



## A review on- Chemical attraction in between the *Polygonum* and its insects

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### Abstract

This review covers total chemical interaction between *Polygonum* plant and its associated insects. Most of the review studies focuses on chemical extraction from the *Polygonum* and design the chemical structure or medicinal value. So, the actual ecological implication still yet to be studied. This article reviews the role of primary and secondary chemicals of an important weed, *Polygonum* (Polygonaceae) on the potential biocontrol agent Coleoptera: Chrysomelid. This review also presents how Secondary chemicals mainly alkanes, fatty acids & volatile compounds are more responsible for attraction of this coleoptera insects. Some are deterrent also. This interaction is highly species specific. Female insects are dependent for feeding and oviposition to *Polygonum* plants. In this article, we review herbaceous weed *Polygonum* which is one of the major impediments of rice production in India, Bangladesh, Malaysia, and China. This weed is well adapted to wet-dry climate typical of tropical and subtropical regions because its above ground leaves is able to die off during Indian summer season, but it regenerates vigorously again between rainy and winter season. In North-eastern India, the weed shows its vigorous growth at the end of the rainy season when flowering is observed (September–October), which is influenced by a decrease in day length occurring in winter.

Our main aim is that how single chemical compound or combined chemicals compound (extracted from *Polygonum* plant) interact with the insects (mainly *Polygonum* associated insects). Our focus is to develop the potential biocontrol agent. Because of *Polygonum* weeds are controlled in the rice-field by herbicide application and physical removal in India that is really tough job and also time consuming. So, finally the implication will be *Polygonum* weed will be controlled by biological methods. That will be the future prospective of this review and also IPM strategy.

