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Recent trends and techniques in weed management under protected environments

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Abstract
In green house grown crops, weeds are the major threat which competes with main crops in all growing factors such as light, water and nutrients. Also weed act as a primary source of pest, disease and nematodes. Integrated weed management approach is helpful to control weed problem in greenhouse cultivation. Integrated management approaches include preventive, physical control measures, chemical control measures and mechanical measures. Since the greenhouse cultivation is under controlled condition it is essential to avoid invading of weeds inside the structure at initial stage itself. Weeds may spread through seeds, manures, machineries, tools and implements. Hence, Sanitsing and cleaning all the tools and implements is necessary.

Keywords: Greenhouse, weed management, protected cultivation, integrated management

Introduction
In modern farming, weeds are the major threat in green house crops like vegetables, greens, flowers. Weeds compete with light, water and nutrients resulting 30-75 per cent reduction in productivity of vegetable crops and also reduce the quality of produce especially in leafy vegetables. Weeds act as primary source of pest, disease and nematodes. Traditional weed control options are no longer viable because high cost and shortage of labour. Integrated weed management approach will help to effectively manage weeds in green house vegetable cultivation. Different approach includes preventive measures, sanitation, physical barriers, hand weeding, stale seed bed, soil solarization and the selective use of post emergence herbicides to help to achieve higher productivity in greenhouse.

Preventive measures
Prevention is the most essential part of weed management. Once a noxious and perennial weed infestation becomes established, any increase in size and density creates increasingly more expensive management efforts. This can be achieved by use of weed free seed, seed certification, and weed laws and by quarantine laws.
Approaches to manage weeds in polyhouses: Maintaining weed-free growing conditions is necessary to produce high quality greenhouse crops. Insects and diseases can be kept to a minimum only if proper weed control practices are carried out regularly, along with appropriate control measures. An integrated weed management program will help to effectively manage weed populations. This approach includes preventive measures, sanitation, physical barriers, hand weeding, stale seed bed, soil solarization and the selective use of post emergence herbicides. These approaches have been discussed below.
Preventive Approaches: They do not offer any remedy to check the existing population of weeds but they focus on the prevention of further introduction of weeds from external sources. For this it is important to know the mechanisms of reproduction & survival of weeds and modes of their dispersal. Weed seeds are easily blown into the greenhouse though vents and other openings. Keep weed seeds, and rhizomes out of the greenhouse by using sterile media," clean" plant materials, and controlling weeds outside the greenhouse. Screening vents and other openings will help to limit the entry of wind blown seed, as well as insects.
It is critical to remove weeds from greenhouse pots, benches and floors before they flower and produce seed. For example, a single plant of bittercress can produce 5000 seeds, that germinate in as little as 5 days and can propel the seeds over 9 feet from the plant.

Yellow wood sorrel and creeping wood sorrel also expel seeds by force throughout a greenhouse. The following measures are important:

- Prevention of seed rain or new weed seeds being carried onto the polyhouse by different means like Organic manures, Crop seeds and farm tools implements
- Preventing the existing weeds in the polyhouse to come to flowering & fruiting.
- Use well decomposed Farm Yard Manure.
- Double door poly houses can help in preventing entry of weed seeds by wind.
- Transport sand and soil from weed free areas to the poly houses.
- Keep the nurseries free from weeds.
- Keep weed propagules (seed, rhizomes, tubers etc.) out of the green house by using sterile substrates.
- Use certified seeds and seedlings from authentic sources.
- Use physical barriers such as a weed block fabric which helps to limit weed establishment on greenhouse floors. Leave the weed fabric bare so it can be easily swept. Covering the weed fabric with gravel makes it difficult to remove any spilled potting media providing an ideal environment for weed growth. Regularly hand pulls any escaped weeds before they go to seed. Repair any tears in the weed block fabric.
- Manage Weeds outside the Green House: Maintain a 10 to 20-foot weed free barrier around the greenhouse. The primary objective of weed control outside the greenhouse is to eliminate a major source of airborne weed seed and to prevent perennial weeds such as Bermuda grass or bindweed from growing under the foundation and into the greenhouse. Additionally, weed control around the greenhouse may also serve to reduce populations of arthropod pests. Many options are available for controlling these weeds. Mowing will prevent the majority of weed seed formation. However, a vegetation-free strip is recommended immediately adjacent to the foundation. Use a geo-textile fabric covered with gravel or other inorganic mulch.

