7.67)	50.81±25.27 (60.41±27.08)	(3)
♀	200	-1.49±0.46 (0.95±0.74)	- (5.33±0.81)	- (68.12±13.12)	- (17.82±16.98)	26.07±6.07 (26.25±19.89)	(3)

[a] Means (± SE) are statistically analyzed using Parametric Test One-Way ANOVA, [b, c & d] Values are significantly different from the control (Parametric t-Test for Two sided Paired comparison) at $P<0.05$, 0.01 & 0.001. Figures in parentheses represent the control. N: Number of observations.

Table 4.8 Nutritional selection, feeding deterrence indices and conversion efficiencies of different instars of *Oxya hyla* on *Oryza sativa* host plant treated with aqueous extract of *Ageratum conyzoides* measured on wet weight basis at 18-20°C temperature and 70-80% humidity. [a]

Stage	Conc $mgml^{-1}$	GR (mg/mg/day wet- wt)	CI (mg/mg/day wet- wt)	AD (%)	ECI (%)	ECD (%)	N
IV	50	13.32±1.98 (16.53±1.09)	32.57±6.28 (53.81±11.07)	66.62±8.38 (50.32±6.88)	40.89±14.39 (30.71±10.80)	69.89±18.77 (32.99±8.34)	(3)
V	50	12.34±2.24 (15.21±0.89)	47.43±5.97 (40.00±4.90)	68.89±5.52 (53.14±3.04)	26.01±7.50 (38.02±3.35)	42.69±13.53 (65.27±1.67)	(3)
VI	50	7.15±0.25^{c} (24.27±3.12)	15.21±2.14^{b} (86.78±20.15)	44.66±38.26 (65.02±7.72)	47.00±5.07 (27.96±5.48)	66.98±15.51 (49.17±13.22)	(3)
♂	50	7.22±3.75 (8.10±1.5)	27.38±2.41^{b} (156.67±11.70)	10.63±6.47 (78.05±3.18)	26.36±11.47 (5.17±0.34)	30.08±4.70 (6.51±0.60)	(3)
♀	50	20.70±1.69 (8.61±1.49)	25.25±0.08^{c} (70.15±0.25)	89.97±6.72 (86.80±3.33)	81.98±6.43 (12.27±2.08)	90.95±0.23 (14.06±1.86)	(3)
IV	100	4.49±0.60^{b} (16.53±1.09)	25.50±0.50^{b} (53.81±11.07)	60.90±0.01 (50.32±6.88)	17.60±1.98 (30.71±10.80)	28.82±3.28 (32.99±8.34)	(3)
V	100	2.81±1.39^{b} (15.21±0.89)	24.14±6.28 (40.00±4.90)	51.29±5.89 (53.14±3.04)	11.64±2.97^{b} (38.02±3.35)	19.82±4.56^{c} (65.27±1.67)	(3)
VI	100	4.02±0.43^{d} (24.27±3.12)	22.94±3.02^{c} (86.78±20.15)	39.59±8.94 (65.02±7.72)	17.52±2.89 (27.96±5.48)	47.49±5.29 (49.17±13.22)	(3)
♂	100	4.84±2.49 (8.10±1.5)	29.06±6.29^{b} (156.67±11.70)	46.00±1.00^{b} (78.05±3.18)	16.65±5.22 (5.17±0.34)	33.60±10.56 (6.51±0.60)	(3)
♀	100	3.74±1.14^{b} (8.61±1.49)	17.50±4.850 (70.15±0.25)	36.90±1.33^{b} (86.80±3.33)	21.37±0.64 (12.27±2.08)	57.62±3.78 (14.06±1.86)	(3)
IV	200	7.51±0.78^{c} (16.53±1.09)	25.76±3.65^{b} (53.81±11.07)	51.22±2.09 (50.32±6.88)	32.99±4.40 (30.71±10.80)	58.86±7.95 (32.99±8.34)	(3)
V	200	6.05±0.42^{c} (15.21±0.89)	17.30±3.43^{b} (40.00±4.90)	67.25±7.11 (53.14±3.04)	34.97±5.35 (38.02±3.35)	54.68±2.12 (65.27±1.67)	(3)
VI	200	8.65±1.56 (24.27±3.12)	22.11±1.88^{b} (86.78±20.15)	57.64±7.54 (65.02±7.72)	39.12±3.75 (27.96±5.48)	69.37±15.56 (49.17±13.22)	(3)
♂	200	7.55±2.88 (8.10±1.5)	24.64±3.25^{b} (156.67±11.70)	30.87±1.42^{b} (78.05±3.18)	30.64±7.80 (5.17±0.34)	73.65±5.87 (6.51±0.60)	(3)
♀	200	14.92±6.26 (8.61±1.49)	24.94±6.43 (70.15±0.25)	40.86±27.65 (86.80±3.33)	59.82±10.36 (12.27±2.08)	69.51±3.82 (14.06±1.86)	(3)

[a] Means (± SE) are statistically analyzed using Parametric Test One-Way ANOVA, [b,c&d] Values are significantly different from the control (Parametric t-Test for Two sided Paired comparison) at P<0.05, 0.01 & 0.001. Figures in parentheses represent the control. N: Number of observations.