**Keywords:** insect-plant interactions, *Polygonum*, coleoptera, biocontrol agent

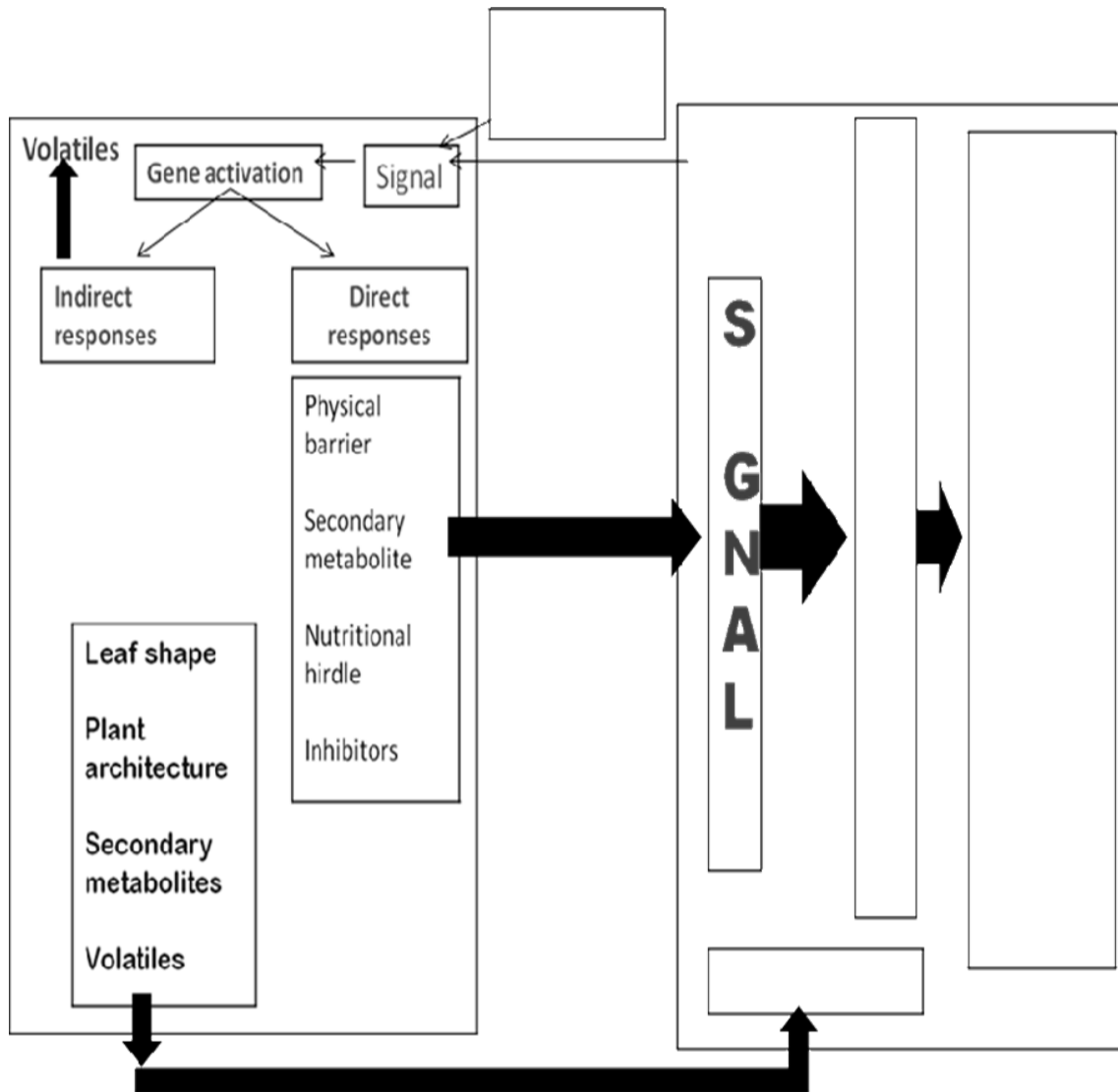
### Introduction

The plant kingdom and the class of insects represent two exclusive taxa of living organisms, both in abundance of species and amount of biomass. Nearly half of all existing insect species feed on living plants. There are more than 4,00,000 herbivore insect species live on roughly 3,00,000 vascular plant species<sup>[1]</sup>. Herbivory does not occur in same extent in all insect groups. Among various insect orders like Lepidoptera, Orthoptera and Phasmida are exclusively herbivorous. Beside food, plants also provide shelter, oviposition sites etc. to the insects, whereas insects also have some beneficial activities including defense, pollination, etc. The remarkable diversity of associations between phytophagous insects and their host plants, with some feeding on a large number of plant species belonging to widely different plant families and others being restricted to one particular plant species, has prompted many biologists to investigate patterns and processes underlying such associations. This was assumed that reciprocal selection between insects and plants has induced both chemical diversification and resistance in plants and food specialization in insects<sup>2</sup>. A plant species that has evolved a new chemical defense due to selection by a range of herbivores alleviates herbivory and therefore this species is able to diversify. A phytophagous insect species that evolves adaptation to these compounds can subsequently diversify. Ehrlich and Raven's hypothesis can be best called 'escape-and radiation coevolution' and in fact they seem to have envisaged diffuse coevolution rather than species specific coevolution<sup>[2]</sup>.

Insect-plant interactions might involve a wide array of biotic and abiotic environment influences as well as geographical and temporal variations, diverse genetic foundations and inducible phenotypic plasticity of species, populations and individuals. A coordinated bio-complexity study is needed to understand the relationships between normal phenological changes in plant leaf (or part) composition throughout the growing season, carbon-nutrient stress, mineral nutrition, plant vigor, phytochemical induction of resistance in damaged/diseased leaves. With the help of this knowledge, the suitability of such plant tissues for insect and herbivores (or the resistance of plants to their enemies) may become more understandable, both in ecological and evolutionary point of view. The insect feeding patterns may also involve population genetics, host-race formation, evolutionary divergence, speciation and phylogenetic patterns. The location (find ability) and utilization (suitability) of plant parts as insect food depends on phenotypic variation. It is induced by previous herbivores and microbes, as well as a wide array of interactions which involves nutrient availability, light regime, water temperature, carbon dioxide, various pollutants, seasonal (ontogenetic) changes in plant growth, reproduction and chemical/ physical defense. The photochemical suitability of leaves for insect herbivores has some genetically based biochemical variation. The physiological and ecological suitability of the plant for supporting herbivore feeding, growth, survival, and reproduction is affected by some genetically based biochemical variations. The nutritional factors are not the only determinants of feeding side

specialization but several other physiological and ecological factors are also be involved and that's why host plant is more than food plant<sup>1</sup>. Besides this, the volatile substances play a dual role in plant-insect interactions. They act as repellent due to the nature of toxic compounds released in air. Plants, herbs, and ethnobotanicals have been selected and used empirically as drugs for centuries, initially as traditional preparations then as pure active principles, with the knowledge and accumulated practice passing from

generation to generation. Medicinal plants are plants containing the substance that are used for therapeutic purposes or which are precursors for the synthesis of useful drugs. Herbal Medicinal can be categorized into two broad parts. The first one includes complex of mixture containing a wide variety of compounds (e.g.: Infusions, essential oils, tinctures or extracts), and the second category refers them as pure, chemically define active principles<sup>[3]</sup>.



