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# Weed Management in Organic Agriculture

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Abstract

Despite the serious threat which weeds offer to organic crop production, relatively little attention has so far been paid to research on weed management in organic agriculture, an issue that is often approached from a reductionist perspective. Compared with conventional agriculture, in organic agriculture weed interactions usually manifest themselves more slowly. It follows that weed management should be tackled in an extended time domain and needs deep integration with the other cultural practices, aiming to optimize the whole cropping system rather than weed control per se. In this respect, cover crop management is an important issue because of its implications for soil, nutrient, pest and weed management. It is stressed that direct (physical) weed control can only be successful where preventive and cultural weed management is applied to reduce weed emergence (e.g. through appropriate choice of crop sequence, tillage, smother D cover crops) and improve crop competitive ability (eg. through appropriate choice of crop genotype, sowing/planting pattern and fertilization strategy). Problem of weeds can be minimized by adopting right and integrated organic weed management approaches which, helps in reducing the competition by weeds without any adverse effect on yield, quality of produce and soil/ecosystem.

*Keywords*: Organic Agriculture, Organic weed management practices and Bio-herbicides

Organic Agriculture has grown out of the conscious efforts by inspired people to create the best possible relationship between the earth and men. Since its beginning the sphere surrounding organic agriculture has become considerably more complex. A major challenge today is certainly its entry into the policy making field, its entry into global market and the transformation of organic products into commodities (Yadav *et al*., 2009). During the last two decades, there has also been a significant sensitization of the global community towards environmental preservation and assuring of food quality. Keen promoters of organic farming consider that it can meet both these demands and become the mean for complete development of rural areas. After almost a century of development, organic agriculture is now being embraced by the main stream and shows great promise commercially, socially and environmentally. While, there is continuum of thought from earlier days to the present, the modern organic movement is radically different from its original form. It now has environmental sustainability at its core in addition to the founders concerns for healthy soil, healthy food and healthy people.

In India, concept of organic farming is not new. In traditional India, only organic farming was practiced. Wherein, no chemical fertilizers and pesticides were used and only organic techniques where natural pesticides and organic manures were obtained from plant and animal products were used. During 1950s and 1960s, the ever increasing population of India lead to a food scarcity. The government was forced to import food grains from foreign countries and compelled to increase the food grain production of India to enhance the food security.

To overcome the problem of food scarcity, Green Revolution took place under the leadership of Dr. M. S. Swaminathan. During this period, high yielding varieties, chemical fertilizers, synthetic pesticides, mechanization, irrigation projects were introduced in the country, which helped in overcoming food crisis, self-sufficiency in food grain and buffer stock of food grains. But, over a period of time, this

lead to Stagnation or fall in productivity of crops, decline in soil fertility, salinity problem, lowering of water table, environmental pollution and others to overcome these problems farmers realized that the organic farming is the best solution.

TABLE 1

Percentage of Area under Organic Farming in the Total Cultivated Area of different Countries of the World

| Country | Area (%) | Country | Area (%) |
|---|---|---|---|
| USA | 0.23 | Switzerland | 7.94 |
| UK | 4.22 | South Africa | 0.05 |
| Germany | 4.10 | Italy | 3.70 |
| Argentina | 1.70 | India | 0.03 |
| Austria | 8.40 | Pakistan | 0.08 |
| Australia | 2.20 | Srilanka | 0.05 |

Source: Rajib Roy Chowdhury *et al.* (2013)

Organic agriculture is a production system that sustains health of soil, eco-system and people, by relying on ecological process, bio diversity and natural cycles and adapted to local conditions than use of inputs with adverse effects (Anon., 1997). It includes various methods like Natural farming, Bio-dynamic farming, Ecological farming, Homa farming, Homestead farming, Humus farming, Sewage farming and Zero chemical farming.

**Advantages of Organic Farming**

1. Organic matter supplies all the essential macro and micro plant nutrients.
2. Organic matter improves physico - chemical and biological properties of soil.
3. Organic farming improves agro-ecosystem and helps in stopping environmental degradation.
4. Organically grown crops are preferred by most people as it is believed to be more nutritious compared to conventional ones.
5. Organic produce fetches more prices in national and international market.

