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Genomic and Chemical Approaches to Weed Control in Pasture

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Abstract: Weeds can be defined as plants that grow where peoples do not want them to grow. It competes with major desirable plants in pastures for resources such as light, soil moisture and nutrients. There are different methods to control these serious weeds in pasture including the use of chemical herbicides (such as phenoxy, benzoic, or picolinic acid herbicides), physical removal (using tillage, root plowing, clipping and hand weeding), biological agents (using of natural enemies such as insects, fungi and animals), burning and integrated weeds management (combines cultural, mechanical, biological and chemical weeds control practices to keep weeds pressure below the threshold levels that can reduce yields qualities and quantities). Different types of natural enemies that can be used in biological control of weeds include fungi, insects, animals and nematodes. There are three types of biological control methods, which include classical, inundative and herbivore management. The purpose of this paper is to review recent advances in biological weeds control in pastures.

Key words: Weeds · pasture · biological control · genomics

INTRODUCTION

Weeds are a serious problem in pastures. Weeds compete with major desirable plants for resources of soil moisture and nutrients [1]. Weeds in pasture compete strongly with desirable plants because of their vigorous growth habit; weeds are usually characterized by root systems which are often more wide than those of useful plants.

Weeds growing at anytime in the land may consume a large amount of water and nutrients, which would otherwise be available for useful plants production in the pasture. There are different methods to control undesirable plants, which include using of chemical herbicides [1], physical removal [2, 3], using biological agent [4, 5], burning and integrated weeds managements [6, 7]. Biological weeds control relies on the use of natural enemies (insects, fungi and animals) to keep weeds pressure below threshold levels that can reduce yields and profits. Biological weeds control methods could be considered the best way to reduce losses in rangeland production form undesirable weeds [8]. As discussed above, there has been a significant amount of research concerning the effects of effects of weed control methods in central Europe and in the USA and Canada. However, little has been published about the principles involved in the biological control of weeds and the current status of biological weed control in Pasture.

TYPES OF ENEMIES THAT CAN BE USED IN BIOLOGICAL CONTROL

There is evidence that different types of enemies can be used in biological control of weeds, which include: fungi, bacteria, and viruses insects and animals [9-12]. About the turn of the 20th century, a thought was put forward that plant pathogens could be beneficial for environment if they were used to control weeds. Now the introduction and release of biological control agents is regulated to make sure the safety of people and the environment.

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Fungal pathogens: Fungal pathogens have been used to obliterate undesirable weeds, or inhibit their growth and their ability to compete with desirable weed or crops in the pasture. These include *Entyloma ageratinae* to control Mistflower, *Ageratina riparia*; Rust, *Diabole cubensis* and the coelomycete *phloeospora mimosae-pigrae* to control giant sensitive plant, *M. pigra*; Head smut, *Sporisorium ophiuri* to control Itch grass, *R. cochinchinensis*; Drechslera gigantea, *Exserohilum longirostratum* and *E. rostratum* to control weedy grasses [13].

Insects: Using insect to destroy undesirable weeds, or slow down their growth and aptitude to compete with useful plants or crops in the pastures [14], such as [the use of the moth (*Cactoblastis cactorum*) to control prickly pear (*Opuntia* spp); flowerhead weevil (*Rhinocyllus conicus* Froeh) to control of Eurasian thistles of the genus *Cardus* L., including musk thistle; weevil to control Water hyacinth (*Eichhornia crassipes*); Solms Laubach (*Chelnidea tabulata*) to control prickly pear (*Opuntia* spp); Cinnabar moth (*Tyria jacobaeae)* to control Ragwort (*Senecio jacobaeae*); plume moth (*Dialectica scalariella*) to control Patterson curse (*Echium plantagineum* L.); *Ucona acaenae* Smith to control Piripiri (*Acaena* spp); *Procecidochares utilis* Stone to control Mexican devil weed (*Ageratina adenophora*); *Agasicles hygrophila* to control Alligator weed (*Alternanthera philoxerides*); *Rhinocyllus conicus* to control Nodding thistle (*Carduus nutans*); *Lema cyanella* to control Californian thistle (*Cirsium arvense*); *Exapion ulicis* to control Gorse (*Ulex europaes*); *Bruchidius villosus* to control Scotch broom, (*Cytisus scoparius*); *Lochmaea suturalis* to control Heather (*Calluna vulgaris*) and *Oxyptilus pilosellae* to control Hawkweeds (*Hieracium spp*)] [15]. Some Insect introduced as classical biological control agents agent of weeds can be seen in the Table 2.