Table 4.9 Nutritional selection, feeding deterrence indices and conversion efficiencies of different instars of *Oxya hyla* on *Oryza sativa* host plant treated with methanol extract of *Ageratum conyzoides* measured on wet weight basis at 18-20°C temperature and 70-80% humidity. [a]

Stage	Conc mgml^{-1}	GR (mg/mg/day wet-wt)	CI (mg/mg/day wet-wt)	AD (%)	ECI (%)	ECD (%)	N
IV	50	1.80±0.57 (16.53±1.09)	6.94±3.30^b (53.81±11.07)	-28.87±63.13^c (50.32±6.88)	25.93±78.45 (30.71±10.80)	39.97±10.70 (32.99±8.34)	(3)
V	50	-3.96±0.89^b (15.21±0.89)	5.67±0.09^b (40.00±4.90)	29.66±20.33 (53.14±3.04)	-69.84±16.84 (38.02±3.35)	-42.35±15.08 (65.27±1.67)	(3)
VI	50	0.15±0.90 (24.27±3.12)	10.89±2.18^b (86.78±20.15)	67.18±8.34 (65.02±7.72)	-1.37±1.64 (27.96±5.48)	-0.65±7.74 (49.17±13.22)	(3)
♂	50	4.40±2.18 (8.10±1.5)	14.12±1.97^c (156.67±11.70)	38.50±7.00^d (78.05±3.18)	31.16±11.31 (5.17±0.34)	73.97±15.84 (6.51±0.60)	(3)
♀	50	4.67±2.11^c (8.61±1.49)	13.38±1.55^b (70.15±0.25)	44.53±15.10 (86.80±3.33)	34.90±20.08 (12.27±2.08)	77.18±18.96 (14.06±1.86)	(3)
IV	100	-2.37±0.50^d (16.53±1.09)	2.75±0.75^b (53.81±11.07)	18.88±6.67 (50.32±6.88)	-86.18±7.75 (30.71±10.80)	-7.28±9.62 (32.99±8.34)	(3)
V	100	-1.76±1.44 (15.21±0.89)	9.82±0.33^c (40.00±4.90)	44.60±9.17 (53.14±3.04)	-17.92±14.11 (38.02±3.35)	-51.71±42.04 (65.27±1.67)	(3)
VI	100	-0.63±1.08^b (24.27±3.12)	8.44±3.39^b (86.78±20.15)	59.44±19.01 (65.02±7.72)	-7.46±18.92 (27.96±5.48)	-36.65±43.55 (49.17±13.22)	(3)
♂	100	2.29±1.11 (8.10±1.5)	8.06±2.87^b (156.67±11.70)	53.89±7.02 (78.05±3.18)	28.41±6.42 (5.17±0.34)	63.05±20.27 (6.51±0.60)	(3)
♀	100	6.87±1.16 (8.61±1.49)	15.02±1.14^b (70.15±0.25)	53.45±1.81^b (86.80±3.33)	45.73±4.29 (12.27±2.08)	86.79±3.13 (14.06±1.86)	(3)
IV	200	-6.66±3.67 (16.53±1.09)	- (53.81±11.07)	- (50.32±6.88)	- (30.71±10.80)	- (32.99±8.34)	(3)
V	200	-4.65±2.05 (15.21±0.89)	- (40.00±4.90)	- (53.14±3.04)	- (38.02±3.35)	- (65.27±1.67)	(3)
VI	200	-1.96±1.54^b (24.27±3.12)	- (86.78±20.15)	- (65.02±7.72)	- (27.96±5.48)	- (49.17±13.22)	(3)
♂	200	-1.81±0.87 (8.10±1.5)	- (156.67±11.70)	- (78.05±3.18)	- (5.17±0.34)	- (6.51±0.60)	(3)
♀	200	-2.76±1.76 (8.61±1.49)	- (70.15±0.25)	- (86.80±3.33)	- (12.27±2.08)	- (14.06±1.86)	(3)

[a] Means (± SE) are statistically analyzed using Parametric Test One-Way ANOVA, [b, c & d] Values are significantly different from the control (Parametric t-Test for Two sided Paired comparison) at $P<0.05$, 0.01 & 0.001. Figures in parentheses represent the control. N: Number of observations.

