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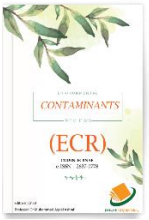

RESEARCH ARTICLE

HYPENA OPULENTA: A BIOLOGICAL WEED CONTROL AGENT FOR CONTROLLING AN INVASIVE WEED SPECIES, SWALLOW-WORT: A REVIEW

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ABSTRACT

Biological weed control agents are eco-friendly measures of controlling various weed species. They are the living organisms which kill or suppress the growth of another organism. This paper aims at organizing the scientific research finding and providing information about biological control of an invasive weed species, Swallowwort of Southern Ottawa region of Canada. *Hypena opulenta*, leaf feeding moth (Lepidoptera: Erebidae) is an effective bio-agent for controlling invasive plant species, Swallowwort *(Vincetoxicum). Vincetoxicum* is native to Mediterranean regions of France, Italy, and Spain and typically grows in calcareous soils on forested slopes. It was introduced to North America (Ontario, Canada) in 19th century. It is found in wide range of habitat that is from agricultural field to the forests and plantations making several adverse impacts in the respective ecosystems of the region. Overwintering Pupa of Leaf feeding moth emerges as an adult and starts laying eggs after 2 days. Eggs are deposited on upper or under side of the main vein and petioles of leaves. Larvae of *H. opulenta* feed exclusively on newly expanded leaves of the plant for completion of its developmental cycle. Though the larvae show the minimal feeding on other plants but they necessarily require *Vincetoxicum* species as a host for completion of their life stages. Before releasing larvae of *H. opulenta* for control of *Vincetoxicum* in the field they were tested in the lab for host specificity and environmental safety. Larvae of *H. opulenta* can spread up to the distance of 100 m from release site and control the growth of swallow-wort by feeding on newly emerged leaves which results in reduced shoot biomass and seed multiplication of the plant.

KEYWORDS

Vincetoxicum, weed, *H. opulenta*, plant.

1. INTRODUCTION

With the increased realization of several negative impacts of chemical weed control such as herbicide resistance, phyto-toxicity and weed flora shift, people's concern on biological weed control has increased in recent days. Biological control method uses a living organism to hamper the growth or to kill another organism. Bio-agents for biological weed control may be specific to the certain weed species or may have wide host range, some affecting the crops also. Bio-agents can be any living organisms such as insects, mites, cattle, goats and other grazing animals, ducks, fish, snails, DRBs, Fungi and botanical agents.

Vincetoxicum rossicum and *Vincetoxicum nigrum,* belonging to the Milkweed family (Asclepiadaceae), commonly referred to as pale swallow-wort and black swallow-wort are invasive plant species of Northern America (Douglass et al., 2009). Swallow-wort was introduced to America in 19th century from Ukraine since then its population has been established throughout the region and is increasingly become ecological threat (Douglass et al., 2008).With no native herbivores to feed on it, it spreads rapidly outcompetes the native species. These two species of swallow-wort are invasive in both disturbed and undisturbed upland natural areas and are increasingly impacting agronomic systems such as horticultural nurseries, perennial field crops and pasture land. It has been found more problematic in all of the Eastern US, Mid-west, and southern Ontario and Quebec of Canada (Ditommaso et al., 2005). Negative impacts the weed includes; disruption of plant succession pattern, threat to the habitat of endangered plants, monocultures shade out background vegetation, monocultures decrease arthropod diversity and community composition, toxic to livestock (Tewksbury and Lisa, 2019).

As a solution of this problem scientist introduced a biological weed control agent, *Hypena opulenta* Christoph (Lepidoptera: Erebidae), commonly known as leaf-feeding moth. *H. opulenta* is native to Ukraine and was collected in 2006; previous to this there was no record of this moth (Hazel). Development cycle of *H. opulenta* from egg to adult is completed in about 5-6 weeks with 5 larva instars which feed voraciously on leaves of swallow-wort, defoliating the plant completely during the development cycle (Casagrande et al., 2010). This article aims at assessing the various researches that are being done for exploring biology, host specificity as well as efficiency of *H. opulenta* for controlling the invasive weed species that is *V. rossicum* and *V. nigrum* including the findings of previous researches on these topics.