Stale seedbed technique

Stale seed bed technique is a cultural-cum - preventive measure. It is cultural from the point of view of pre-sowing 2-3 tillages invariably adopted by farmers since long time to prepare a good seed bed and to control early flushes of weeds. It is preventive from the view point of its effect, which exhausts soil seed bank before crop is sown and reduces the number of flushes of weeds.

In stale seed bed technique, first irrigation is applied to the field. The field is then ploughed thoroughly optimum moisture status and levelled. Crop sowing is withheld and the field is left as such for about a fortnight or so to allow germination of weeds. Sufficient soil moisture particularly at the upper 3-5 cm layer/stratum will result in weed seed germination, which may be controlled by a non-residual herbicide, e.g. paraquat, glyphosate, glufosinate-ammonium, or by shallow cultivation with spike-tooth harrow, spring - tooth harrow etc. Thus the germination of initial 2 or more flushes of weeds are facilitated/pampered/induced and later destroyed. Thereafter, the crop is planted with minimum soil disturbance to avoid exposing new weed seed to favourable germination conditions. Stale (`false') seed beds are sometimes used for vegetables when other selective weed-control practices are limited or unavailable. Success depends on controlling the first flush of emerged weeds before crop emergence, and on minimal disturbance, which reduces subsequent weed flushes.

A stale seedbed is one where initial one or two flushes of weeds are destroyed before planting of a crop. This is achieved by soaking a well prepared field with either irrigation or rain and allowing the weeds to germinate. At this stage a shallow tillage or non- residual herbicide like paraquat may be used to destroy the dense flush of young weed seedlings. This may be followed immediately by sowing. This technique allows the crop to germinate in almost weed-free environment

Stale seed bed techniques could be a preventive method with the precise aim of reducing seed emergence within the next crop cycle. This method involves the soil preparation of a seedbed to allow germination of weeds and killed either by a non-selective herbicide or by completing shallow tillage before the sowing (Singh *et al*., 2012) [1]. This method reduces weeds emergence weed density, delaying early crop-weed competition and also reduces weed seeds bank within the dirt. The success of stale seedbed depends on several factors like method of seedbed preparation, method of killing emerged weeds, weed species, duration of the stale seedbed and status (Singh, 2014) [12]. Reckoning on location and year, stale seedbed preparations followed by weed control before planting, reduced the quantity of weeds during crop growth by 43–83 per cent in lettuce after stale seedbed than without this practice. Bed orientation can make a difference within the suppression of weeds. Weeds often emerge on the edges of the beds, because they're shaded and, therefore, soil temperatures cannot rise to detrimental levels. Beds orientated north-south had reduced weed emergence compared to east-west orientation (McGovern *et al.,* 2004) [2].

Mulching Techniques

Mulch is a protective covering of material maintained on soil surface. Mulching has smothering effect on weed control by excluding light from the photosynthetic portions of a plant and thus inhibiting the top growth. It is very effective against annual weeds and some perennial weeds like *Cynodon dactylon.* Mulching is done by dry or green crop residues, plastic sheet or polythene film. To be effective the mulch should be thick enough to prevent light transmission and eliminate photosynthesis.

The use of plastic mulching is very popular in many vegetable-growing areas. A non-transparent plastic is used to impede the transmission of photosynthetic radiation through the plastic to the weeds so that the development of weeds is then arrested. Advantages are also a better moisture conservation as a reduction in irrigation needs means a reduction in nitrogen leaching, a better soil structure conservation, and an increase in the vegetable yield in an arid climate. Inconveniences are mainly the price of plastic (although it can be reused) as well as management costs. Some perennial weeds are not controlled (e.g. Cyperus spp., Convolvulus arvensis) and interrow cultivation or treatments are necessary. It is obligatory to remove the plastic residues from the field in theform of waste (burning is prohibited). Black plastic mulching, other organic materials likeplant residues, straw etc on the crop rows and inter row cultivation is a satisfactory option for organic cultivation. Their advantages are similar to plastic, but weeds can easily manage to reach the surface if the layer is not thick enough.