Table 4.10a Nutritional selection, feeding deterrence indices and conversion efficiencies of different instars of *Oxya hyla* on *Oryza sativa* host plant treated with Precocene I measured on wet weight basis at 18-20°C temperature and 70-80% humidity. [a]

Stage	Conc mgml^{-1}	GR (mg/mg/day wet- wt)	CI (mg/mg/day wet- wt)	AD (%)	ECI (%)	ECD (%)	N
III	10	0.76±0.85^c	5.68±4.51^b	62.62±33.21	13.38±4.88	14.34±5.65	(3)
		(17.63±2.35)	(68.11±9.94)	(70.52±5.55)	(25.88±1.48)	(27.04±3.83)	
III	20	-1.64±1.15^c	30.97±23.55	29.87±15.35	-5.29±2.47	-46.85±21.17	(3)
		(17.63±2.35)	(68.11±9.94)	(70.52±5.55)	(25.88±1.48)	(27.04±3.83)	

Table 4.10b Nutritional selection, feeding deterrence indices and conversion efficiencies of different instars of *Oxya hyla* on *Oryza sativa* host plant treated with Precocene II measured on wet weight basis at 18-20°C temperature and 70-80% humidity. [a]

Stage	Conc mgml^{-1}	GR (mg/mg/day wet- wt)	CI (mg/mg/day wet- wt)	AD (%)	ECI (%)	ECD (%)	N
III	1.0	2.34±0.40^b	26.70±15.31	56.04±26.86	8.76±5.25	21.49±0.87	(3)
		(17.63±2.35)	(68.11±9.94)	(70.52±5.55)	(25.88±1.48)	(27.04±3.83)	
III	2.0	4.11±0.72^b	44.57±25.73	40.81±9.19	9.22±10.40	33.27±18.00	(3)
		(17.63±2.35)	(68.11±9.94)	(70.52±5.55)	(25.88±1.48)	(27.04±3.83)	

[a] Means (± SE) are statistically analyzed using Parametric Test One-Way ANOVA, [b & c] Values are significantly different from the control (Parametric t-Test for Two sided Paired comparison) at P<0.05, 0.01 & 0.001. Figures in parentheses represent the control. N: Number of observations.