**Constraints of Organic Farming**

1. Organic manure contains fewer amount of nutrient; 2. Lack of awareness; 3. Pest management (Weed, Insect and Diseases; 4. Marketing problems of organic inputs and products; 5. Shortage of organic biomass; 6. Poorly supporting infrastructure; 7. Lack of financial support; 8. Low yields during conversion period; 9. Political and social factors; 10. Complex certification procedure & 11. Lack of organic input responsive variety.

Weeds are often recognized as the most serious threat to organic crop production (Penfold *et al*., 1995; Stonehouse *et al*., 1996; Clark *et al*., 1998) and fear of ineffective weed control is often perceived by farmers as one of the major obstacles to conversion from conventional to organic farming (Beveridge and Naylor, 1999). Despite this, researchers have so far paid relatively little attention to weed management-related issues in organic agriculture. Further more, weed management is often approached from a reductionist perspective, e.g. focusing only on the comparison between types and adjustments of implements for mechanical weed control in a given crop. This conventional approach neglects the systemic (holistic) nature of organic agriculture, which has long been recognized as a pillar for the design of real, effective organic crop production systems (Andrews *et al*., 1990; Lockeretz, 2000). Cover crop use is then presented as an important link between soil, crop, pest and weed management in organic systems.

In this respect, a too narrow view of weed management is questionable, because of the likely under estimation of interaction effects among system components and of their carry over across growing seasons, which may also result in information of little practical value to farmers. After a reasoned analysis of the literature on this subject published recently, this paper illustrates how some peculiar features of organic systems suggest the need to undertake an integrated approach to weed management.

**How to Manage Weeds in Organic Farming?**

Among the various constraints in organic farming, weeds are one of the major constraints. Organic farmers struggling to develop effective and economical weed management practices since, major yield losses are by weeds apart from pest and diseases. Farmers

rank weeds as the number one barrier to organic production (Walz, 1999) and organic farmers cite weed management as their number one research priority.

In approaching weed management within an organic system, it is important to remember the central goal; to reduce weed competition and reproduction to a level that the farmer can accept (Barberi, 2002). In many cases, this will not completely eliminate all weeds. Weed management should, however, reduce competition from current and future weeds by preventing the production of weed seeds and perennial propagules (the parts of a plant that can produce a new plant). Consistent weed management can reduce the costs of weed control and contribute to an economical crop production system.

*Organic weed management* **:** It begins with careful planning of the cropping system to minimize weed problems, and seeks to utilize biological and ecological processes in the field and throughout the farm ecosystem to give crops the advantage over weeds. In addition, mechanical and other control measures are usually needed to protect organic crops from the adverse effects of weeds. This is particularly true in vegetables and other annual crops, for which production practices keep natural plant succession at its earliest stages (Bond and Grundy, 2001).

**Strategies for Successful Weed Management in Organic Farming**

Important practices / Methods to control weeds in organic farming are Prevention, Cultural, Mechanical, Biological, 5. Chemical (organically approved)

I. *Prevention*: Avoid the entry of weed seeds on to the farm through Manures, Planting material, Mulching material, Intercultivation equipments / implements, Animals and Water *etc*.

**II Cultural Methods/Practices**

**Improve Crop Competitiveness**

1. Increase crop density through narrow row spacing and increased seeding rate.
2. Use transplants, rather than seed.
3. Choose competitive crop cultivars.
4. Manage fertility according to crop needs; avoid excess application.
5. Spot application of organic fertilizers.

**Cultural Methods**

i) *Crop rotation*: Crop rotation involves alternating different crops in a systematic sequence on the same land. It is an important strategy for developing a sound long term weed control program. Weeds tend to thrive with crops of similar growth requirements as their own and cultural practices designed to contribute to the crop may also benefit the growth and development of weeds. Mono culture, that is growing the same crop in the same field year after year, results in a build-up of weed species that are adapted to the growing conditions of the crop. When diverse crops are used in a rotation, weed germination and growth cycles are disrupted by variations in cultural practices associated with each crop (tillage, planting dates, crop competition, etc.).