Crop residue management

Crop residues are a source of organic carbon for soil microorganisms, and also contribute to plant nutrients. Crop residue retention on the soil surface, substantially reduces runoff and eating away, and might decrease weed emergence (*Dahal et al*., 2014) [3]. Crop residue management is a important component of sustainable agriculture and main objective to improved soil physical, chemical and biological properties, which they're a primary function of soil organic matter. Crop residues control the weeds. Globally there's mounting evidence that retention of crop residues from one season to the following suppresses the germination and development of weeds in minimum tillage systems, thus enhancing system productivity. Residue retention has significantly influenced weed emergence (Bahadur *et al.*, 2015) [4], although several interacting factors may determine the extent of this influence including residue nature, height, type and quantity, prevailing weed flora, soil type and climatic conditions. Residue mulching as a practical method for early season weed control in minimum tillage systems for smallholder farmers. Surface application of residue 5 to 7 t/ha significantly suppressed weed growth and development as compared to incorporation and no-residue retention (Brar and Walia, 2010) [5]. In rice-wheat system, majority of the farmers (65%) were burning rice straw in north-western Indian plains (*Chhokar et al*., 2007) [6]. Although seeds of the many weed species will be devitalized by stubble burning, this system is often to discourage due to its negative effect on soil organic matter content. For sustainability of rice-wheat system, rather than burning, residue should be either retained on surface or incorporated. Because residue retention on soil surface significantly contribute to the suppression of weeds. (Chauhan and Abugho, 2013) [7] reported that utilization of crop residue at 6 t/ha can help suppress weed emergence (50%). However, there's a necessity to integrate other weed management strategies with residue retention to attain season-long weed control.

Fertilizer application

Fertilizer application strategy to crop play important role in reducing weed population in crop as weeds are always strong competitor of crops for available resources. Proper crop nutrient management can play a pivotal role in weed management. Urgent to develop fertilization strategies for vegetables production that enhance the competitive ability of crop, minimize weed competition. Significant research during this area has shown that there exists a robust relationship between nutrient management and weed behaviour and management. Abouziena *et al*. (2008) [8] reported that increasing amount of nitrogen can cause the enhancement of plant performance, but weed may have a negative effect on performance.

Nasrollahzadeh *et al*. (2015) [9] observed that biomass reduces harvesting index and final corn performance under low nitrogen condition in contrast to high nitrogen and this can be a brief time after greening weed and its intervention with corn. Different weed species show a variable response to nutrient management. The character of fertilizers may affect weed biology and ecology. Yin *et al*. (2005) reported that the abundance of weeds was highly variable in cropped field within the nutrients application. Toler *et al*. (2004) observed that normally weeds respond positively to the starter fertilizer dose and grow well.

Soil solarisation

It is an effective method for the control of weeds, soil-borne diseases and pests. The basic principle behind soil solarisation is that light received from the sun is in the form of electromagnetic short waves, which easily pass through the transparent polyethylene films and reach the soil. As a result soil is heated up and emits long wave radiation which cannot pass through transparent polythene films and result in trapping of heat The soil must be clean, surface-levelled and wet, previously to being covered with a thin (0,1-0,2 mm or 25-50 micron) transparent plastic and very well sealed. The soil must be kept covered during the warmer and sunnier months (30-45 days). Soil temperatures must reach above 40 °C to exert a good effect on various soil-borne pests, including weed seeds. Surface soil temperature may increase up to 55-60 °C due to solarisation during summer months (Kumar *et al*., 1993), which proves lethal to many weed seeds and vegetative propagules. Soil solarisation is a broad-spectrum control method, simple, economically feasible and environmentally friendly. It does not affect soil properties and usually produces higher yields.