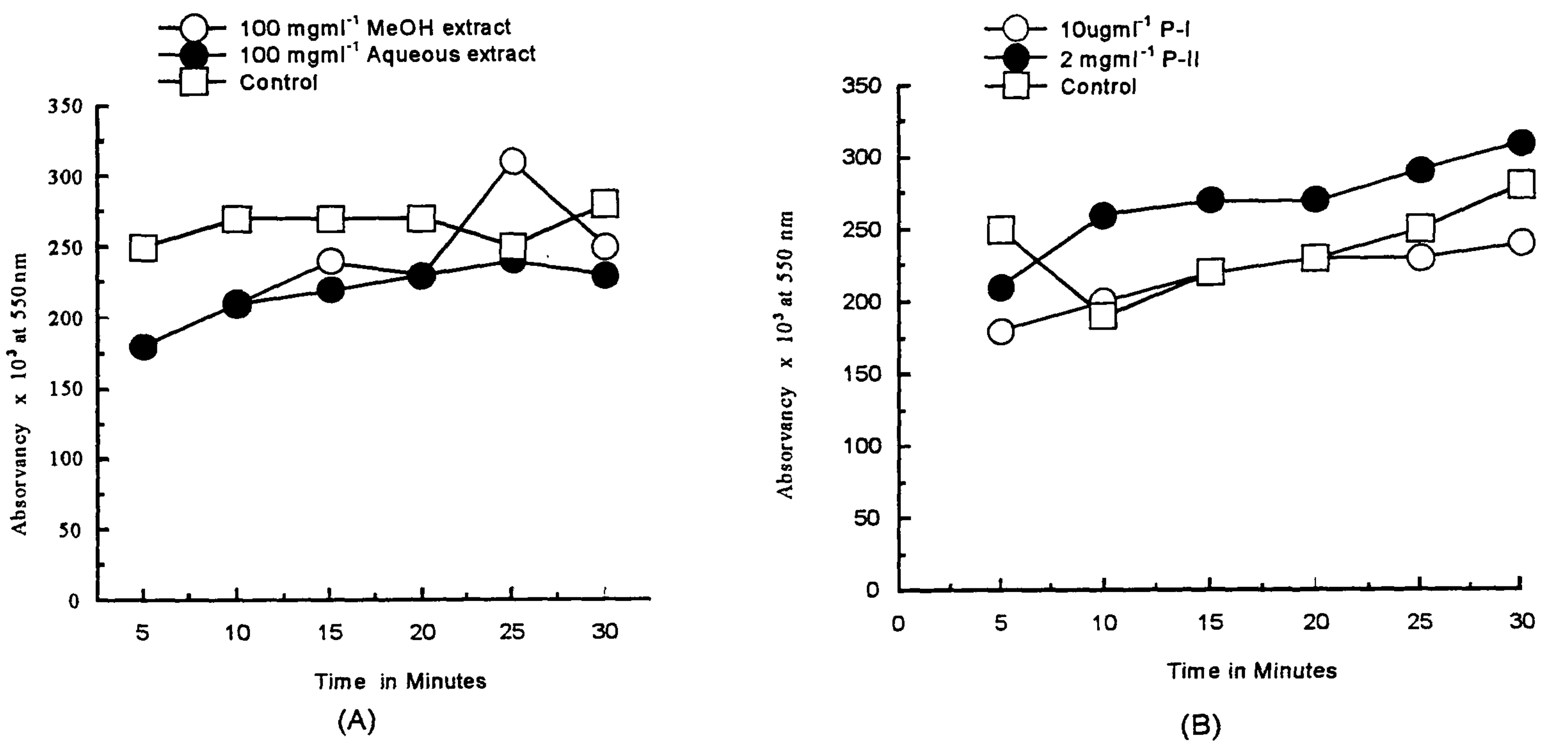
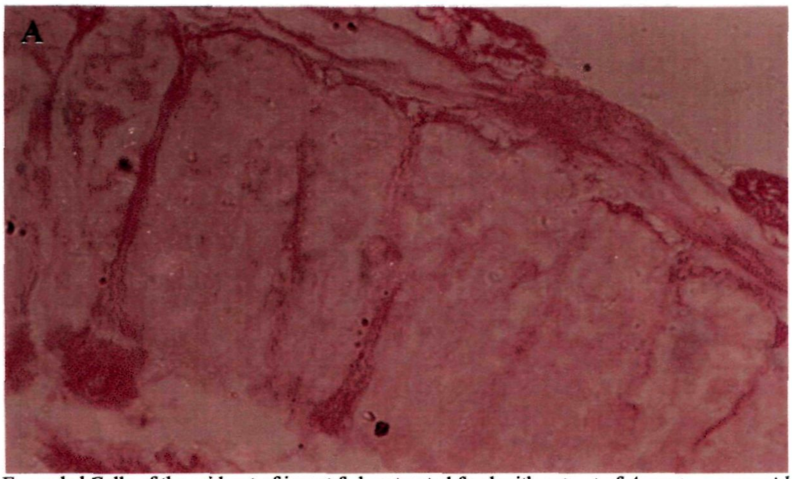
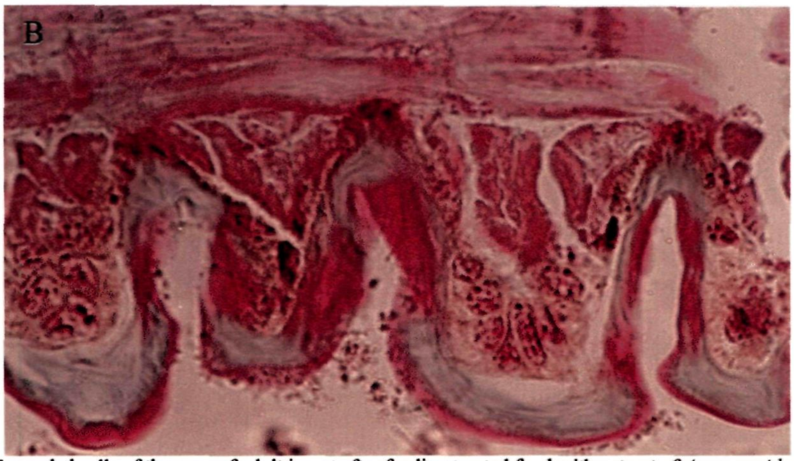


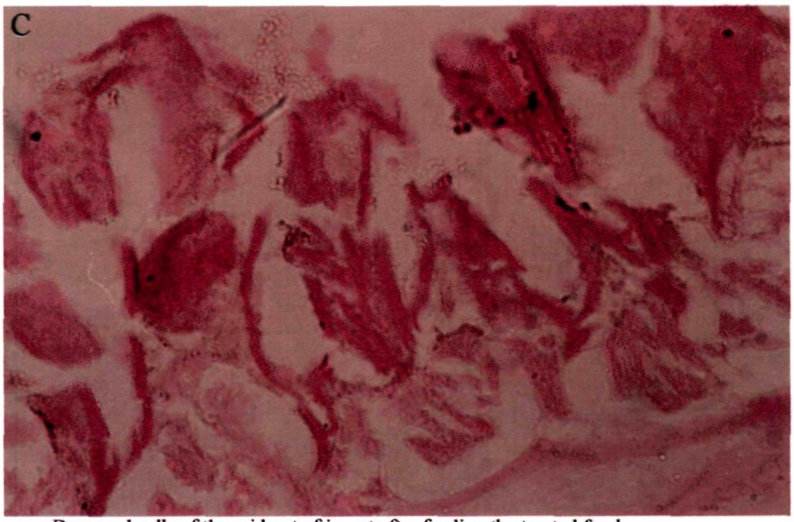
Figure 4.1 Effect of *Ageratum conyzoides* extracts (A) and Precocene I and II (B) on Amylase activity in adults' *Oxya hyla*



Expanded Cells of the mid gut of insect fed on treated food with extract of *Ageratum conyzoides*



Expanded cells of the crop of adult insect after feeding treated food with extract of *A. conyzoides*



Damaged cells of the mid gut of insect after feeding the treated food

Figure 4.2 Histological study of the gastrointestinal cells of adult *Oxya hyla* after feeding the treated food plant (*Oryza sativa*) with methanol extract of *A. conyzoides*.

