Review Article

Indian Journal of Plant and Soil
Volume 10 Number 2, July - December 2023
DOI: http://dx.doi.org/10.21088/ijps.2348.9677.10223.3

Biological Control of Weeds

Neeshu Joshi[1], U.N. Shukla[2], H.P. Parewa[3], B.L. Meena[4]

How to cite this article:
Neeshu Joshi, U.N. Shukla, H.P. Parewa *et al*. Biological Control of Weeds. Indian J Plant Soil. 2022;10(2):77–84.

Abstract

The escalating environmental and anthropogenic challenges have propelled the biological approach to the forefront of integrated and sustainable weed control strategies. With a historical background spanning century, the success of using biological agents for weed control takes center stage in this chapter. Our exploration begins with a classical perspective on the biological approach, shining a spotlight on arthropods, particularly insects. A unique angle introduced involves the redistribution of local arthropods as a nuanced method for effective weed control. Transitioning to the bioherbicide section, we delve into the realm of formulated natural products and their diverse formulations, recognizing their pivotal role in biological weed control.However, the landscape of biological weed control is not without its challenges. Financial constraints, side effects, and divergent opinions pose hurdles that warrant attention. Yet, despite these challenges, the narrative maintains an optimistic outlook. The underlying belief is that, in the future, biological methods will evolve to offer not only effective but also sustainable solutions for weed control practices. In essence, this abstract navigates through the historical successes of biological weed control, explores specific facets such as arthropods and bioherbicides, confronts existing challenges, and ultimately anticipates a future where biological methods emerge as more promising and sustainable players in the field of weed control.

Keywords: Biological Weed Control; Arthropods; Bioherbicides; Sustainable Agriculture; Weed Control Practices.

Author's Affiliation: [1]Department of Agronomy, College of Agriculture, Agriculture University, Nagaur, Jodhpur 341001, Rajasthan, India, [2]Department of Agronomy, College of Agriculture, Agriculture University, Mandore, Jodhpur 342002, Rajasthan, India, [3]Department of Soil Science, College of Agriculture, Agriculture University, Angor, Jodhpur, Sumerpur 306902, Rajasthan, India, [4]Department of Agronomy, Agriculture University, KVK, Gudamalani, Jodhpur 344031, Rajasthan, India.

Corresponding Author: Neeshu Joshi, Department of Agronomy, College of Agriculture, Agriculture University, Nagaur, Jodhpur 341001, Rajasthan, India.

E-mail: neeshu.joshi@gmail.com

Received on 14.09.2023

Accepted on 20.10.2023

INTRODUCTION

Ever since the first cultivation systems were developed for food production, farmers of all generations and areas have been faced with the problems of non crop plants growing amongst the crops. These non-crop plants, which compete with the crops for moisture, light, nutrients and space, have long been known as weeds. The weeds often cause many problems to farmers as they are difficult to control and are being used as an insult to other humans, inferring lack of courage or strength. Yet thin, spindly and pale weeds often have the resilience and ability to compete with the crop plants. A weed can be thought as any plant growing in the wrong place at the wrong time. In crops, weeds can cause problems of severely reduced yields and also affect the efficient use of machinery.

So effective weed control is therefore an essential part of crop husbandry and has traditionally been a labour intensive operation of controlling the weeds. In less developed countries, the situation of labour shortage still exists where the peak labour requirement is often for hand weeding *(Rogers, 1979)*. If this labour demand cannot be met, then the crop must be grown on a smaller area that would otherwise be economically viable. Some herbicides have also been developed which are a challenge worth combating as in methods of weed control in systems, herbicides are too expensive or ineffective to use. Thus, with the much greater public awareness of food and environmental issues, it is probably worth looking at weed control from a wider perspective specially non-chemical weed control.

Weed Competition

At this stage it is worth considering some basic aspects of weed management, before looking in detail at the techniques available for non-chemical weed control. Awareness about the common weeds in the crop fields is important, so operations such as cultivations, sowing and weeding can be timed according to the peak germination periods of the predominant species.

Crop rotations, one option for weed control in the cropping system, should be designed such that the differences in the timing of seedbed cultivations prevent one weed species becoming dominant *(Lockhart et al., 1990)*.

Why are Weeds Important?

In a review of crop losses due to pests, it was stated that: overall, weeds produced the highest potential loss (34%) with animal pests and pathogens being less important (losses of 18% and 16%) *(Oerke,2005)*. Herbicides accounted for 46% of global pesticide sales in 2005, with insecticides (26%) and fungicides (23%) accounting for smaller proportions of the $33,600 million total spend *(Agrow, 2006)*.