Within a rotation, crop choice will determine both the current and the potential future weed problems that a grower will face. Traditionally, potato (*Solanum tuberosum* L.) was included in the rotation to reduce weed problems before a less competitive crop was grown (Shreshta *et al*., 2000). For an organic grower, crop choice is complicated further by the need to consider soil fertility levels within the cropping sequence and to include fertility building periods in the rotation. Variations in crop and weed responses to soil nutrient levels can also play an important part in weed management. The inclusion of a fallow period in the rotation in known to reduce perennial weeds. It is best to alternate legumes with grasses, spring planted crops with fall planted crops, row crops with close planted crops and heavy feeders with light feeders.

ii) *Cover crops*: Rapid development and dense ground covering by the crop will suppress weeds. The inclusion of cover crops such as rye, red, clover, buckwheat and oilseed radish or over wintering crops like winter wheat or forages in the cropping system can suppress

weed growth. Highly competitive crops may be grown as short duration 'smother' crops within the rotation. Additionally, cover crop residues on the soil surface will suppress weeds by shading and cooling the soil. When choosing a cover crop, consideration should always be given to how the cover crop will affect the succeeding crop. In addition, decomposing cover crop residues may release allelo chemicals that inhibit the germination and development of weed seeds.

iii) *Intercropping*: Intercropping involves growing a smother crop between rows of the main crop. Intercrops are able to suppress weeds. However, the use of intercropping as a strategy for seed control should be approached carefully. The intercrops can greatly reduce the yields of the main crop if competition for water or nutrients occurs.

Sunflower+groundnut

Sugarcane+soybean

Zahid Hussain *et al*. (2014) reported that, weed densities in the intercropping treatments were less than the weed densities in the sole crops .

iv) *Field Scouting*: It involves the systematic collection of weed and crop data from the field (weed distribution, growth stage, population, crop stage *etc.,*). The information is used, in the short term, to make immediate weed management decisions to reduce or avoid economic crop loss. In the long term, field scouting is important in evaluating the success or failure of weed management programs and for making sound decisions in the future.

v) *Mulching*: Mulching or covering the soil surface can prevent weed seed germination by blocking light transmission preventing seed germination. All elopathic chemicals in the mulch also can physically suppress seedling emergence. There are many forms of mulches available. Listed are three common ones.

Anup Das *et al*. (2016) recommended that, mulching with fresh Eupatorium 10 t/ha after earthling up at 30 DAS followed by soybean green manure incorporation in situ + one hand weeding 45 DAS had suppressed the weeds drastically and resulted in higher grain weight per cob in maize.

Significantly higher rice grain (4816 kg/ha) and straw yield (7108 kg/ha) was obtained in the treatment rice bran at 2 t/ha on 3 DAT + hand weeding in 35 DAT due to significant reduction in weed dry density and dry weight followed by *Azolla* + conoweeder incorporation on 20 and 40 DAT as compared to unweeded control which has fetched higher B:C ratio (2.45) (Table 2).

vi) *Planting patterns*: Crop population, spatial arrangement, and the choice of cultivar (variety) can affect weed growth. For example, studies have shown that narrow row widths and a higher seeding density will reduce the biomass of later-emerging weeds by reducing the amount of light available for weeds located below the crop canopy. Similarly, fast growing cultivars can have a competitive edge over the weeds.

vii) *Crop/Variety selection*: Careful selection of crop varieties is essential to limit weeds and pathogen problems and to satisfy market needs. Any crop variety that is able to quickly shade the soil between the rows and is able to grow more rapidly than the weeds will have an advantage.

viii) *Stale seed bed*: A false or stale seed bed is a useful weed control technique which involves creating a seedbed some weeks before seed is due to be sown. Preparation of such seedbed makes sure that any weed seeds that have been disturbed and brought to the soil surface during cultivation will thus have a chance to germinate and can then be hoed off or eliminated with the use of a flame weeder before sowing of the actual crop is carried out.