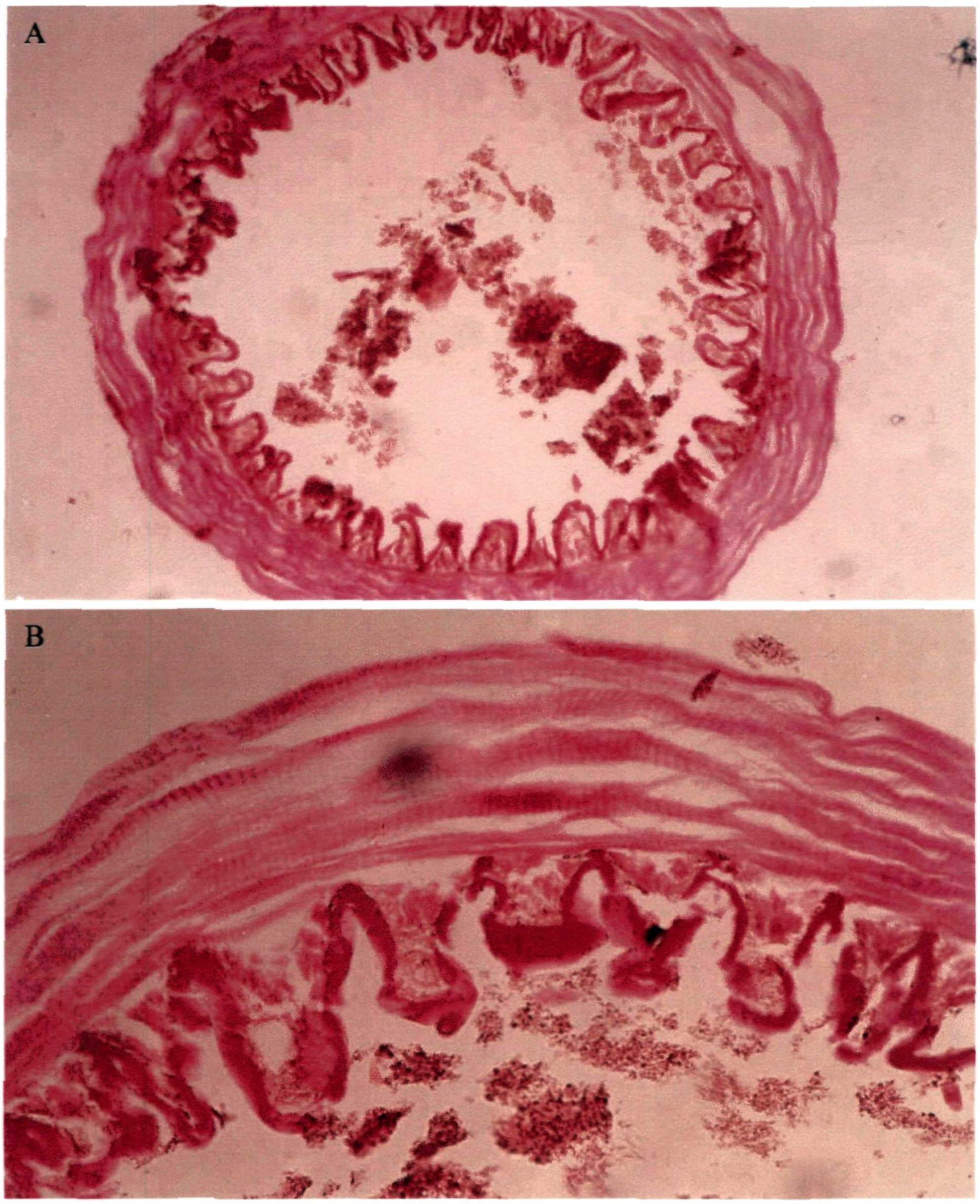


Figure 4.3 Sections of the expanded cells from the crop/ gizzard (A) and the magnified portion of the same (B) from adult individuals of *Oxya hyla* fed on treated food plant with methanol extract of *A. conyzoides*.