The problem with Weeds: Weeds compete with crop for space, light, moisture and soil nutrients thus causing reduction in yield. It causes health problems to human beings. For example, Parthenium hysterophorus. Similarly, morning glory is beautiful in the garden, but when it entwines corn stalks, it can destroy a farmer's crop. Heavy infestation by perennial weeds makes the land unsuitable for cultivation resulting in loss in its monetary value. Aquatic weeds that grow along the irrigation canals, channels and water streams restrict the flow of water. Aquatic weeds form breeding grounds for obnoxious insects like mosquitoes. They reduce recreational value by interfering with fishing, swimming, boating, hunting and navigation on streams and canals. For example, water hyacinth is beautiful in floating gardens but can rapidly clog water ways, making navigation impossible.

So, there are many methods of destroying weeds either by burning, pulling out or chopping down and treating them with herbicides. A combination of control methods is generally required to best manage these nuisance plants. Biological control holds much promise for long-term, economical and environmentally sensitive weed management.

Biological Weed Control

Origin: In ancient times, the Chinese discovered that increasing ant populations in their citrus groves helped decrease destructive populations of large boring beetles and caterpillars. That use of a natural enemy to control a pest marked the birth of biological control. Biological control research and implementation is even more relevant today. As a weed management method, biological control offers an environmentally friendly approach that complements conventional methods. It helps meet the need for new weed management strategies since some weeds have become resistant to certain herbicides. Biological control agents target specific weeds. Moreover, this technology is safe for applicators and consumers.

What is Biological Control of Weeds?

Biological weed control involves use of living organisms, such as insects, nematodes, bacteria, or fungi, to control the weeds. In biological control method, it is not possible to eradicate weeds but weed population can be reduced. This method is not useful to control all types of weeds. Introduced weeds are best targets for biological control. In nature, plants are controlled biologically by naturally occurring organisms called bioagents.

Qualities of Bio-Agent

1. The bio-agent must be host specific.
2. Must be free of predators or parasites.
3. Must readily adapt to environment conditions with sufficient reproductive capacity.

4. Must be capable of seeking out itself to the host.
5. Must be able to kill the weed or prevent its reproduction in some direct or indirect way.

Merits

1. Environmentally benign/eco-friendly since it does not lead to environmental pollution.
2. No residual effect.
3. Preserves bio-diversity.
4. Economical in the long run, although initially monetary investment is high.
5. Will not affect non-targeted plants and safer in usage.

Demerits

1. Requires/incurs higher initial cost.
2. Multiplication is costlier.
3. Control is very slow.
4. Weeds are not eradicated, but managed at a lower density.
5. The span of activity of bio-agent in most cases is small/narrow, whereas weeds may grow all through the year. For example, Parthenium hysterophorus grows all through the year, but Zygogramma bicolorata, the bio-agent is active only during rainy season for a period of 2-3 months starting from July.

How does it Work?

- Roots provide plants with water and nutrients. Some bio-agents attach to roots and there by stunt plant growth. Some bacteria release toxins that stunt root growth. Many fungi disrupt the water transport system, which reduces leaf growth. Beneficial insects and nematodes feed directly on the weed roots causing injury which allows bacteria and fungi to penetrate.
- Plant leaves capture energy from the sun and store it as sugar. Insects feeding on leaves reduce the leaf area available for energy capture. Fungi and bacteria infecting leaves reduce leaf ability to make sugars. In either case, there is less energy available for weed growth.
- Many weed species survive from year to year by producing seeds. Fungi or insects that attack seeds reduce the number of weed seeds stored in the soil, which in turn reduce the size of weed populations. This lowers the effort needed to control the remaining emerging weeds.

Some bacteria and fungi applied as biological control agents do not survive from year to year. These organisms must be applied on an annual basis. This technique is called the "*bioherbicide*" strategy. With this tactic, biological agents are used in manner similar to chemical herbicides.

Methods of Biological Weed Control

- Classical/Inoculative Biological Control.
- Inundative/Augmentative/Bio-Herbicide Biological Control.
- Broad-spectrum Biological Control.
- Allelopathy.
- Bio-dynamics.

