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# EFFICACY OF BIOLOGICAL CONTROL ON HARMFUL INSECTS, INVASIVE PLANTS AND INTERACTION AMONG THEM.

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**Abstract:** Our study was primarily focused on efficacy of biological control on insects, invasive plants and interaction among them. Biological control uses biological agents viz.predators, parasitoids and pathogens to suppress pest (insects and invasive plants) population. Ecofriendly, high benefit cost ratio, ameliorating the natural balance, self-perpetuating and permanent are the stepping stone for wide use of bio control. By compiling different literatures thoroughly we reviewed that, invasive plants compete with our native ecosystem resulting in the negative consequences of our native ecological niche. Insects belonging to family Chrysomelidae and Curculionidae were effective in controlling invasive plants through reduction in plant size,plant biomass and flower-seed production .The target pest diversity was reduced and non-target plants diversity was fortified through the release of these insects. Below ground herbivores were effective bio control agent than above ground herbivores for invasive and alien plants control. Similarly, majority of parasitoids which were utilized for biological control of insect belonged to Hymenoptera and Diptera order. There are two revelations firstly, that there is no any substitute to control insects which can compete with biological control regarding efficiency and secondly, if dual bioagents are released in the field, they act as bioagent without disrupting each other's ecosystem but, they are conditioned by release of suitable bio control agents in a favourable condition .This review can be a useful tool for researchers and students who are working in bio control tactic to suppress pest in Nepal.

**Keywords:** Biological control, Parasitoids, Invasive plants and insects, Ecosystem, Chrysomelidae and Curculionidae, Hymenoptera



## 1 Introduction

Biological control is defined as application of biological agents to control a particular pest.H.S Smith in 1919, first gave the term "biological control".It also can be defined as use of living natural organism to control other harmful living organism termed as pest (Kenis, 2019).International standards for phytosanitary measures (ISPM) defines biological control agent as natural enemy or rival which control pests. Biological control is one of the tactics of integrated pest management (IPM) where application of chemical is minimized (Reeves, W.K).The mechanism of biological control may be hyperparasitism, antibiosis or competition (Sharma, 2013). Biological control agents disrupt the survival and reproduction of pest (Abrams, 1990).Biological control has wide applications but, this review is focused on the control of invasive plants and insects using insects as an entity of biological control.

Due to the spike in trade all over the world, exotic pest are sprawling which interfere with human welfare (Evans H,2007) and the best solution to control such exotic pest is biological control or bio control (Yang,2007). Environmentally safe, non-hazardous to man and domestic animals, scaling up the natural balance, self-perpetuating and permanent are the key beneficial aspects entangled with biological control thus, resulting in its extensive use and endorsed by many countries.Biological control agents should only be released after scrutiny and long term evaluation because some of them may bother us by attacking non target species along with target species (Coop L, 2019).

Insects which damage agricultural and forest crops can be controlled through bio control. It has been revealed that there is no any substitute of technique to control insects which can compete with biological control regarding efficiency if provided with suitable bio control agent in favourable condition (F.M, Scott et al). Harmful insects are definitely controlled by beneficial insects but, their worth is yet to derive mathematically due to data limitation (Losey, 2006).Predators and parasitoids of harmful insects can be found in our native ecosystem or can be imported from foreign countries. Predator is the one which feeds or preys on other living organism that is more than one during its life span (van Lenteren ,2012) whereas parasitoid is the one which is parasitic only in its immature stages and is free living in adult stage (ISPM).Majority of parasitoids which are utilized for biological control of insect pest belong to Hymenoptera and Diptera order. Invasive plants are those which are not native to a particular ecosystem and whose introduction or dispersion leads to harm of environmental, sociocultural, economic, and human arena as well (FAO, 2007).

There are many invasive and alien plants around us which can be controlled through insects sustainably rather than direct application of herbicides.Biological control agents which have high dispersive capacity are preferred in bio control which can effectively control the pest through population reduction or elimination from an ecosystem (Kenis,2019).It has been reported that beetles of Chrysomelidae and Curculionidae significantly reduced the plant size (Clewley,2012).Invasive plant control through biological control is not popularized due to some invasion biologists and related stakeholders (Seastedt,2015) .However,biocontrol technique releases us from economic burden of controlling such invasive plants.

This review article written by compiling different literatures deals with efficacy technicalities of biological control on insects and invasive plants.However, it doesn't deal with risks and limitations entangled with biological control.