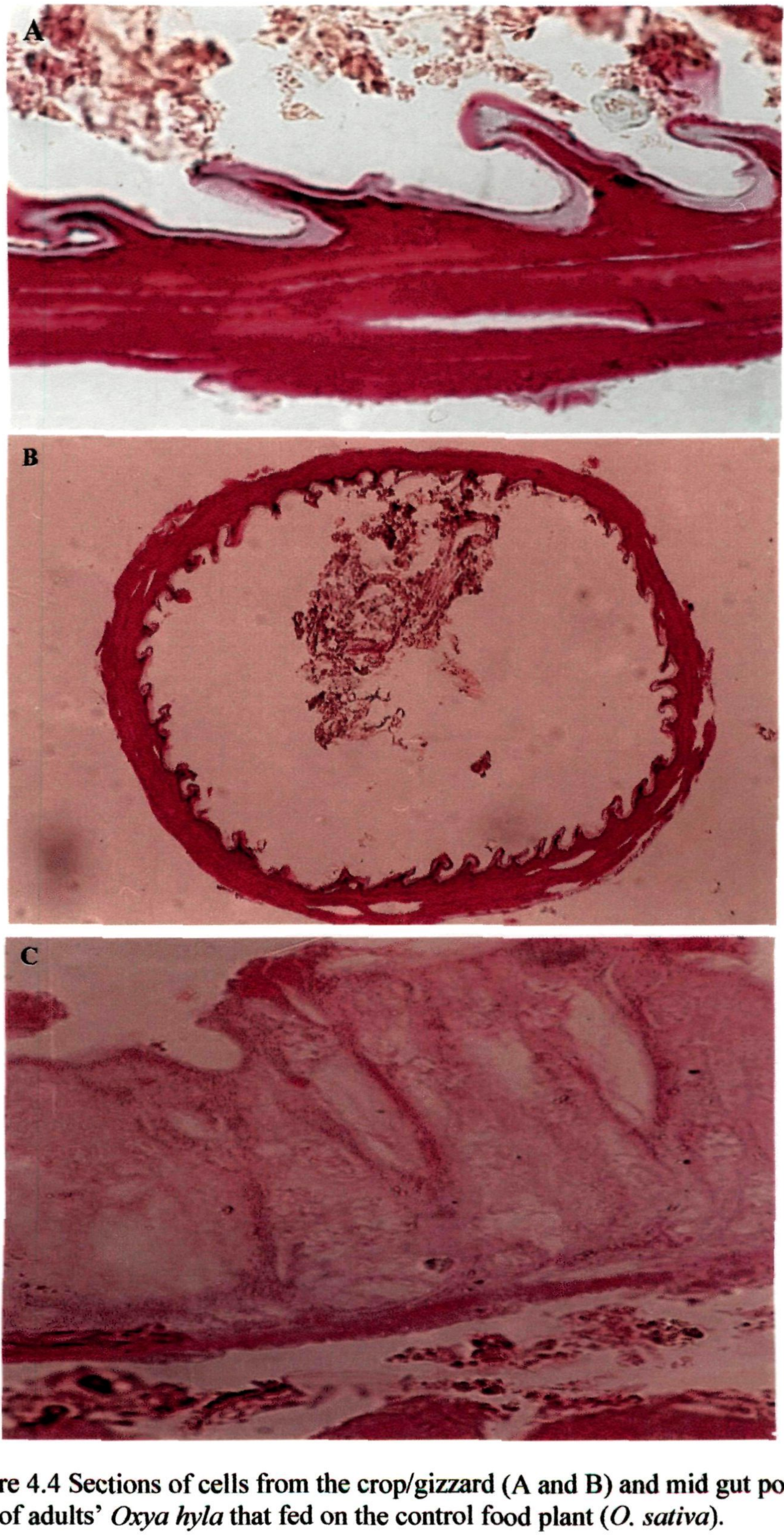


Figure 4.4 Sections of cells from the crop/gizzard (A and B) and mid gut portion (C) of adults' *Oxya hyla* that fed on the control food plant (*O. sativa*).

Table 4.11 Effect of the methanol extracts of *A. conyzoides* at 100 $mgml^{-1}$ on testicular cell cycle of adult males of *Oxya hyla* [a]