**Chart 1:** Interactions between plants and insects

**Generalists & Specialists**

Plant-feeding insects can be classified as generalist or specialist herbivores<sup>[4]</sup>. Generalist insect herbivores rear on a wide variety of plant species and their adaptive mechanisms are more complex since polyphagous insects tend to respond to a large array of different plant chemicals and proteins. On the other hand, specialist insect herbivores hosting only on a few related plant species. They might be expected to have a more efficient form of adaptation, either involving the production of large quantities of an enzyme to detoxify their food, or evolve storage mechanisms<sup>[5, 6]</sup>. Eruptive insect herbivores commonly adopt a generalist feeding strategy. Even though they are able to grow and develop on a variety. The majority of insect herbivores are relative specialists, using a restricted number of hosts with

similar phytochemicals and taking advantage to colonize an open niche<sup>[7]</sup>. During the course of evolution, specialist herbivores adapted to plant chemical defenses developing mechanisms that use these chemicals as attractants. These insects frequently detoxify or sequester plant defense compounds and, sometimes, they result in protection against parasitoids and predators being used as toxic or unpalatable at defense. Further, these compounds are of great importance since they provide insects with signals for identification of the host, turning the process of host finding at feeding and oviposition rapid and efficient. On the other hand, secondary metabolites of a non-host plant have the potential to deter specialists that show an equal sensitivity to these phytochemicals. The ability to choose superior hosts is shown to be greater in specialists than in relative generalists

in the presence of a choice of mixed-quality hosts [7]. So, this review depicts different insect (i.e., generalist and specialist) interaction with the *Polygonum* that helps to biological control of these weeds. As a result, many important crops of India are saved and any ecological implications of the phytochemicals present in this plant.

### Taxonomic position of genus *Polygonum*

Kingdom Plantae -Plants  
Subkingdom Tracheobionta -Vascular plants  
Super division Spermatophyta-Seed plants  
Division Magnoliophyta- Flowering plants  
Class Magnoliopsida-Dicotyledon  
Order polygonales  
Family polygonaceae  
Genus *Polygonum*

### A brief description of *Polygonum* sp

*Polygonum* is a genus in the Polygonaceae family, and they are commonly known as knotweed, knotgrass, bistort, tearthumb, mile-a-minute, and several others. In the Middle English glossary of herbs "Alphita" (ca. 1400-1425), it was known as ars-smerte. There have been various opinions about how broadly the genus should be defined. For example, Buckwheat has sometimes been included in the genus.

The genus name is from the Greek poly, "many" and gonu, "knee" in reference to the swollen jointed stem, and grows in northern temperate regions. They vary widely from prostrate herbaceous annual plants under 5 cm high, others erect herbaceous perennial plants growing to 3–4 m tall, and yet others perennial woody vines growing to 20–30 m high in trees. Several are aquatic, growing as floating plants in ponds. The smooth-edged leaves range from 1–30 cm long, and vary in shape between species from narrow lanceolate to oval, broad triangular, heart-shaped, or arrowhead forms. The stems are often reddish or red-speckled. The small flowers are, pink, white, or greenish, forming in summer in dense clusters from the leaf joints or stem apices.

*Polygonum* species are occasionally eaten by humans, and are used as food plants by the larvae of some Lepidoptera species. Most species are considered weedy, especially in moist soils in the USA. *Polygonum* comprises of about 60 species, distributed nearly worldwide and in Pakistan represented by 20 species [8]. The genus is characterized by its prostrate habit, sometimes sub prostrate or erect, alternate leaves, presence of ochreae on nodes, axillary flowers, tepals with only one main vein, stamen in two whorls, outer smaller in size than inner, filaments swollen at the base and absence of nectaries [9].

### Economic importance of Polygonaceae

Only a few genera of family Polygonaceae are economically important (Steward, 1930). However, medicinal and chemical studies have been conducted in the Polygonaceae species.