**2. Rationale of study**

The continuous use of chemical pesticides for controlling insects and invasive plants lead to the degradation of ecological niche as well as the resistance development in pest.The demand for quality food and food safety is increasing worldwide. So, this review reflects the effectiveness and pros of bio control for control of harmful insects and invasive plants (pests) and their interaction. This review can be a useful tool for researchers and other students who are working in the field of biological control.

**3. Reflection on reasons of using biological control:**

Biological control utilizes predators, parasitoids and pathogens to suppress pest population and keep pest population in farmers desired level.Biological control can be an alternate pathway for achieving a main goal of agriculture that is mounting crop productivity and production (Sharma,2013).The strategy to control pest through chemicals not only curtail us from taking the benefits of bio control but also plummet the efficacy of future biological control (VanDenBosch,1976).It is argued that biological control is a slowly progressive and ecofriendly portfolio which provides optimum benefit cost ratio in long-term (Randall,2000).It has been revealed that biological control maintains biological diversity thus, securing food and other resources for human being (Seastedt,2015).Thus, it can be touted that biological control is positively associated with the environment contrast to chemical method of pest control.

**4. Insects as Bio Control Agent (BCA) for reducing insects:**

Some species of insects can be deployed for controlling harmful insects but, species to be released and favourable condition is utmost important. It has been reported from the experiment that Whitefly and Broad mite were effectively controlled in brinjal by the use of predaceous mite *Amblyseius swirskii* (Stansly,2018).It has been revealed from the research in Shakarganj Sugar Research Institute (SSRI) of Pakistan that 80% of the eggs of *Pyrilla perpusilla* were predated by release of *Chrysoperla l*arvae (7-8 days) and in the same institute another study showed that release of *Chrysoperla* larvae resulted in the 65% nymphs mortality of *Pyrilla perpusilla* (Zia-ul-Hussnain ,Asia Naheed and Saadia Rizwana,1997). In a research done in China ,it has been showed that a predatory bug flower bug *Orius sauteri* (Hemiptera ;Anthocoridae) , has equal potential for acting as a predator for 6 species viz. four aphid species,flower thrips and 2 spotted spider mite mostly noticed on vegetables and ornamentals, without any negative consequence on ecosystem(Wang,2014).In an experiment in South Texas ,it was found that Citrus leaf miner (*Phyllocnistis citrella*) was effectively parasitized by native parasitoid *Zagrammosoma multilineatum* ranging from 5 to 10% but, with high recovery rate than exotic parasitoid Logvinoskaya *Ageniaspis citricola* with low recovery rate and high percentage of parasitism reaching up to 39 % (Kaloter,1996).Similarly,in a research done in Jordan in cucumber ,it showed that Whitefly *Bemisia tabaci* was significantly reduced through the release of Indian Ladybird *Serangium montazerii* (Al-Zyoud,2010).Insecticide application was reduced by 75% on poinsettia in Massachusetts by release of *Encarsia formosa* (Hymenoptera :aphelinidae) to control whitefly *Bemisia argentifolii* but, cost was high (Hoddle and Driesche,1996).It has been revealed that in Hawaii , release of *Encarsia diaspidicola* ,a parasiticwasp,effectively controlled the White peach scale (Hemiptera :Diaspididae) in papaya and wasp being reported with two peculiar traits viz. high host specific capacity and positively correlated with ecosystem (Follett, 2015).In a research done in Spain in Sweet pepper, it showed that Mercet *Eretmocerus mundus* (Hymenoptera: aphelinidae) parasitized mostly 2nd and 3rd nymphal stages of whitefly Bemisia tabaci (Urbaneja,2004) .*Anovia punica* and *Rodolia cardinalis* were two ladybird beetles which effectively predated Columbian Fluted Scale (CFS) *Crypticerya multicicatrices* (Hemiptera : Monophlebidae) in a research done in city of Cali in Columbia focusing on mainly Leguminous urban trees (Pinchao,2004).It has been revealed from the research done in California for four years that , a parasite *Trioxys pallidus* (Hymenoptera : Apidiidae) significantly reduced walnut aphid *Chromaphis juglandicola* (Homoptera : Callaphididae) (VandenBosch,1979) .There are not bountiful evidences to support that aphid parasitoid interactions could be used for biological control (Federici,1996).It has been argued that aphid *(Macrosiphum euphorbiae*) population was significantly reduced in greenhouse rose by dual use of biological control agent Ladybird beetle *(Harmonia axyridis*) and parasitoid *Aphelinusasychis* without disturbing each other niche(Snyder,2004).It has been shown from the research that when dual biological control entities fireant *Solenopsis invicta* (Hymenoptera:Formicidae) and parasitoid were deployed in collard (Brassica oleracea ),Diamond back moth (*Plutella xylostella*) (Lepidoptera:Plutellidae) was effectively suppressed without disrupting each other's niche by two bio control agents (Harvey,2005).Mango mealybug *Rastrococus invadens* (Homoptera :Pseudococcidae) population significantly reduced in mango in a research done in Africa by release of *Gyrannusoidea tebygi* Hymenopterous parasitoid (Agounke,1993).In Sub Saharan Africa ,cassava mealy bug (*Phenacoccus manihoti*) Homoptera Pseudococcidae was effectively controlled by *Apoanagyrus lopezi* (Hymenoptera:Encyritidae) and Benefit cost ratio was found to be high when 40 years long extrapolation was done (Zeddies et al.,2001). Sawfly species viz.*Cephalcia lariciphila* was significantly reduced in UK forest through introduction of parasitoids (Evans H, 2007).