Classical/Inoculative Biological Control

Classical/Inoculative biological control involves the release of bio-agents (insects, pathogens) *(Evans & Ellison, 1990)* just for once in the belief that it will readily adapt to the prevailing climate and multiply enough to keep pace with the multiplication rate of weed in question. Therefore, repeated release of bio-agent is not advocated. No augmentation and large-scale mass production of the bio-agent are practiced. It has been suggested that some of the introduced, invasive perennial weeds such as giant hogweed (Heracleum mantegazzium), Himalayan balsam (Impatiens glandulifera) and the Japanese knotweeds (Reynoutriaspp.) would be ideal candidates for classical biological control *(Child et al., 1993; Evans & Ellison, 1990; Fowler et al., 1991).* The introduction of a classical bio-control agent may not be deliberate. In this approach, a small amount of inoculum (pathogen) or insects, based on the assessment of weed problem and prevailing situation, is initially released in the standing population of weeds and allow it to multiply and feed on the weeds. The rust Pucciniala genophorae is of Australian origin where it attacks a range of Seneciospp. (Senecio vulgaris) *(Evans & Ellison, 1990).* The rust does not kill the weed but makes it less competitive. Higher yields have been recorded in lettuce experiments with rusted ground sel compared with rust-free plants *(Paul & Ayres, 1986).*

Inundative/Augmentative/Bio-Herbicide Biological Control

Inundative/Augmentative/Bio-Herbicide

biological control involves the culture and release of large numbers of a bio-control agent (inoculum) into the region or field where the target weed needs to be controlled. This inoculum is bio-herbicide. Bio-herbicides are native pathogens mostly fungi and hence called myco-herbicide. It has the advantage that native organisms can be used but there is the same requirement for host specificity *(Weidemann & Tebeest, 1990)*. Several inoculums such as fungi, bacteria, parasitic nematodes, viruses can be applied as sprays in the same way as conventional herbicides. Bio-herbicides are sprayed in every season on the target weed in crop field. The bio-agent generally remains active only on concurrent weed population. The specificity of a bioherbicide is increased where the susceptibility of the target organism can be enhanced. This may allow a selected area of a weed to be controlled without affecting near by plants of the same species. For example, Isolates of *Xanthomonas campestris pv. poae* have some activity against annual meadow grass, Poaannua *(Imaizumi et al., 1997)*. In groundsel *(Senecio vulgaris)*, plants naturally infected with the rust *Puccinia lagenophorae*, were killed by inoculation with the pathogen Botrytis cinerea, while healthy plants were not *(Hallettet al., 1990)*.

Table 1: Mycoherbicides (Bioherbicide) that have been registered and their targeted weeds, October 2008.

Product	Pathogen	Target weeds
Lubao	Colletotrichum gloeosporioides f. sp. cuscutae	Dodder in soybean
De Vine	Phytophthora palmivora	Strangler vine in citrus orchard
Colle go	Colletotrichum gloeosporioides f. sp. aeschynomene	Northern joint vetch in rice and soybean
CASST	Alternaria cassiae	Sickle pod and coffee senna in soybean and peanuts
Dr Bio-Sedge	Puccinia canaliculata	Yellow net sedge in soybeans, sugarcane, maize, potato and cotton
Bio Mal	Colletotrichum gloeosporioides f. sp. Malvae	Round leaved mallow in wheat, lentil & flax
Stump out	Cylindrobasidium leave	Acacia species in native vegetation and water supplies
Biochon	Chondrosteremum purpureum	Woody weeds like black berry in plantation forests
Camperico	Xanthomonas campestris pv poae	Turf grass in golf courses
Hakatak	Colletotrichum acutatum	Hakea gummosis & H. sericea in native vegetation
Woad Warrior	Puccinia thlaspeos	Dyers woad (Isastis tinctoria) in farms, rangeland, waste areas and roadsides

Broad Spectrum Biological Control

The oldest example of broad spectrum biological control is the use of grazing animals and birds to maintain pasture. In aquatic situations, the use of grass carp *(Ctenopharyn godonidella)* and other phytophagous fish has been investigated. In Australia, goats have been used to control blackberry *(Rubus fruticosus agg.) (Dellowet al., 1988)*. In cereals, sheep grazing in spring is a traditional practice of many organic growers to aid weed control. Weeding increased grain yield but grazing reduced ear number. It is known that different breeds of live stockvary in their grazing or browsing preferences and abilities and should be taken into account for improved weed control *(Soil Association, 2002)*.