The complex genus *Polygonum* L. is of little economic importance. A densely grown *P. aviculare* L. is an accepted plant in pharmaceutical market, sold in German drug stores as Homeriana Tea. It contains 2-2.5% sugar, traces of essential oil, tannin, resin and wax. Its seeds are cathartic and emetic [10]. It is a good fodder plant and its roots yield a blue dye [11]. It is a bad weed, resistant to herbicide in many

places [12]. It is used as an astringent, tonic, antipyretic, diuretic, its extract is given in dysentery and to check menses. *P. plebium* R.Br. is used to cure pneumonia and its roots are used in bowl complaints. *P. arenastrum* Boreau contains tannins and is used in medicine [13]. In European countries, the extract of *P. hydropiper* L. is used for menstrual irregularities [14]. The plant is also famous for its ant fertility properties. In India, folk women usually use its powdered dry roots for the abortion and its uninterrupted use for more than one year leads to permanent infertility. This effect is due to the presence of steroidal compounds that may be endocrine disrupter or regulator [15]. *P. capitata* Buch-Ham. and *P. orientalis* L. are used as ornamental plants. *P. chinense* L. (Mountain knotweed or Chinese knotweed) roots are used for the treatment of fluxes, to remove intestinal worms and neutralize scorpion poisoning. *P. minus* Huds. is used for sprains and body aches. It is mixed with rice powder and used on effected area. The plant is used as an antidote for dyspepsia in children [16]. Infusions and decoctions are made from *P. lapathifolium* L. are used as cathartic and emetic drugs. The infusion of *P. persicaria* L. leaves are used to relieve stomach pains and its decoction is used in the treatment of rheumatism [17]. Watery sap from the roots of *P. barbatum* L. is used as an antiseptic [18]. Fleshy roots of *P. viviparum* L. are cooked and eaten because of its almond flavour and also used as a substitute for nuts and raisins. The rhizome of *Bistorta amplexicaulis* (D. Don) Green is used for making tea and decoction [8]. *Fagopyrum* Mill. (Buckwheat) is reported to be economically important genus. In conventional Chinese medicine *F. dibotrys* (D. Don) Hara was used for the treatment of lung diseases, including lung tumor. In India, its seeds are used for the treatment of colic, choleraic diarrhea fluxes and abdominal blockage troubles. It is considered as a fodder crop while its leaves are used as vegetable and its grain are used in stomach disorders [8]. Polyphenols like rutin and quercetin have been isolated from *F. esculentum* Möench. (Common buckwheat). These polyphenols have anti-inflammatory and anticarcinogenic properties. *F. esculentum* is also known as honey crop because in many countries it has been used as source of nectar for honey production.

High proportion of anthraquinones is present in the roots of *R. dentatus* L. are used as an astringent and for dyeing purposes because of high percentage of tannin [18]. Due to the presence of anthraquinones, its extract show molluscicide activities against the schistosome vector snails. The leafy juice of *R. vesicarius* L. produces cooling effect in snake bite<sup>8</sup>. It can be used for the treatment of various blood diseases and its young leaves are used as vegetable and green fodder crop<sup>8</sup>. In China, Japan, Korea and Bhuttan buckwheat flour is used to make traditional noodles. Its proteins have balanced amino acid composition and lower the blood cholesterol level, hypertension and effective in constipation. It is non poaceous alternative human crop, famous for its nutritious qualities [19]. It has been reported the use of *F. tataricum* (L.) Gaertn. (Tatary buckwheat) for the treatment of bleeding gums and the people who used tatary buckwheat flour for brushing their teeth and gargling showed 62% recovery in their gum diseases. It is an important crop in Himalayan hills and mountainous regions of southern areas [20].

Main *Polygonum* in West Bengal (Fig: 1-4)



Fig 1: *Polygonum lapthafolium*



Fig 3: *Polygonum barbatum*



Fig 2: *Polygonum hydropiper*



Fig 4: *Polygonum orientale*

Table 1: Chemical derived substances involved in host-plant resistance to insects.

Class/ subclass	Function	Reference
Alkanes, aldehyde, ketones, Waxes	Protective layer	29
Lignins, tannins	Mechanical barrier, unpalatability, post absorptive inhibition	30
Terpenoids (monoterpenoids, iridoids, sesquiterpenoids diterpenoids, triterpenoids)	Toxicants, antibiotics, feeding deterrents, oviposition deterrents	
Phenolics	Toxicants, ovicidal, photo sensitizing insects	31
Flavonoids (anthocyanins, flavones, flavonols, isoflavonoids)	Antifeedant, phytoalexins, inhibition of mitochondrial oxidation.	31
Quinones	Toxicants, antifeedant	29
Alkaloids	Toxicant, antifeedant, interfere in nervous system, glucosidase and digestive enzyme inhibitor	29
Cyanogenic glycosides	Toxicant	29
Glucosinolates	Repellent, toxicant, irritant and antibiotic	32