Bacteria: Kremer *et al.* [16] reported that the majority of the bacteria with an aptitude to produce toxins are Gram - postive bacteria such as *Pseudomonas*, *Erwinia*, *Xanthomonas* but there are a small number of Gram - negative bacteria such as *Streptomyces*, *Corynebacterium fasciomonads* and some are non-fluorescent *pseudomonads*. Dye *et al.* [17] reported that there are 41 host range varieties of *pseudomonads. syringae* which are able to cause diseases on characteristic host plant species but induce defence in other plant. Bender *et al.* [18] reported that Coronatine, syringomycin, syringopeptin, tabtoxin, and phaseolotoxin are the most intensively studied phytotoxins of *Pseudomonas syringae*, and each contributes significantly to bacterial virulence in plants. Tabtoxin and phaseolotoxin are strongly antimicrobial and function by inhibiting glutamine synthetase and ornithine carbamoyltransferase, respectively [18]. Stephen and Lydon [19] reported that phytotoxins from *Streptomyces saganonensis* (herbicidines and herbimycins) is used to control grassy weeds as selective herbicide. Yufen and Zhang [20] state that phytotoxins (anismycins) from Streptomyces actinomycetes is used to control grassy weeds such as barnyardness and common crabgrass and broad- leaved weeds. It is mechanism is to destroy synthesis of plant chlorophl [20].

Herbivore: If a rangeland is infested with undesirable weeds, sheep and goats can be used to graze the undesirable weeds early in the growing season (to remove flowering /seed-producing structures before viable seeds are produced). Grazing at light stocking rates during the early stages of crop growth has the potential to suppress weed competition for moisture, nutrients and light, enabling the crop to outgrow the weeds. Because the grazing of undesirable weeds at reproductive stage can cause more weeds problems. Ghorbani *et al.* [21] suggest that grazing with 400 sheep per hectare for duration of 3 days is required for acceptable control of weeds in saffron field without any significant reduction in above-ground saffron biomass. Scientific research and experience has demonstrated that the most effective control strategies integrate several tools.

TYPES OF BIOLOGICAL CONTROL METHODS

Classical approaches: This approach involves the importation of insects, micro-organisms, and animals which feed or graze on a particular weed species. Some of desirable aspects of this method are that there are no chemical residues also, it has self-perpetuating and can extend on their own. Possible disadvantage include are not available for all target weeds, also, in most situations it control one species. Biological weed control has been practiced for over 200 years it has a good safety record and a respectable rate of success, despite some high profile criticism [22]. Julien and Griffiths [23] reported that over 1000 releases of more than 350 biological control agent species have been made against more than 100 target alien plants around the world. The concept involved in classical biological control is very simple. It is

Table 1: Bioherbicdes introduced in Canada and USA as Inundative biological control agents of exotic weed

Country (date)	Product/ pathogen	Exotic weed
USA: 1960	*Acremonium diospyri*	Persimmon (*Diospyros*
USA:1981	DeVine®: *Phytophthora palmivora*	Strangler vine (*Morrenia odorata*)
USA: 1982	Collego™: *Colletotrichum gloeosporioides* f. sp *aeschynomene*	Northern joint vetch (*Aeschynomene virginica*)
USA: 1983	CASST™: *Alternaria cassiae*	Sickle pod & coffee senna (*Cassia* spp.)
USA: 1987	Dr BioSedge: *Puccinia canaliculata*	Yellow nutsedge (*Cyperus esculentus*)
Canada: 1992	BioMal®: *Colletotrichum gloeosporioides* f. sp. *Malvae*	Round-leaved mallow (*Malva pusilla*)
USA: 2002	Woad Warrior: *Puccinia thlaspeos*	Dyers woad (*Isastis tinctoria*)
Canada: 2004	Chontrol™ = Ecoclear™: *Chondrostereum purpureum*	Alders, aspen & other hard-woods
Canada: 2004	Myco-Tech™ paste: *Chondrostereum purpureum*	Deciduous tree species
USA: 2005	Smolder: *Alternaria destruens*	Dodder species:

Table 2: Some Insect introduced as classical biological control agents agent of weeds