**5. Listing of target pest and bio control agent:**

1. aphid

- Predatory midge *Aphidoletes aphidimyza*
- Parasitoid wasp *Aphidius ervi,A matricariae*
- *A colemani*
- *Trioxys pallidus*
- Big eyed bug *Geocoris pallens*
- Lady beetle *Hippodamia convergens*
- Lacewing *Chrysoperla downesi*
- *C plorabunda*
- *C rufilabris*
- Minute pirate bug *Orius insidiosus*
- *O. minutus*

2. Armyworm Braconid parasitoid wasp *Chelonus insularis*

3.Butterfly and moth larvae Parasitoid wasp *Bracon hebeter*

4.Leaf miner Braconid parasitoid*Dacnusa sibirica*

5.Mealy bug Lady beetle *Cryptolaemus montrouzieri*

6. Borer *Trichogramma species*

7. San Jose scale, ivy scale

Lady beetle *Chilocorus fraternus*

8. Whitefly nymph Parasitoid wasp of eggs *Encarsia Formosa*

*Eretmocerus californicus*

9. Weevil on landscape plants Prasitoid wasp of larvae *Anisopteromalus calandrae*

10. Thripslarvae Predatory mite *Amblyseius cucumeris*

11. Lacewing*Chrysoperla downesi*&*C plorabunda*

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**6. Invasive plants and Bio control:**

Invasive plants are plants growing in places and at times where or when we wanted either some other plants to grow or no plant grow at all. Invasive plants are any plants not intentionally sown or propagated by the grower and requires management to prevent it from interfering with crop or livestock production. Many plant species either purposely or accidentally introduce into the place and become established in course of time and cause economic and ecological damages. Invasive species when get established in an area dominates an ecosystem and influences the performance of individual species and their population dynamics. Invasive alien plants have significant ecological impacts on species, communities and ecosystems. Exotic weeds can completely affect the biotic and abiotic components of native ecosystem putting a threat to survival of native species. Failure to control invasive weeds results in severe global consequences, including loss of agricultural, forestry, and fishing resources. Invading species that become established often proliferate rapidly and become devastating (Mack, et al., 2000). In the absence of natural enemies, exotic species gain a competitive advantage over native species which may result in an irreversible impact on ecosystem function (Tomberlin, 2003). A key impact of invasive plants is the loss of local plant diversity (Vila, et al., 2011).If the invasive species is not managed throughout the invaded region, control efforts will fail because pest refuges in unmanaged areas and later multiply.

Biodiversity is valuable for providing ecosystem services (Ehlirch & Wilson, 1991) and biological pest control is prominent among those services. Growing awareness of plant invasions has stimulated growth in biological control activity, evidenced by the rising numbers of target and control organisms (McEvoy & Coombs, 1999). Biological control is currently being practiced primarily in one dimension— enhancing natural-enemy function by introducing new natural enemies (augmenting or conserving existing natural enemies play secondary roles)—and growth in the number, size, and complexity of biological control systems is a consequence of this practice. Biological control programs develop by stages from selecting a target organism to finding, screening, releasing, establishing, and moving control organisms, plus assessing their ecological and economic effects.Mechanical and cultural methods and use of herbicides are the traditional practices for the removal of crop weeds. But there is also the other option biological control which gives effective results for control of invasive plants as they are ecofriendly in comparison to chemical methods. Most biological controls are practiced in such areas where it is difficult to practice mechanical and cultural methods like in marshy and slopy areas. In biological control methods , self-reproducing herbivores are used to control target weeds. Using herbivorous insects as a bio controlagent has been proven successful in reducing weed population (Crawley, 1989).