Table 2

	Name	Local name	Flowering and fruiting time
1.	<i>Polygonum barbatum</i>	Bekhunjubar	Aug-April
2.	<i>Polygonum hydropiper</i>	pakurmul	Sept-June
3.	<i>Polygonum orientale</i>	jal marich	June-Feb
4.	<i>Polygonum glabrum</i>	pani marich	June-Marc

**Insects associated with *Polygonum* sp**

Order	Species	Possible host range
Coleoptera		
Rutelidae		
	<i>Popillia quadriguttata</i> Fabricius	polyphagous
	<i>Popillia mutans</i> Newman	polyphagous
	<i>Anomala virens</i> Lin	polyphagous
	<i>Blitopertha pallidipennis</i> Reitter	polyphagous
Curculionidea		
	<i>Piazomias dilaticollis</i> Chao	polyphagous
	<i>Calomycterus obconicus</i> Chao	polyphagous
	<i>Lixus amurensis</i> Faust	polyphagous
Coccinellidae		
	<i>Henosepilachana operculata</i> (Liu)	polyphagous
Cleridae		
	<i>Trichodes</i> sp	polyphagous

Lilioceridae		
	<i>Lema diversa</i> (Baly)	oligophagous
Chrysomellidae		
	<i>Gallerucida bifasciata</i> (Motschisky)	polyphagous
	<i>Gallerucella grisescens</i> (Joannis)	polyphagous
	<i>Altica</i> sp	polyphagous
	<i>Cassida nebulosa</i> L.	polyphagous
	<i>Aulacophora indica</i> (Gmelin)	polyphagous
	<i>Psylliodes punctifrons</i> (Baly)	polyphagous
	<i>Gallerucella placida</i> (Baly)	polyphagous
Hispidae		
	<i>Dactylispa angulosa</i> (Solsky)	polyphagous
Hemiptera-Heteroptera		
Coreidae		
	<i>Hygia touchei</i> (Distant)	polyphagous
	<i>Cletus bipunctatus</i> (Herrich-Schaefer)	polyphagous
Miridae		
	<i>Crenotidaes</i> sp	polyphagous
Pentatomidae		
	<i>Erthesina fullo</i> (Thunberg)	polyphagous
	<i>Dolycoris baccarum</i> (Linnaeus)	polyphagous
Lepidoptera		
Geometridae		

<i>Timandra griseata</i> Peterson	polyphagous
<i>Ectropis</i> sp	polyphagous
Noctuidae	
<i>Spodoptera exigua</i> (Hubner)	polyphagous
<i>Trachea atriplicis</i> Linnaeus	polyphagous
Hymenoptera	
Tenthredinidae	
<i>Allantus fusipennis</i> (Smith)	polyphagous

### Active constituents present in *Polygonum*

A number of compounds such as tannins, saponins, flavonoids and sesquiterpenes have been isolated. These compounds are active against Gram positive bacteria. The main constituents of the essential oils were (E)  $\beta$ -farnesene, phytols, caryophyllene and nerolidol. Different flavones such as 6, 7-methylenedioxy-5,3,4,5 tetra methoxyflavone and a methyl flavonol:6,7-4,5-dimethylene dioxy -3,5,3-trimethoxyflavone have been isolated. Nine compounds including emodin, chrsophanolrchin, 6-hydroxy-emodin, emodin 8- $\beta$ -D glucoside, polygonimitin  $\beta$ ,2,3,5,4 tetrahydroxystilben-2- $\beta$ -D-glucoside, gallic acid and unknown glycoside have been identified. Further, kampferol, quercitrin, galic acid, afzelin, o-methyl-quercetin are present in this weed. Another study indicated presence of isoquercitin, methyl gallate, 5-rutin, 1-luupol,  $\beta$ -sitosterol-3-o- $\beta$ -D-glucoside. A triterpene compound – sequalene (47.01%) and a plasticizer compound 1, 2-benzenedicarboxy acid, mono L-2-ethylhexyl ester (40.30%) have been isolated, and these compounds exhibited antimicrobial activity. Sitosterone, viscozulenilic acid, acetophenone are identified, which indicated free radical scavenging activity. A new anthraquinone glucoside 1-hydroxy-8-methoxy-3 methyl-6-o- $\beta$ -D-glucopyranosyl recently have been isolated from this weed.