Weeds	Insects	Type of Damage
Canada Thistle	*Urophora cardui*	Stem gall fly
	Larinus planus	NA
	Ceutorhynchus litura	Stem and crown mining weevil
	Cassida rubiginosa	Defoliating beetle
Knapweeds	*Metzneria paucipunctella*	Seed head moth
	Larinus minutus/obtusus	Seed head weevil
	Sphenoptera jugoslavica	Root mining moth
	Cyphocleonus achates	Root boring weevil
Leafy Spurge	*Aphthona nigriscutis*	Root mining beetle
	Aphthona flava	Root mining beetle
	Aphthona cyparissiae	Root mining beetle
	Aphthona lacertosa	Root mining beetle
	Aphthona spp	Root mining beetle
	Oberea erythrocephala	Stem mining and girdling beetle
	Spurgia esulae	Gall forming midge
Musk Thistle	*Trichosirocalus horridus*	Rosette feeding weevil
	Cassida rubiginosa	Defoliating beetle
Yellow Starthistle	*Bangasternus orientalis*	Seed head weevil
	Eustenopus villosus	Seed head weevil
Poison Hemlock	*Agonopterix alstroemeriana*	Defoliating moth
St. Johnswort	*Chrysolina quadrigemina*	Foliage feeding beetle
	Aplocera plagiata	Leaf eating moth
Rush Skeletonweed	*Eriophyes chondrillae*	Gall mite
	Cystiphora schmidti	Leaf & stem gall fly

Adapted from Integrated Weed Control Bozeman, Montana, 2007.http://www.integratedweedcontrol.com

based on the hypothesis that plant populations, once freed of their natural enemy's multifaceted, can expand fast and so, become more competitive, than those subject to natural control. Therefore it is very important to set up biological control agents that can restore the natural checks and balances that control exotic weeds in their native habitats. Worldwide, classical biological control has successfully controlled introduced weeds on numerous occasions. In North America, there have been successes in controlling nodding thistle (Canada; Kansas, U.S.), ragwort (British Columbia, Canada; California and Oregon, U.S), klamath weed (Ontario, Canada; California, Oregon and southeast Washington, U.S.) alligator weed (Florida, Louisiana, and Texas, U.S.), and water lettuce (Florida). Classical biological control has internationally recognized standards and procedures under the International Plant Protection Convention [24], the Organization for Economic Co-operation and

Development [25] and the European and Mediterranean Plant Protection Organization [24,26].

Genomic and biochemical approaches: This approach involves controlling of weeds by using tools of genomics and biochemistry.

Fundamentally, genomics involves the use of molecular methods to study the structural and the function of a species genome and the gene product in a large-scale. This approach has significantly improved our understanding of several model plants such as *Arabidopsis* [27], and has been successfully applied to several agro-economically important plants such as rice [28]. Genomics has also utilised in improving in several certain crop traits, including quality characteristics and herbicide and insect resistance. We believe that advances in genomics can be used as useful tools in increasing our understanding of weeds and their management in different agricultural ecosystems.

Genomics can be used to determine the genes involved in a crops' competitive ability, identifying genes involved in the production of allelochemicals for natural weed control, genes for safening crops against specific herbicides. Moreover, genomics can be used to study characteristics which affect weed fitness, competitiveness, and adaptation of weeds in different agricultural ecosystems. This information provided by genomics is prerequisite for the development of improved management strategies to enhance crop production [29].

Genomics has been used in studying weed invasions and hybridization between different species [30-32]. Genomics can be used to identify the genes that would weaken a weeds' competitive ability. Once these genes are identified and isolated they can be introduce into an out-crossing weeds and, over time through sexual recombination, this will result in a less fit weed type (reference to this paper). Isolated genes involved in the competitive ability of weeds will be useful to the growth and resource utilization of crops and allow the development of crops that produce allelochemical compounds for natural weed control [33]. There is a growing interest in allelopathy research in weed control and management [34]. Using genomic allelopathic pathways can be manipulated to produce natural herbicide with a high management potential.

Using genomic tools gene flow between weedy species and crop plants, which is called introgression, can be investigated. Understanding introgression can shied light on weed - crop relationship the genetic factors controlling this interaction. Such investigations are important to understand the evolution and adaptation of weed species which maybe help in management programs [13].