Patil and Reddy (2014) reported that, in finger millet crop, at 60 DAP the total weed density and weed dry weight was significantly lower in hand weeding twice

TABLE 2

Effect of organic weed management practices on productive tillers, grain and straw yields of rice during *rabi* 2012 at TNAU, Coimbatore

| Treatments | Weed dry weight (g) at 30 DAT | | Productive tillers (No./m$^2$) | Grain yield (kg/ha) | Straw yield (Kg/ha) | B:C ratio |
|---|---|---|---|---|---|---|
| $T_1$ - *S. aculeata*as intercrop and incorp. on 35 DAT | 3.81 | (12.54) | 160.0 | 3856 | 6175 | 1.96 |
| $T_2$- *Azolla*+ manual incorpn. on 20 and 40 DAT | 3.21 | (8.32) | 165.0 | 4256 | 6558 | 1.97 |
| $T_3$- *Azolla*+ rotary weeder incorpn. on 20 and 40 DAT | 3.21 | (8.33) | 174.0 | 4321 | 6400 | 2.09 |
| $T_4$- *Azolla*+ conoweeder incorpn. on 20 and 40 DAT | 3.09 | (7.54) | 188.7 | 4716 | 6905 | 2.28 |
| $T_5$ - Rotary weeder four times on 10, 20, 30 and 40 DAT | 3.14 | (7.87) | 168.0 | 3874 | 6218 | 2.14 |
| $T_6$ - Conoweeder four times on 10, 20, 30 and 40 DAT | 3.11 | (7.70) | 182.0 | 4282 | 6441 | 2.36 |
| $T_7$ - Rice hull solution (50%) on 3 DAT + HW on 35 DAT | 6.44 | (39.51) | 143.0 | 3604 | 5964 | 1.87 |
| $T_8$ - Rice hull solution (50%) on 15 DAT + HW on 35 DAT | 7.23 | (50.30) | 130.0 | 3423 | 5909 | 1.78 |
| $T_9$ - Sunflower dried stalk on 3 DAT + HW on 35 DAT | 7.24 | (50.46) | 147.0 | 3550 | 5868 | 1.87 |
| $T_{10}$ - Sunflower dried stalk on 15 DAT + HW on 35 DAT | 7.20 | (49.88) | 141.0 | 3436 | 5796 | 1.81 |
| $T_{11}$ - Rice straw at 3 t/ha on 3 DAT + HW on 35 DAT | 3.73 | (11.93) | 154.3 | 3658 | 5993 | 1.87 |
| $T_{12}$ - Rice bran at 2 t/ha on 3 DAT + HW on 35 DAT | 2.71 | (5.34) | 192.2 | 4816 | 7108 | 2.45 |
| $T_{13}$ - Hand weeding on 15 DAT and on 35 DAT 35 DAT | 3.18 | (8.11) | 185.0 | 4512 | 6585 | 2.20 |
| $T_{14}$- Unweeded control | 8.01 | (62.25) | 105.3 | 2577 | 4471 | 1.50 |
| LSD (P=0.05) | | 0.28 | 16.66 | 380.0 | 539.8 | |

at 20 and 30 DAP (26.32 and 6.4 g/m$^2$) treatment and it was on par with stale seed bed technique + inter cultivation twice at 20 and 35 DAP (29.67 and 8.0 g/m$^2$) and passing wheel hoe at 20, 30 and 40 DAP + one hand weeding (41.26 and 10.7 g/m$^2$). Also, significantly higher grain yield was obtained in hand weeding twice at 20 and 30 DAP (5460 kg/ha) as compared to unweeded control (2730 kg/ha) and it was on par with stale seedbed technique + Inter cultivation twice at 20 and 35 DAP (5365 kg/ ha). The trends were similar in the straw yield (Table 3).

ix) *Tillage system*: Tillage systems alter the soil seed bank dynamics and depth of burial of weed seeds. Studies have found that almost 75 per cent of the seedbank was concentrated in the upper 5 cm of soil in no-till fields. In the moldboard plough system however, the seed bank is more uniformly distributed over depth. Other conservation tillage systems are intermediate to these two systems.