Stage	Expt. set 1	Expt. set 2	Expt. set 3	Expt. set 4	Expt. set 5	Expt. set 6
Leptotene	22.66±1.20 (23.33±2.72)	24.00±2.88 (18.66±1.20)	19.33±3.92 (10.00±2.64)	16.33±2.96 (17.66±2.40)	7.00±3.60 (15.33±3.17)	15.66±1.45 (16.33±2.84)
Zygotene	16.33±6.33 (25.66±2.66)	15.00±2.65 (15.66±1.76)	20.00±1.00 (7.66±0.88)	18.00±2.64 (16.33±1.20)	4.00±1.52[b] (11.00±1.15)	17.66±1.45 (22.33±1.76)
Pachytene	12.66±1.20 (15.66±2.60)	17.66±1.76 (10.00±2.31)	9.66±3.84 (7.66±1.76)	5.00±1.15 (8.00±1.00)	6.33±2.84 (5.00±1.73)	9.66±1.85[b] (24.33±1.33)
Diplotene-	-	-	-	-	-	-
Diakinesis	1.00±0.57[b] (5.00±0.57)	1.33±0.88 (10.33±3.66)	0.66±0.66[b] (14.33±2.90)	0.00±0.00[b] (12.00±2.64)	10.00±2.08 (6.00±1.52)	0.00±0.00[c] (12.00±0.57)
Metaphase I	0.00±0.00 (5.66±1.33)	0.00±0.00 (5.00±3.05)	0.00±0.00 (3.33±2.02)	0.00±0.00 (2.00±1.52)	0.00±0.00 (5.33±1.45)	0.00±0.00 (3.33±2.40)
Metaphase II	0.00±0.00 (4.33±1.76)	0.00±0.00 (1.00±0.57)	0.00±0.00 (1.66±1.20)	0.00±0.00 (0.66±0.33)	0.00±0.00[b] (1.66±0.33)	0.00±0.00 (2.00±0.57)
Telophase	0.00±0.00 (0.33±0.33)	0.00±0.00 (0.66±0.66)	0.00±0.00 (1.00±0.57)	-	0.00±0.00 (1.33±0.88)	0.00±0.00 (0.66±0.66)

[a] Means were statistically analyzed using Parametric Test One-Way ANOVA, [b & c] Values are significantly different from the control at (Parametric t-Test of Two Sided Paired Comparison) $P< 0.05$ & 0.01 Values in the parentheses are control.

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GENERAL CONCLUSION

There are many plants in the globe which human beings called them as weeds. In the Indian subcontinent also these alien species are so prevalent and some of them could not be eradicated. Some of these weeds like, *Lantana camara, Ageratum conyzoides, Eupatorium riparium, E. adenophorum, Artemisia nilagarica* and others, are spreading their danger to both forest and grassland ecosystems all over India. In the local situation of Eastern India, the above weeds have also created havoc in the agricultural lands both in the hill slopes and the lowlands. Moreover, the ongoing forestry and agricultural practices have not been able to control the spread of these weeds. Till more effective control measures are available, these weeds could be made use in some other spheres of human activity, possibly as a source of biopesticides.

The agricultural life of the people of North Eastern India is closely link to rice cultivation, since it is their staple food. The production of this crop although not sufficient to meet the demand of consumption, still largely depend on hostile climate, insect pests, pathogens and other such natural calamities. If insect pests could be controlled to large extent, then the production will still provide the rural populace with minimum food security. Of late, the small rice grasshopper, *Oxya hyla* has become a major pest of rice (*Oryza sativa*) in the hill agroecosystems as well as in the plains. This insect pest feed largely on plants belonging to poaceae (gramineae) family but may switch over to other non-host plants depending on season, climate and availability.

In the present study the pattern of interaction between the rice plant and the small rice grasshopper was investigated in field and laboratory conditions. Some findings of this study are represented here for possible future use.

The life cycle duration of the small rice grasshopper is quite long. The adults have different life span. The female passed through 196 days to complete the life cycle while the male takes 155, when reared on rice plants in laboratory condition.

Some of the plants selected, when used as insecticidal source in the form of methanol and aqueous extracts, show some effect on the various biological activities of the small rice grasshopper. The most effective among these plants tested was *Ageratum conyzoides* along with its two active principles namely Precocene I and II. These interpretations were on the basis of results obtained from standardized experiments. Food consumption, growth, conversion efficiencies, behaviour and development in various instars of *Oxya hyla* were affected when extracts of *Ageratum conyzoides* were used as insecticide source. Along with these results, it was also observed that gastrointestinal histology, amylase activity and testicular cell cycle were severely affected by treatments with methanol and aqueous extracts of the same plant. These observations indicate that *Ageratum conyzoides* is a potential candidate for insecticidal source for controlling the damage to rice plantations cause by *Oxya hyla* or some other related acridids as well as other phytophagous insects. Although the well known active principles of *Ageratum conyzoides*, Precocene I and II with their well known antijuvenile activity, also show some positive results in controlling this pest in laboratory conditions.

Field experiments have also shown that, when rice plots were sprayed with methanol extracts of *Ageratum conyzoides* during the growing season, the attack by the small rice grasshopper is much less in comparison to control plots, thereby leading to higher yield of paddy.

Although the study has not covered all the biological and chemical aspects of interaction, it may be said that growing of *Ageratum conyzoides* in and around the rice plots would be helpful in warding off attack by *Oxya hyla*. The extracts of the plant could be formulated for spraying during the paddy growing season and this would benefit the paddy growers because purchasing and applying of synthetic insecticides has been very costly to the farmers and the environment at large.