2. MATERIALS AND METHODS

This review paper is based on various research papers, journal articles, books, documents from websites and reports available online and offline. Data and information required for making this paper informative,

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conclusive and comprehensive were taken from various research papers, journals, books, project results, conference reports and documents on website which are based on various researches and observation about Swallow- Wort and its control by using leaf feeding moth (*H. opulenta*).

3. Swallow-wort (Genus: *Vincetoxicum*): An Invasive Species of Weed

Swallowwort or dog strangling vine is a perennial herbaceous plant with woody rootstalk and can grow up to the height of 0.6 to 2m. Stems are twinning or climbing type and covered with fine hairs. Leaves are opposite, green with entire to wavy margin ranging in size from7 to 12cm in length and 5 to 7 cm in width. Leaves are roundish and narrow at the tip. The plant flowers in late June and July producing 5-20 flowers in cluster at the axils of leaves which are red- brown or maroon to pinkish in color. Fruits are formed in late July and August. Fruits of this species are long, slender and pod like. There are two smooth pods at each leaf axil and the pods are 4-7 cm long. Pods contain milky sap and turn from green to light brown in color. Seeds are attached to feathery tufts of hair that facilitates the easy dispersal of seeds through wind (Ramanujan and Krishna, 2018).

Vincetoxicum is native to Mediterranean regions of France, Italy, and Spain and typically grows in calcareous soils on forested soil. It first arrived in Ontario through a horticultural or accidental introduction and was further introduced multiple times in different regions. The province's first recorded specimen is believed to have been collected in Toronto in 1899 (Anderson et al., 2012). In Ontario, Canada; it can be found in wide range of habitat including crop field, shrub thickets, lake coasts, stream banks, forests and plantations. It reduces the vigor and reproductive potential of forest that is invaded by it and also dominates the ground cover in the gaps between canopy and hence hampering the entire forest ecosystem (Kricsfalusy and Miller, 2008).

It is increasingly abundant in agricultural fields and pasture lands across Ontario and is gradually moving towards maize and soybean field. Heavy growth of the vine has increased the risk of short-circuit of electric wires around the pasture. Moving of livestock can also be difficult due to the dense mat of the vines over the ground. Besides invading forests and agricultural fields, the vine growth inhibits the recreational activities in the area and also reduces the aesthetic value by reducing the number and variety of native species. Growth of swallow-wort has adversely affected the diversity of arthropods in the region and it has indirectly affected monarch butterfly by acting as false host which provides the site for oviposition for monarch butterflies but do not provide food for them.

4. Biology of *H. Opulenta*

Hypena opulenta overwinters as pupa and moths emerge in late-winter. Adult starts laying eggs 2 days after emergence and produce approximately 600 eggs. Egg production is peak shortly after initiation with daily decline in egg production over time. Eggs are deposited on the upper and under sides of host plants along the main veins (Winston, 2017). Larva undergoes five instars and takes 4-6 weeks to develop. Larvae have been reported to feed on the leaves of *Vincetoxicum rossicum* in the wild. Larva is also a key which separates *H. opulenta* from others species of *Hypena* in the Northern America (Young and Weed, 2014).

Pupation occurs either within the host plants within the leaves tied with the silk or in the ground within the leaf litter. Pupal diapause is facultative, resulting in at least two generations per year (Casagrande, 2011). Diapause induction is affected by photoperiod and seasonal change in plant quality as evidenced by increasing diapause induction when larvae are gown under a short day photoperiod and on senescing plants in the fall (Casagrande, 2010).

5. Host Specificity and Larval Feeding

*H. opulenta*is specific for the control of genus *Vincetoxicum* however, minimal feeding can be observed in *Urticadioca* and *G. stephanotrichus* also but larval development can't be completed in these species (16). Larva mainly attacks on newly expanded leaves of the plants as they are soft and chew them voraciously during the entire larval phase. Only 2 larvae per plant are enough to reduce shoot mass, seed multiplication and also to some extent root growth (Doubleday and Cappuccino, 2011). Larval host range of this moth has been tested in 79 species of following families but pupal stage completed successfully only in *Vincetoxicum* (Weed and Casagrande, 2010):

S.N	Family	No. of species tested
1	Apocynaceae	48
2	Gentianaceae	4
3	Loganiaceae	1
4	Gelsemiaceae	1
5	Rubiaceae	9
6	Scrophulariaceae	2
7	Asteraceae	6
8	Cannabaceae	1
9	Convulvulaceae	1
10	Urticaceae	6