Weed seedling emergence is often more uniform shallow buried weed seeds and may result in better weed control. Weed seeds closer to the soil are more

TABLE 3

Effect of organic weed management practices on weed density, weed dry weight, weed control efficiency grain and straw yield at 60 days after planting infinger millet during *kharif,* 2013 at MRS, UAS, Bengaluru

| Treatments | Weed density (No./ $m^2$) at 60 DAP | | Weed dry weight ($g/m^2$) at 60 DAP | | WCE(%) at 60 DAP | No. of productive tillers | Grain yield (kg/ha) | Straw yield (kg/ha) |
|---|---|---|---|---|---|---|---|---|
| $T_1$-Passing wheel hoe at 20, 30 and 40 DAP | 1.72 | (50.22) | 1.62 | (39.7) | 58.2 | 4.2 | 4095 | 6567 |
| $T_2$- Inter cultivation twice at 20 and 35DAP | 1.92 | (80.95) | 1.76 | (55.8) | 41.3 | 4.2 | 3937 | 6300 |
| $T_3$ Stale seedbed technique | 2.25 | (177.51) | 1.91 | (80.0) | 15.8 | 3.9 | 3397 | 4900 |
| $T_4$ -$T_1$ + one hand weeding | 1.64 | (41.26) | 1.10 | (10.7) | 88.7 | 4.9 | 5143 | 7100 |
| $T_5$- $T_2$ + one hand weeding | 1.69 | (47.34) | 1.65 | (42.9) | 54.9 | 4.1 | 4222 | 6200 |
| $T_6$-$T_3$ + Inter cultivation twice at 20 and 35 DAP | 1.50 | (29.67) | 1.00 | (8.0) | 91.6 | 5.6 | 5365 | 7533 |
| $T_7$-Organic mulching @ 10 t $ha^{-1}$ after transplanting | 2.10 | (124.0) | 1.74 | (52.4) | 45.2 | 3.9 | 3778 | 6300 |
| $T_8$- Growing cover crops (Horse gram / cowpea) and passing blade hoe | 1.89 | (76.08) | 1.74 | (53.5) | 43.7 | 3.7 | 3206 | 6200 |
| $T_9$ -Spray of Eucalyptus leaf extract on weeds | 2.22 | (165.5) | 1.92 | (81.3) | 14.5 | 4.0 | 2921 | 5267 |
| $T_{10}$ -Spray of cattle urine on weeds | 2.27 | (185.8) | 1.84 | (67.7) | 28.8 | 4.1 | 3302 | 5600 |
| $T_{11}$ -Hand weeding twice at 20 and 30 DAP | 1.45 | (26.32) | 0.92 | (6.4) | 93.2 | 5.9 | 5460 | 7200 |
| $T_{12}$ -Unweeded check | 2.45 | (279.6) | 1.99 | (95.1) | 0.0 | 3.2 | 2730 | 4500 |
| LSD(P=0.05) | 0.20 | | 0.06 | | NA | 0.82 | 945.6 | 639.8 |

Figures in parenthesis are original values; data analyzed using transformation log (x+2), NA: Not Analyzed

likely to be eaten or damaged by insects, animals, other predators and disease causing organisms.

x) *Sanitation*: It is possible to prevent many new weeds from being introduced onto the farm and to prevent existing weeds from producing large quantities of seed. The use of clean seed, removing weeds around the edges of fields or after harvest to prevent weeds from going to seed and thoroughly composting manure before application can greatly reduce the introduction of weed seeds and difficult weed species. It is even possible to selectively hand-eradicate isolated outbreaks of new weeds, effectively avoiding future infestations. Planting clean, high-quality seed is essential to crop success. Other sanitation factors to consider would include thorough cleaning of any machinery which might have been used in weedy fields, and the establishment of hedge rows to limit wind blown seeds.

xi) *Irrigation*: Effective water management is key to controlling weeds in organic farming. There are a number of ways that careful irrigation management can help to reduce weed pressure on crops. Drip irrigation is more water efficient and also by directing

water to the crop it minimizes weed germination and reduces need to cultivate**.**