The use of natural insecticides as a component of pest control programs ensures greater longevity of insecticides through multiple modes of action and reductions in the amount and frequency of chemical applications. This can be effectively used as a mean of crop protection. Scientists must ensure that a new method of pest control promotes rather than endangers the ecological balance in the field that protects the crop from insect pest problems.

Crop protection research and extension methods alone usually fail to produce appropriate innovations, and that best results are achieved when farmers are instrumental in every step of the process. Under this model, farmers, extension agents and researchers work together as equal partners each having specialized skills and knowledge to contribute. The latter two become collaborators, facilitators, and consultants empowering farmers to analyze their own situation, to experiment and to make constructive choices.

More understanding as to how these compounds affect organisms on various ecological processes and the potential for eco-friendly products to control the pest is enormous. Further research in this field should expand out of the laboratory into the real world. In this way these novel products can be evaluated as viable alternatives to the persistent, less environmentally friendly products.

Too little is known about the effect of secondary plant compounds on small rice grasshopper. Attention is required for further research to enhance this control program which is a key research area. Hence continued research is essential to the production of additional natural insecticides available to the consumers for pest control.

RESUME

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1. Workshop on People's" *Participation in Bio-Diversity Conservation*" in Shillong, India, 4-5th March 1999
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3. National Symposium "*On Trends in Environmental Biology*" in NEHU, Shillong, India, June 23-25, 1999.

4. Workshop on *"Conservation of Biodiversity and Community Participation"*. in New Delhi, 14-15 March, 2000.
5. Regional Seminar *"On Recent Trends In Zoology"* in Shillong, India, Sept 14, 2000.
6. Workshop on *"Biodiversity and Indigenous Knowledge"* in Miao, Arunachal Pradesh, India, 13-14, March 2001.
7. Regional Workshop on *"Trace Elements Analysis"* from November 29-30, 2001 at the Regional Sophisticated Instrumentation Centre (RSIC), North Eastern Hill university, Shillong, India.
8. National Seminar on *"Intellectual Property Rights (IPR)"* in NEHU, Shillong, India, 24-25th May 2002.

Research Contributions.

Conferences/ Seminar/ Workshop

1: Syiem D., Kharbuli B., Das B., Nongkhlaw D.G., Thamar I., **Marngar D**., Syngai G., Kayang H., Myrboh B., Yobin Y.S.H and Buam D.R.M. Medicinal plants and Herbal medicines: a case study in Meghalaya. In Workshop on *"People's participation in Bio-diversity Conservation"*. In Shillong, India, on 4-5th March 1999.

2: **Marngar D**. Bio-diversity: A preliminary study of West Khasi Hills, Meghalaya. In Workshop on *"People's participation in Bio-diversity Conservation"*. In Shillong on 4-5th March 1999.

3: Kharbuli B., Kayang H., Syiem D., Myrboh B., **Marngar D** and Khongsai M. Role of Community in Biodiversity Conservation: A case study in Khasi Hills, Meghalaya. In Workshop *on "Conservation of Biodiversity and Community Participation"*. In New Delhi, 14-15 March 2000.

Abstracts

1. Raghuvarman A., Kharbuli B., Choudhury S., **Marngar D**., Thamar I and Hajong S.R. Sexual dimorphism in the body cuticle colour of the Sawfly, *Profenusa krishnanai* (Das) (Hymenoptera: Insecta). *In "Regional Seminar On Recent Trends in Zoology"*, in Shillong, India, 14 September 2000.
2. Raghu Varman, A., Hajong, S.R., Kharbuli B., Sentimenla., **Marngar D** and Renthlei, C.Z. Role of Vitamin T (Torutilin) In the differentiation of soldier caste in the termite, *Odontotermes distans* (Holmgren). In *"XX National Symposium on Reproductive Biology and Comparative Endocrinology"* in Tiruchirapalli, 7-9 January 2002.

3. **Marngar Dainingstar**., Kharbuli, B. and Laloo, R. Sajayma. Insecticidal activity of some plant extracts against the Rice grasshopper, *Oxya hyla* (Serville). *3rd International Conference on Biopesticides (ICOB)*, Kuala Lumpur, Malaysia, 22-26 April 2002.

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1. **Marngar Dainingstar**, Kharbuli B. and Laloo R. Sajayma. 2002. Insecticidal activity of some Phyto-extracts against the small rice grasshopper, *Oxya hyla hyla* (Serville). *GEOBIOS*. **29**:16-19.

2. **Marngar Dainingstar** and Kharbuli. B. 2001. The influence of some plant extracts on the feeding activity of small rice grasshopper, *Oxya hyla hyla. Uttar Pradesh J. Zool*. **21** (3): 241-247.

3. **Marngar, D**. and Kharbuli, B. Life cycle study of small rice grasshopper, *Oxya hyla* (Serville). GEOBIOS (Communicated).