Populations of the annual summer weeds Amaranthus hybridus and galinsoga (Galinsoga parviflora), and of the annualwinter weeds spotted bur medick (Medicago arabica), chickweed (Stellaria media), sowthistle (Sonchus oleraceus) and twincress (Coronopus didymus) growing in soil that had been solarised for 42days were significantly ($P<0.05$) less than in soil from control plots. Carnations growing in soil that had been solarised for 22 days had significantly greater root weights, flower dry weights and numbers of flowers than carnations growing in unsolarised soil (Moya and Furukawa, 2000).

There are also some disadvantages in its implementation. For example, previous irrigation is a requirement, (or frequent and abundant rain) and the soil must be kept solarized (non-producing) for a period of at least one month. Results are often variable, depending on weather conditions. Cold (high latitude) or cloudy places are usually not suitable for implementing solarization. Some species can tolerate solarization (e.g. deep rooted perennials: Sorghum halepense, Cyperus rotundus, Equisetum spp. and also some big weed seeds such as legumes). After solarization the plastic must be recovered, and the use of deep or mouldboard tillage must be avoided. This system is more suitable for small areas of vegetables, but it has been mechanized for extensive areas of tomatoes. Soil solarization is widely used under plastic greenhouse conditions

Solarization is a Utilization of solar energy for the desiccation of weeds. Soil Solarization could be a useful non-chemical technique for controlling weeds, nematodes, and a number of other soil-borne diseases. This hydrothermal process occurs in moist soil which is roofed by a transparent sheet for 4–6 weeks and exposed to sunlight. In this method, the soil temperature is further raised by 5 – 10 ºC by covering a pre-soaked fallow field with thin transparent plastic sheet. The plastic sheet checks the long wave back radiation from the soil and prevents loss of energy by hindering moisture evaporation. Solarization has been shown to be handiest in regions that are cloudless and have weather condition. Solarization was found to be a cheap and low-risk management practice for little farmers and has the potential to extend crop yield. Efficacy of soil solarization for weed control within the field is increased by providing irrigation a

minimum of 2–3 week before solarization, letting the weeds grow, and incorporating them in soil before establishing the solarization treatment. Benlloglu *et al.* (2005) [10] reported solarization together with other weed management practices effectively control annual weeds, like, Portulaca oleracea, Amaranthus retroflexus, Echinochloa crusgalli, but Conyza canadensis. Solarization is additionally a vital tool to manage nutsedge, which is usually hard to regulate with regular mulches because it grows as a rhizome (not requiring sunlight) until it encounters light, then pierces mulches with its sharp growing point and thereafter expands its leaves above the film (Johnson *et al*., 2007) [11]. The success of soil solarization is affected because of intensification and therefore the length of exposure to sunlight. Significant reduction in weed emergence was observed over the subsequent 12 months after one month's solarization (Singh, 2014) [12].

Chemical weed control

Herbicide treatments under plastic cover are always hazardous and therefore, careful application should be carried out. Under plastic, high levels of moisture and elevated temperature are common and plants grow very gently. Selectivity could be easily lost and phytotoxicity symptoms may occur, while sometimes they are just temporary. The effects are often erratic. The best way to deal with it is to be prudent and make some trials before a general treatment.

Pre-emergence herbicides are applied before weeds emerge. They provide residual control of weed seedlings but can persist for many months, and in some cases, over a year. Pre-emergence herbicides continue to vaporize, causing crop damage. Currently, there are no pre-emergence herbicides labeled for greenhouse use. Avoid use of pre-emergence herbicides. Post-emergence herbicides are applied after the weeds have emerged. Currently, often four herbicides can be used when crops are in the greenhouse: Out of these paraquat, glyphosate, and glufosinate ammonium are non-selective herbicides. They should not come in contact with desirable crop foliage. They are only for use under benches, in walkways and around the foundation of the greenhouse. They are not for use in pots or ground beds where crop plants are growing. But fluazifop butyl can be used selectively to control grass weeds in broad leaved crops. Glyphosate is applied to actively growing weeds when temperatures are above 50°F and can only be used in an empty greenhouse. Selective use of Post-emergence Herbicides is important.

Conclusion

Weeds cause considerable losses within the medium and low tech polyhouses. They'll effectively be controlled by integrated approaches of weed management. But there's urgent need to figure out the critical period of crop weed competition of various high value crops, standardization of all the physical and mechanical methods.

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