Setting specific goals based on the impacts of the target species prior to release like setting an acceptable target density against which the effectiveness of control can be measured, can be beneficial (Paterson, Coetzee, Hill, & Downie, 2011) . Pre and post release comparisons need to be done to assess the effect of biocontrol agents. Over half of the studies used , Coleopteran bio control agents (57%), with the Curculionidae (38%) and Chrysomelidae (17%) were the most common families that had a significant impact on invasive species plant growth. Beetles of Chrysomelidae and Curculionidae families of order Coleoptera are the most effective agents for reducing plant size (Clewley, Eschen, & Wright, 2012) . Most successful weed management programs integrated the use of bio control agents with other weed management strategies, especially modifications of disturbance and competing vegetation.

**7. Selection and Releasing:**

Biological control of invasive weeds uses exotic herbivores from the same habitat as that of problematic weed. The traditional ways to design biological control systems for plant invaders include introducing, augmenting, or conserving natural enemies. Weed biological control organisms are traditionally classified into guilds by the plant resources they consume (e.g., roots, stems, leaves, flowers, fruits, or seeds) and (to a lesser extent) the manner in which they consume them (sucking, chewing, galling, mining, etc.) By rationally manipulating disturbance, plant competition, and natural-enemy regimes, it may be possible to engineer biological control systems for plant invaders that are parsimonious, potent, and pose minimum risk to non-target organisms.

Biological control scientists are very far from agreement on how to select the most promising target and control organisms for biological control. Some propose screening biological control organisms for critical attributes prior to release. For example, the numerical scoring system proposed by (Harris, 1973) involves three phases (1) initial assessment of destructiveness in native range (direct damage inflicted, indirect damage inflicted, phenology of attack, number of generations, number of progeny per generation, extrinsic mortality factors, feeding behavior, distribution), (2) suitability as a biological control agent (host-plant source of insect, ease of culture, potential safety, host-plant specificity), and (3) potential effectiveness in area of introduction(evidence of effectiveness as a control agent, ecoclimatic similarity, colonization history of agent). Measuring control-organism effects is difficult due to the given reasons: (1) there are many factors affecting biological control organisms in their native habitat, (2) it is difficult to understand how these factors are related to the biological characteristics of the weed and its agents, and (3) the prospective importance of similar factors in the invaded habitat is unknown . Initially the effect of biocontrol agents need to be tested in a confined area or in laboratory prior to release in the field so that the possible impacts can be studied. For.eg. In order to determine growth and reproductive response of lantana to herbivory by *Ophiomyia camarae*, first tests were done under field cage conditions (Simelane & Phenye, 2005). This was undertaken primarily to indicate the potential contribution of this agent to the biological control of lantana prior to major efforts being channeled into mass-rearing and distribution. An investigation of this kind, carried out at this stage of a biocontrol programme, could prevent unnecessary loss of resources that would otherwise be committed during mass rearing and distribution of a less effective agent.