Genomics can also be an effective tool to manipulate biocontrol agents of bacterial and fungal compounds. It is possible to isolate responsible genes and genetically engineering them to increase their potential virulence on weeds but not on crop plants [35, 36].

Current international research in weed control: It has been more than 200 years since control of weeds based on biological method was applied. The American Asa Fitch (1809-1879) was the first to advice biological control of weeds around 1855, when he noticed that a Eurasian weed in USA pastures had no American insects feeding on it. He recommended that introduction of European insects feeding on this weed might resolve the problem [37]. Li *et al.* [38] reported that real microbial herbicides by meaning began to be studied in the middle stage of the last century and urbanized quick with advance of phytotoxin science. During the last ten years, some phytotoxins screened from pathogenic weeds showed potential herbicide activity [38]. The first bioherbicide registered in Canada was in 1992 under the trade name of "BioMal". It was formulated from the fungus Colletotrichum gloeosporioides f. sp. malvae to control round-leaf mallow (*Malva pusilla*) in eight field crops. On the other hand, second bioherbicide registered was Myco-Tech Paste in 2002. It was formulated from the fungus *Chondrostereum purpureum* strain HQ1, intended to inhibit regrowth of deciduous tree stumps in rights-of-way and conifer release management situations in boreal and mixed forests east of the Rocky Mountains in Canada [39]. In USA, Johnson is the first scientist who studied *Xanthomonas* as bioherbicde and screened many *Xanthomonas* Campestris pv. Poannua for controlling annual bluegrass (*Poa annua* L.) in burmudagrass (*Cynodon dactylon* L.). In Japan Imaizumi *et al.* [40] reported that *X. campestris pv.* poae has great potential for controlling annual bluegrass without harming desirable turf grasses such as creeping bentgrass (*Agrostis palustris*) and Kentucky bluegrass (*Poa pratensis*). Gronwald *et al.* [41] have deliberated the effect of *Pseudomonas syringae* pv. *tagetis* (Pst as a biocontrol agent for Canada thistle in growth chamber and field experiments, and found that foliar application of Pst (10^9 cfu ml^{-1}) plus Silwet L-77 (0.3%, v/v) on 4- to 5-wk-old Canada thistle reduced shoot dry weight by 52% (measured 14 d after treatment) and chlorophyll content of emerging leaves by 92% (measured 10 d after treatment).

In Quebc, Canada, Dr. Alan Watson's Weed Research Group form McGill University has been developing biological weed control strategies using the weed's own natural enemies, diseases and insects, to kill the weed. They found that *Sclerotinia minor* advances fruiting and reduces germination in dandelion (*Taraxacum officinale*). The Bioherbicdes introduced in Canada and USA as Inundative biological control agents of exotic weed can be seen in Table 1.

ADVANTAGES OF BIOLOGICAL WEED CONTROL

The most commonly cited benefits of biological weed control include (i) it is cheap (ii) it has little danger to non-target organisms (iii) it has self perpetuating and can extend on their own (iv) it provides a long-term crash on the target plants (v) are more environmentally friendly (vi) it is highly selective.

DISADVANTAGE OF BIOLOGICAL WEED CONTROL

A number of concerns should be considered when deciding to use of biological weed control. These concerns include (i) biological control agents are not available for all target weeds (ii) it takes long time of research and testing before agents are released (iii) shift in weeds species (iv) it takes place slowly compared with other weeds control methods.

INTEGRATING BIOLOGICAL CONTROL INTO WEED MANAGEMENT

Integrated weed management programs in pastures combines cultural (e.g managing fertilizer rates, timing and placement, planting more competitive varieties) mechanical (using tillage, root plowing, clipping and hand weeding), biological (using natural enemies insects, fungi and animals) and chemical (rotating herbicides with different mode of action) weed control practices to keep weeds pressure below the threshold levels that reduce yields qualities and quantities [42]. It is very important to integrate two or more control methods into a system of management.

CONCLUSIONS

With the development of sustainable agriculture and consciousness of human environmental protection, biological control agent can be considered the best choice to control unwanted weeds in pastures and should be included in any weeds management program because it has a lot of environmental benefits. As well the successful biological control will, at best, reduce the vigour, abundance and economic losses caused by the weed in pasture. To ensure high crop yield, weed management programs require holistic approach rely on classical, genomic and biochemical methods. Using single approach maybe not suitable to ensure proper weed management due to the high cost or and the effect on crop plants and environment.

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