Complete larval stage or up to certain instars, *H. opulenta* can be raised on the plants of family Urticaceae however, pupation can't take place in these plants (Weed and Casagrande, 2010). Pupal development and oviposition of this moth seems to occur only in *Vincetoxicum* plants more specifically in *V. rossicum.* Extensive research on H. opulenta has shown that it can only develop on Vincetoxicum spp. and poses no risk to native North American plant species. This insect species causes extensive defoliation of V. nigrum and V. rossicum, reducing aboveground biomass, flowering, seedpod production and number of seeds of V. rossicum in the following year. The multiple, overlapping generations of H. opulenta is known to have a substantial impact on Vincetoxicum spp. under field conditions – particularly in the shade. Repeated defoliation over several years should facilitate interspecific competition in mixed plant communities and potentially significant reduction in Vincetoxicum populations (Casagrande, 2013).

6. Weed Control Mechanism of *H. Opulenta*

The insect, *Hypena opulenta*, was first identified by URI and CABI researchers as a potential biological weed management tool in 2006.The moth larva was released in 2013, as a biological control agent for pale swallow wort (*Vincetoxicum rossicum*), an invasive vine, in Ottawa, Ontario, Canada. Before introducing the moth in the wild, it was tested in laboratory for its host specificity and environmental safety through no choice larval development test and some test for fecundity were also carried out (Milbrath et al., 2016; Milbrath and Biazzo, 2013). In lab, the moth larvae successfully fed on both pale and black swallow-worts. Following testing, AAFC scientist permitted for the release of larvae in late 2013 in Canada. Results are encouraging till date, *Hypena* caterpillars released by AAFC and Carleton University in Ottawa area in 2014, overwintered successfully in field cages during 2014/15 winter. From both this release and subsequent release in 2015, there was confirmed second generation of larvae. Various surveys and black light trapping has shown the feeding damage and spread up to 2km from the site of release (Bourchier, 2019).

Though minimal feeding of the moth larvae has been recorded in some others plants of Urticaceae family, moth completes its development cycle only in *Vincetoxicum rossicum* (Swallow-wort) belonging to the family (Asclepiadaceae) (Hazelhurst et al., 2012). Overwintering pupae emerges as the moth in late-winter and starts laying eggs on the under and upper side of the main veins and petioles of leaves of *Vincetoxicum*. Larvae on emergence start feeding on the leaves and goes through 5 instars to complete their larval stages in about 4-5 weeks. Only 2 larvae per plant are sufficient to reduce the plant growth. Larvae feed exclusively on newly emerged, expanding leaves of the plant resulting in complete defoliation of plant (Weed and Casagrande, 2010; Hazelhurst, 2012). Low light intensity may enhance the impact of defoliating agent but defoliation is not often enhanced by very low light. Defoliation of plants at the site of release is easily detectable and yellowing of entire plants in response to the insect feeding on just few leaves is seen. Adult moths and larvae of the insect are able to spread up to 100 m from the site of release but once they become established and increased its abundance they can spread up to 2 km and effectively defoliate the weed plants (Casagrande, 2011). Larval feeding results in reduced shoot biomass, seed multiplication and hence the weed growth and dispersal. Complete defoliation repeated within and across the years may be needed for suppression of forest infestation of swallow-wort.

7. Conclusion

H. opulenta, leaf feeding moth can complete its life cycle only on swallow-wort (*Vincetoxicum* species) without causing significant harm to other plant species. The insect larvae feed on and defoliate the leaves of the plant

and only two larvae per plant are sufficient for the reduction of shoot biomass and seed multiplication. A single generation of the insect has significant effect in reduction of weed biomass in the region and also seed bank for the following season. Defoliation is often triggered by low light condition. Multiple and overlapping generation has great effect in weed control through reduced biomass due to defoliation and reduced competing ability of *Vincetoxicum* species. For controlling *Vincetoxicum nigrum* and *V. rossicum* in crop field multiple and timely release of this insect can be the best solution. Till now the result from the release of this insect for controlling swallow-wort are encouraging and this method has been found to be more effective than other conventional method. As this insect species does not possess any risk to other non-target plant species and is ecologically sound, this can be the best option for controlling increasing population of the weed in North America.

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