Allelopathy

Within the broadening perceptions of biological control, allelopathy is regarded as a component of biological control *(Lovett, 1991)*. Allelopathy is derived from two Greek words, "allelon or allelo" means "mutual or each other" and "pathos or patho" means "suffering or to suffer." Molisch (1937) coined the term allelopathy, which includes all stimulatory and inhibitory reciprocal biochemical interactions among plants including microorganisms. The effect is exerted through the release of allelochemicals by the growing plant or its residues. Allelopathy has been considered a defence mechanism in plants *(Lovett,1982)*. It makes a significant contribution to the process of plant succession *(Numata, 1982)*. Allelo chemicals may be present in the mucilage around a germinating seed *(Kosemura et al.,1993)*, in leachates from the aerial parts of plants *(Tukey, 1966)*, in exudates from plant roots, in volatile emissions from the growing plant *(Charron et al., 1995)*, and among decomposing plant residues *(Bewick et al., 1994)*. The effectiveness of living mulches, intercrops or smother crops may in part depend on their allelopathic ability. While allelopathic crops or their residues inhibit the growth of certain weeds *(Steinsiek et al., 1982)*, weeds such as fat-hen (Chenopodium album) that has allelopathic ability, may also influence the growth of some crops *(Goel et al., 1994; Qasem & Hill, 1989)*. Weeds can also inhibit the growth of other weeds *(Anaya et al., 1988)*. Allelopathy could be used to manipulate the crop-weed balance by increasing the toxicity of the crop plants to the weeds.

There are two types of allelopathy: *(True and Functional)*

- *True allelopathy* involves the release of compounds into the environment and are toxic in the form they are produced.
- *Functional allelopathy* involves the release into the environment substances that are toxic as a result of transformation by microorganism.

Table 2: Allelochemicals and their functions

Chemicals	Impact
Sorgoleone and its hydroquinones	Inhibit chlorophyll formation and photosynthetic oxygen evolution
Coumarins and flavonoids	Blocks mitosis, seedling and germination inhibitor
Terpenoids	Germination and growth
Breviones	Etiolation of coleoptile (wheat)
Dehydroazulanin	Rapid leakage of plasama membrane and growth inhibitor
Strigolactones	Germination stimulants
Heliannauols	Enhance growth of monocots and restricts dicots

Biodynamics

Although not strictly part of biological control, biodynamics and related methods are included here because they rely on the use of natural materials for their effect. The control of perennial weeds by treating them with the potenced ashes of those particular weed or their seeds is one area of particular interest to organic farmers. There is little scientific information on how these so called weed peppers work. The principle is similar to the use of homeopathic medicines. *Scherrer (2000)* has begun testing the impact of weed peppers on *Solidago alissima* and S. gigantean but the treatments are expected to take several years of repeated applications to show an effect. Bio dynamically prepared compost applied to field crops reduced weed numbers but no more than non-biodynamic compost *(Carpenter-Boggs, 2000)*.

Outstanding and Feasible Examples of Biological Weed Control

a. Larvae of *Coctoblastis cactorum,* a moth borer, control prickly pear *Opuntiasp.*

Larvae of Coctoblastiscactorum

The larvae tunnel through the plants and destroy it. In India it is controlled by cochinial insects *Dactylopius indicus* and *D. tomentosus.*

b. Lantana *camarais* controlled by larvae of *Crocidosema lantana*, a moth bores into the flower, stems, eat flowers and fruits.

c. *Cuscuta spp*. is controlled by *Melanagromyza*

Steel Blue Beetle (Alticacvnanea)

Mexican Beetle (Zygogramma Bicolorata)

cuscutae.

d. *Cyperus Rotundus* - Bactra verutanaa moth borer.

e. Ludi wigia parviflora is completely denuded by Alticacynanea (steel blue beetle).

f. *Herbivorous Fish* - Tilapia controls algae. Common carp, a non-herbivorous fish controls submerged aquatic weeds. It is apparently due to uprooting of plants while in search of food. Snails prefer submersed weeds.

Table 3: Some examples of Biological Weed Control

Bioagent	Weeds
	Insect
Beetles: Octotoma scabripennis and Uroplata giraldi	Lantana camara
Scale insect: Dactylopius tomentosus.	Prickly-pear weed - Opuntia
Flea beetle: Agasicles hygrophyla	Alligator weed Alternanthera philoxeroides
	Fish
Common carp and Chinese carp	Aquatic weeds
Mammals: Manetee or sea-cow	Water hyacinth
Snails: Marisasp and other fresh water snails	Submerged weeds like coontail and algae
Fungi: Rhizoctiniab light.	Hyacinth
	Mites
Tetranychus sp	Prickly pear
Plants: Cowpea as intercrop in sorghum	Effectively reduces the growth of weeds in sorghum