### III. Mechanical Methods

Mechanical removal of weeds is both time consuming and labor-intensive but is the most effective method for managing weeds. The choice of implementation, timing, and frequency will depend on the structure and form of the crop and the type and number of weeds. Cultivation involves killing emerging weeds or burying freshly shed weed seeds below the depth from which they germinate. It is important to remember that any ecological approach to weed management begins and ends in the soil seed bank. The soil seed bank is the reserve of weed seeds present in the soil. Observing the composition of the seed bank can help a farmer make practical weed management decisions. Burial to 1.0 cm depth and cutting at the soil surface are the most effective ways to control weed seedlings mechanically.

i) *Improved Farm Equipment's /Machineries:* Mechanical weeders include cultivating tools such as hoes, harrows, tines, high residue cultivator, brush weeders, cutting tools like mowers and stimmers and dual-purpose implements like thistle-bars. The choice of implement and the timing and frequency of its use depends on the morphology of the crop and the weeds. Implements such as fixed harrows are more suitable


for arable crops, whereas inter-row brush weeders are considered to be more effective. The brush weeder is mainly used for vegetables such as carrots, beetroot, onions, garlic etc. The optimum timing for mechanical weed control is influenced by the competitive ability of the crop and the growth stage of the weeds.

ii) *Thermal Weed Control : Flamers* **-** These are useful for weed control. Thermal weed control involves the use of flaming equipment to crate direct contact between the flame and the plant. This technique works by rupturing plant cells when the sap rapidly expands in the cells. Sometimes thermal control involves the outright burning down of the weeds. Flaming can be used either before crop emergence to give the crop a competitive advantage or after the crop has emerged. However, flaming at this point in the crop production cycle may damage the crop. Although the initial equipment cost may be high, flaming for weed control may prove cheaper than hand weeding.

iii) *Soil solarization*: During summer and fall, organic farmers sterilize their soil through solarization. In this process, a clear plastic film is placed over an area after it has been tilled and tighly sealed at the edges. Solarization works when the heat crated under the plastic film becomes intense enough to kill weed seeds.

iv) *Infrared weeders*: Infrared weeders are a further development of flame weeding in which the burners heat ceramic or metal surfaces to generate the infrared radiation directed at the target weeds. Some weeders use a combination of infrared and direct flaming to kill the weeds. In general, flame weeders are considered to be more effective because they provide higher temperatures, but burner height and plant stage are important too. Infrared weeders cover a more closely defined area than those of the standards flame weeder, but may need time to heat up.

### IV. Biological Weed Control

Biological control would appear to be the natural solution for weed control in organic agriculture.

i) *Allelopathy*: Allelopathy is the direct or indirect chemical effect of one plant on the germination, growth or development of neighboring plants. It is now commonly regarded as component of biological control. Species of both crops and weeds exhibit this ability. Allelopathic crops include barley, rye, annual ryegrass, buckwheat, oats, sorghum, sudan sorghum hybrids, alfalfa, wheat, red clover and sunflower. Vegetables, such as horse radish, carrot and radish, release

particularly powerful allelopathic chemicals from their roots. Suggestions have been made that all elochemicals and other natural products or their derivatives could form the basis of bio herbicides. However, it is unclear whether the application of natural weed killing chemicals would be acceptable to the organic standard authorities.

ii) *Beneficial organisms*: Little research has been conducted on using predatory or parasitic micro orgnising or insects to manage weed populations. However, this may prove to be a useful management tool in the future. Natural enemies that have so far been successful include a weevil for the aquatic weed salvinia, a rust for skeleton weed and probably the most famous, a caterpillar (*Cactoblastis* sp.) to control prickly pear. There is also considerable research effort aimed at genetically engineering fungi (myco-herbicides) and bacteria so that they are more effective at controlling specific weeds. Myco-herbicides are a preparation containing pathogenic spores applied as a spray with standard herbicide application equipment.

iii) *Breeding for Crop Competitiveness and Weed Suppression*: Plant breeding is one way to improve weed management in organic systems. Development of crops with increased competitive ability and enhanced weed suppressive qualities. Crop qualities that promote crop competitiveness include early, rapid establishment in less favorable conditions, crop structures that limit weed access to light and nutrients increased plant hardiness etc.