**8. Pros of bio control agents in controlling of invasive plants:**

Compared with other methods, minimal effect on nontarget species make bio control method environmentally sounds. Classical biological control (bio control) is advocated as an alternative to conventional invasive species management that has the potential for long term, self-perpetuating and effective control, especially in more sensitive environments such as protected areas or riparian habitats (McFadyen, 1998). Control of alligator weed, principally by the flea beetle *Agasicles hygrophila* (Coleoptera: Chrysomelidae) was one of the early successes in the use of biological control agents (Coulson, 1959). Alligator weed was becoming resistant to herbicides and thus out-competed native plants. Herbicides used to treat alligator weed were not only ineffective and costly but also reduced non target native flora. Many health problems like headache, nausea, irritation, vomiting, and even cancer are caused by the use of chemicals for controlling weeds. Use of bio control agents significantly reduced plant size (28 ± 4%), plant mass (37 ± 4%), flower and seed production (35± 13%) and 42 ± 9%) respectively and target plant density (56 ± 7%). Non target plant diversity significantly increased by (88 ± 31 %) at sites where bio control agents were released (Clewley, Eschen, & Wright, 2012). Chrysomelidae and Curculionidae families are the most effective agents. Biocontrol agents affect the flower production in target species thereby reducing the multiplication of invasive plants. Moreover, biocontrol agents are usually highly host-specific and thus produce fewer nontarget impacts than does widespread use of chemical and mechanical control methods (Denslow & Antonio, 2005). At least 46 species of Cactaceae have been identified as problem weeds and 65 species of insects and mites have been introduced to control them. The most effective have been species of the Cochineal insect in the family Dactylopidae (Moran & Zimmermann, 1991). (Chikwenhere, 1994)described the rapid substantive (80%) reduction in *Pistia* cover by the beetle *Neohydronomus affinis* (Coleoptera: Curculionidae) in Zimbabwe. Leaf miner *Ophiomyia camarae* (Diptera: Agromyzidae) was released against *Lantana camara* in South Africa and the flower number of the target was reduced by 97.5% (Simelane & Phenye, 2005). The reduction in size of plants of the target species following the release of control agents is likely to reduce the competitive strength of the target species and enable other plants to become established. On a longer time-scale, a reduction in seed production may reduce the spread or regeneration of the target species. At lower initial density, Ophiomyia *camarae* reduced stem height, stem diameter, leaf density, flower density and above-ground biomass by 5, 22, 54, 100 and 41%, respectively. At higher initial density of *Ophiomyia camarae* , stem height, stem diameter, leaf density, flower density and above-ground biomass were substantially reduced by 19, 28, 73, 99 and 49%, respectively (Simelane & Phenye, 2005). The profound effect of herbivory by Teleonemia scrupulosa on plant growth and reproductive capacity suggests that it is making much greater contribution to the biological control of *Lantana* in South Africa than was previously thought. Feeding damage by *T. scrupulosa* on leaf buds and apical meristems reduces primary stem height and branching pattern thereby reducing vegetative and reproductive capacity of *Lantana*. Feeding damage by *O. camarae* larvae, which appears to block the leaf transport system and promote premature abscission (Simelane & Phenye, 2005), caused heavy defoliation, which in turn decreased the total photosynthetic capacity of the plant. Reduction in total photosynthetic capacity of the plant caused by both agents was reflected in subsequent flower production, vegetative growth and biomass. The feeding damage by *T. scrupulosa* on the leaf buds and apical meristems of the plants was severe enough to prevent subsequent flower production. Throughout the recent history of weed biocontrol programmes, below-ground herbivores have been found to be more successful in suppressing invasive plant populations than above-ground herbivores (Blossey & Hunt-Joshi) . Future investigations are needed to assess the possible role of synergistic or competitive interactions of *O. camarae* and other established agents on biological control of *Lantana*. Therefore, *O. camarae* on its own should not be expected to reduce *Lantana* populations in the long term, but rather be seen as one of the complementary suite of control agents.

**9.Conclusion:**

The success rate of use of bio control agents in pest and invasive species management has fostered its use in insect pests control and weed management. Insect pathogen synergisms are the foundation for biological control of weeds and pests. However bio control methods should be cost effective, parsimonious, without causing any harm to non-target species. Only release of insects for pest and invasive species control is not sufficient. Different lab tests, prerelease studies and regular monitoring are the key factors that play a great role in the effectiveness of bio control. Releasing more and more control organisms challenges the capacity for thorough monitoring of both target and non-target effects, increasing the likelihood that significant effects go undetected. To avoid revenge effects, rather than introduce all host-specific control organisms, we should introduce the agents which are necessary, effective, and safe. We should probe and experiment, monitor results, and update assessments and modify policy accordingly. The promotion of use of bio control agents should not be encouraged unless evidence of harmlessness is obtained. Chrysomelidae and Curculionidae families of order Coleoptera were the most effective agents against different invasive species. Similarly, parasitioids belonging to order Diptera and Hymenoptera were also found effective and used in bio control programs. In fact, biological control method is a valuable management tool for control of different pests and restoration of ecosystem services. They are found much effective than chemical and mechanical methods of control. However, integrated use of biological control method along with other methods of control is preferred over its sole use. Successful biological control requires sound definitions of the goals to be achieved and an intimate knowledge of the available organisms. Promising agents need to be identified through the study of natural enemy biology and ecology. Determination of biological characteristics such as tritrophic relationships, and effects of climate on behavior and population dynamics is needed . Safety and effectiveness should be regarded as two sides of the same coin. Preventable causes of poor performance in biological control should be systematically analyzed. Greater effort should be made to measure the benefit and harm that accrues from each control-organism species.

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