Table 4: Factors Affecting Biological Success

Biotic Factors	Abiotic Factors	Procedural Factors
Plant Community: Host density, Succession	**Climate:** Temperature, precipitation	**Before release:** Site selection, colony source, collection method, shipment, sex ratio
Interactions: Predation, parasitism, competition	**Site characteristics:** Soil, slope, aspect, shade, moisture	**Release:** Method, Wrong agent or host, timing, life stage, documentation
Biological Organism: Synchronization, physiology, fecundity, behavior, genetic diversity, emigration	**Elevation:** Temperature, precipitation **Latitude:** Season, day length **Disturbance:** Fire, flood	**After release:** Site management, agent detection, vandalism **Personnel:** Training, experience, continuity, prioritization, follow up

Table 5: Exotic natural enemies field-released for Classical biological control of weeds in India.

Weed (Purported year of Introduction)	Agents Released (year) a	Establishment in the Field and Impact
Terrestrial weeds Ageratina adenophora (Spren gel) R. King and H. Robinson-1900	Procecidochares utilis Stone (1963)	Established - minimal control due to parasitoids
Chromolaena odorata (L.) King and H. Robinson -1914	Apionb run neonigrum Béguin Billecocq (1972) Pareuchaetes pseudoinsulata Rego Barros (1973and 1984) Cecidochares connexa (Macquart) (2005)	Not established Recently reappeared Established - too early to assess
Lantana camara L. (1809)	Ophiomyia lantanae (Froggatt) (1921) Teleonemia scrupulosa Stål (1941) Diastematigris Guenée (1971) Salbia haemorrhoidalis Guenée (1971) Octotoma scabripennis Guérin-Méneville (1972) Uroplatagirardi Pic (1972)	Established - not effective Established - provides minimal Control Not established Not established Established - not effective Established - not effective

table cont....

Mikania micrantha H.B.K(1914)	Puccinia spegazzinii de Toni (rust pathogen, 2005 Assam and 2006 Kerala)	Established in Kerala - too early
Opuntiaspp. (unknown)	Dactylopiuscey lonicus(Green) against Opuntia vulgaris Miller (1795) Dactylopius confusus (Cockerell) against O. vulgaris (1836) Dactylopius opuntiae (Cockerell) against Opuntia elatior Miller and Opuntia stricta (Haworth) Haworth var. dillenii (KerGawler) L. Benson (1926)	Established and provided excellent Control Not established Established and provided complete control of both species
Partheniumhy sterophorus L.(1955)	Zygogramma bicolorata Pallister (1984)	Excellent control in some areas
Aquatic weeds		
Eichhornia crassipes (Martius) Solms-Laubach (1900)	Neochetina eichhorniae Warner (1983) Neochetina bruchi Hustache (1984) Orthogalumna terebrantis Wallwork (1986)	Established - provides good to variable control Established - provides good to variable control Established - alone not very effective
Salvinia molesta Mitchell-1955	Paulinia acuminat a(Degeer) (1974) Cyrtobagous salviniae Calder and Sands (1983)	Established - uncertain control Established - spectacular control

All agents are arthropods except where indicated otherwise.

g. Weed like Parthenium hysterophorus completely controlled by a Mexican beetle (Zygogramma bicolorata).

CONCLUSION

Techniques for non-chemical weed control have been developed to reduce chemical costs in conventional agriculture, in response to environmental pressures and to provide for the needs of organic food production. A wide range of equipment is available to cover the major crops grown. Successful non-chemical weed control requires a well managed, integrated system and attention to detail. Future work is required to research the effects of heat from thermal techniques on soil micro organisms, weed seed germination and viability. The effects of the different soil/ weed combinations on the success of the weeding operation and on the soil structure also needs merit attention.