a) Commercial Myco-herbicides

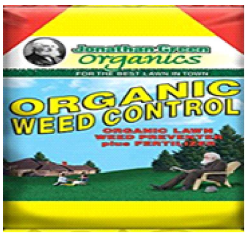
| Trade name | Pathogen | Target weed |
|---|---|---|
| Devine | *Phyophthorapalmivora* | *Morreriaodorata* (Strangler vine) in citrus |
| Collego | *Colletotrichum gleosporoides*f.sp. aeschynomene | *Aeschynomene virginica* (Northen Joint Vetch) in rice and soybean |
| Biopolaris | *Biopolarissorghicola* | *Sorghum halepense* (Johnson grass) |
| Biolophos | *Streptomyces hygroscopius* | General vegetation (non-specific) |
| LUBAO 11 | *Colletotrichum gleosporoides* f.sp. Cuscuttae | *Cuscuta*sp. (Dodder) |
| 01 | *Alternaria cassiae* | *Cassia abtusifolia* |
| ABG 5003 | *Cercosporarodmanii* | *Eichhorneacrassipes* (water hyancinth) |

## V. Chemical Methods (Organically Approved)

Extensive use of synthetic herbicides poses serious threats to both the environment and public health. From both public health and environmental perspectives, there is a great incentive for biologically active natural products from higher plants that are as good as or better than synthetic herbicides and that are likely to be much safer. Further more, in comparison to long-persistence, non-target toxicity, polluting, carcinogenic and mutagenic activities of synthetic herbicides, natural plant products are biodegradable, somewhat specific, and likely to be recycled through nature. Commonly used bio herbicides are:

*Processed from naturally occurring products* -

- Vinegar (Acetic acid) $C_2H_4O_2$
- Clove oil (about 85 % eugenol)
- Eugenol (extract from clove, cinnamon, basal or bay leaf)
- Citric acid $C_6H_8O_7$
- Lactic acid $C_3H_6O_3$
- Corn gluten meal
- Fatty acid soaps
- Fe HEDTA




*Corn gluten meal (Turf builder, Weed Ban and Corn Weed Blocker)*: It has been used successfully on lawns and high-value crops as pre-emergent herbicide.

b) Use of bio-control agents for weed control

| Name of the weed | Bio-agent |
|---|---|
| *Cyperus rotundus* | *Bactra verutana* |
| *Ludwigia parviflora* | *Halticacynea* (Steel blue beetle) |
| *Parthenismhy sterophorus* | *Zygrogramma bicolarata* |
| *Lantana camara* | *Crocidosema lantana, Teleonnemiascrupulosa* |
| *Opuntia dilleni* | *Dactylopiustomentosus, D. indicus* (cochineal scale insect) |
| *Eichhorneacrassipes* | *Neochetinaeichhornea, Bruchi* (Hyachinthweevil) *Sameodesalliguttalis* (hyancinth moth) |
| *Salvinia molesta* | *Crytobagussingularis* (weevil) *Paulinia acuminate* (grasshopper), *ameamutiplicalis* |
| *Alternanthera philoxaroides* | *Agasideshygrophilla (fleabeetle) mynothripsandersoni* |
| *Tribulus terrestris* | *Microlarinuslypriformis, M. lareynii* |
| *Solanum elaegnifolium* | *Frumentanephalomicta* |

*Commonly used vinegar or lemon juice or clove oil ingredients -*

- Burnout: 23 per cent acetic acid.
- Biogenic: 10 per cent acetic acid plus clove oil and thyme oil.
- Matran & Weed Bye Bye *etc.,*
- Post-emergent herbicides..


**Future Line of Work**

- Development and evaluation of mechanically operated weeders are to be taken up on priority.
- Evaluation of cover crop, green manure species and different mulches with respect to their time, dosage and methods of using is essential.
- Standardization of duration of stale seedbed technique in combination with inter cultural implements for different types of soils and crops is needed.
- Standardization of concentration and time of spraying of eucalyptus leaf extractions and other allelopathic botanicals needs to be done.

Problem of weeds can be minimized by adopting right and integrated organic weed management approach's which, helps in reducing the competition by weeds without any adverse effect on yield, quality of produce and soil/ecosystem.

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