### Problems of *Polygonum* weeds

Aquatic weeds are major impediments in rice production as they compete with rice for nutrients thereby reducing nutrient availability for the crop. The heavy infestation by the aquatic weeds in the rice-field results 62–75 % loss in grain yield depending on the field condition such as dry-seeded rice, wet-seeded rice, and transplanted rice. One such weed of Polygonaceae family is *Polygonum orientale* L., which belongs to Persicaria section, is native to India, Malaysia and China, and is widely distributed in North America, Europe and Asia [21, 22]. The adaptive capability of this herbaceous weed is often troublesome in rice-fields and elsewhere [21, 22]. Use of biological control agents such as herbivores is a method to combat weeds without interfering with the cropping system. The chrysomelid, *Galerucella birmanica* cause complete defoliation of *Trapa* spp. plants in Asia [23]. The presence of *Gallerucella placida* Baly (Coleoptera: Chrysomelidae) has been recorded on *Polygonum glabrum* in India [24]. The adults and larvae of *G. placida* also feed on *Persicaria hydropiper* in Australia [25]. The insect is widespread from Pakistan to Vietnam [26, 27] and occurrence of the insect is also noted on *Rumex* sp in Java [28]. The insect is harmless in the crops as it feeds on weeds [28]. The black larvae and adults of *G. placida* feed voraciously leaves of *P. orientale* L in rice-fields of India particularly in West Bengal. The insect breeds freely in the winter and until April in the rice-field weed, *P. orientale*.

### Ecological Implications of insect plant Interaction

The extraordinary species richness of plant-feeding insects is a salient feature of terrestrial biodiversity. It is therefore not surprising that insect-plant interaction has been a prominent model in the modern revival of interest in diversification. Full understanding of the diversification of phytophagous insects will require both detailed analysis of speciation mechanisms, and ecological study of this diversification patterns. Special attention has focused on the evolution of diet breadth, namely, the diversity of host plants fed on by a single herbivore species. Restriction to a small subset of the available plants is a dominant feature of phytophagous insect ecology. In addition to demanding an explanation in its own right [4], it has made herbivorous insects a leading example for investigating the ecological consequences of specialization. An understanding of the behavioral processes involved in selection of a host plant can be used to improve the accuracy of host specificity testing by biocontrol practitioners and others interested in predicting field host use. These behavioral processes include the sequential nature of host selection behavior, the effects of experience, and time-dependent changes of host acceptance or rejection. However, only little is known on the mechanisms how these factors affect an insect, and, moreover, how they act in concert. Knowledge on the receptors by which insects perceive plant cues as well as more information about the enzymes and transport proteins necessary for digestion and detoxification will show us which physiological and molecular changes are necessary to successfully use a host plant.

Most herbivorous insects are specialized to particular host tissues, such as leaves, flowers, fruits, seeds, stems, or roots, in addition to particular host taxa. On any one plant part, moreover, insects are typically specialized for one of a great variety of feeding modes. For example, a partial list of feeding behaviors exhibited by insects that eat leaves includes galling, mining, leaf rolling or tying, and external folivore. The relative rates of evolution of the various niche dimensions are fundamental to assessing their roles in phytophagy diversification. Thus, in future numerous ecological and behavioral studies as well as quantitative genetic analyses are needed to provide a deeper insight into the ecology and evolution of host location behavior in insects.

The present review highlights certain basic information regarding the chemical analyses of some primary and secondary substances, particularly secondary ones from leaf (i.e., alkanes, free fatty acids and volatile organic compounds) from *Polygonum* weed and their interaction with the insect. For assessing the role of attractiveness of the secondary chemicals, a series of olfactory bioassay with the female coleoptera was done using different concentrations of n-alkanes, free fatty acids and volatile organic compounds from leaves from *Polygonum*. This review adds valuable information regarding the combination of certain secondary chemical substances in different concentrations which might be helpful in developing a lure to monitor field population. This review also embodies basic information involving the life cycle and reproductive behavior of the beetle, by feeding on leaves of *Polygonum* plants, which might help in efficient control strategies of the weed.

## Conclusion

Finding of secondary compounds from Polygonum weed leaves and flowers that are causing attraction/oviposition of the biological control agent might help to strengthen the newly emerged area of plant-insect interaction study, i.e., chemical ecology. The secondary compounds such as alkanes, fatty acids, monoterpenes or other volatile compounds from the weed leaves could be applied during the initial stage of the weed emergence in a rice-field for early defoliation of weed by the potential biocontrol agent *Gallerucella* sp.

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