REFERENCES

1. Agrow (2006). Global agrochemical market flat in 2005. A grow No. 490, p. 15.
2. Anaya, A.L., Gliessman, S.R., Ortega, R.C., Rosado-May, R. and Rodriguez, V.N. (1988). Effects of allelopathic weeds used as cover crops on the floristic potential of soils. Proceedings 6th International Conference I.F.O.A.M. Global perspectives on agroecological and sustainable agricultural systems, Santa Cruz, California, USA, 607-624.
3. Bewick, T.A., Shilling, D.G., Dusk, J.A. and Williams, D. (1994). Effects of celery (Apium graveolens) root residue on growth of various crops and weeds. Weed Technology 8:625-629.
4. Carpenter-Boggs, L., Reganold, J.P. and Kennedy, A.C.(2000). Biodynamic preparations: Short term effects on crops, soils and weed populations. American Journal of Alternative Agriculture 15 (30): 110-118.
5. Charron, C.S., Cantliffe, D.J. and Heath, R.R. (1995). Volatile emissions from plants. Horticultural Reviews 17: 43-72.
6. Child, L.E., De Waal, L.C. and Wade, P.M. (1993). Herbicides - is there a better way to control Fallopia japonica. Communications of the 4th International Conference I.F.O.A.M.N on Chemical Weed Control, Dijon, France, 225-232.
7. Dellow, J.J., Mitchell, T., Johnston, W., Hennessey, G. and Gray, P.(1988). Large area blackberry (Rubus fruticosus agg.) control using grazing goats. Plant Protection Quarterly 3(2): 83-84.
8. Evans, H.C. and Ellison, C.A. (1990). Classical biological control of weeds with micro organisms: past, present, prospects. Aspects of Applied Biology 24, The exploitation of micro-organisms in applied biology: 39-49.
9. Fowler, S.V., Holden, A.N.G. and Schroeder, D. (1991). The possibilities for classical biological control of weeds of industrial and amenity land in the UK using introduced insect herbivores or plant pathogens. Brighton Crop Protection Conference - Weeds, 1173- 1180.
10. Goel, U., Saxena, D.B. and Gupta, A.K. (1994). Allelopathic potential of Chenopodium album L. Allelopathy Journal 1(2): 105-113.
11. Hallett, S.G., Paul, N.D. and Ayres, P.G. (1990). Botrytis cinereakills groundsel (Senecio vulgaris)

infected by rust (Puccinia lagenophorae). New Phytologist 114: 105-109.

12. Imaizumi, S., Nishino, T., Miyabe, K., Fujimori, T, and Yamada, M. (1997). Biological control of annual blue grass (Poaannua L.) with a Japanese isolate of Xanthomonas campestris pv. poae (JT-P482). Biological Control 8: 7-14.
13. Kosemura, S., Yamamura, S., Kakuta, H., Mizutani, J. and Hasegawa, K. (1993). Synthesis and absolute configuration of lepidimoide, a high potent allelopathic substance from the mucilage of germinated cress seeds. Tetrahedron Letters 34(16): 2653-2656.
14. Lockhart, J.A.R. (1990). The evolution of weed control in British agriculture. In Weed Control Handbook: Principles (R.J. Hance and K. Holly, eds.), pp. 43-74. Blackwell; Oxford.
15. Lovett, J.V. (1982). Allelopathy and self defence in plants. Australian Weeds 2(1): 33-36.
16. Lovett, J.V. (1991). Changing perceptions of allelopathy and biological control. Biological Agriculture and Horticulture 8: 89-100.
17. Numata, M. (1982). Weed-ecological approaches to allelopathy. In, Biology and ecology of weeds, Dr Junk Publishers, The Hague, 169-173.
18. Oerke, E-C. (2005). Crop losses to pests. Journal of Agricultural Science 144: 31-43.
19. Paul, N.D. and Ayres, P.G. (1986). Effects of rust infection of Senecio vulgaris on competition with lettuce. Weed Research 27: 431-441.
20. Qasem, J.R. and Hill, T.A. (1989). Possible role of allelopathy in the competition between tomato, Senecio vulgaris L. and Chenopodium album. Weed Research 29: 349-356.
21. Rogers, B. (1979). What do women want? Appropriate Technology, 5(4), 8-9. Soil Association (1989). Standards for Organic Agriculture. The Soil Association; Bristol.
22. Scherrer, B. (2000). Anthroposophic, selective weed control. Proceedings 13th IFOAM Conference – The World Grows Organic. Basle, Switzerland, 184.
23. Soil Association (2002). Organic weed and scrub control on nature conservation sites. Soil Association Technical Guide, Soil Association Producer Services, Bristol, UK.
24. Steinsiek, J.W., Oliver, L.R. and Collins, F.C. (1982). Allelopathic potential of wheat (Triticumaestivum) straw on selected weed species. Weed Science 30: 495-497.
25. Tukey, H.B.Jr. (1966). Leaching of metabolites from above-ground plant parts and its implications. Bulletin Torrey Botanical Club 93: 385-401.
26. Weidemann, G.J. and Tebeest, D.O. (1990). Biology of host range testing for biocontrol of weeds. Weed Technology 4: 465-70.