ISSN: 0975-833X

Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 8, Issue, 12, pp.43418-43427, December, 2016

INTERNATIONAL JOURNAL
OF CURRENT RESEARCH

RESEARCH ARTICLE

NON - CHEMICAL WEED MANAGEMENT FOR SUSTAINABLE AGRICULTURE

[1,*]Sanbagavalli, S., [2]Somasundaram, E. [3]Ganesan, K. and [4]Marimuthu, S.

[1]Department of Pulses, Tamil Nadu Agricultural University, Coimbatore - 641003, India
[2,3]Department of Sustainable Organic Agriculture, Tamil Nadu Agricultural University, Coimbatore - 641003, India
[4]Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore - 641003, India

ARTICLE INFO

Article History:
Received 25th September, 2016
Received in revised form
18th October, 2016
Accepted 14th November, 2016
Published online 30th December, 2016

Key words:

Weed management,
Non-chemical methods,
Cultural practices,
Mechanical methods,
Biological approaches.

ABSTRACT

Farmers have struggled with the presence of weeds in their fields since the beginning of agriculture. Weeds can be considered a significant problem because they tend to decrease crop yields by increasing competition for water, sunlight, and nutrients while serving as host plants for pests and diseases. Today, some farmers have a renewed interest in organic methods of managing weeds since the widespread use of agrochemicals has resulted in purported environmental and health problems. It has also been found that in some cases herbicide use can cause some weed species to dominate fields because the weeds develop resistance to herbicide. The recent upsurge in environmental awareness of the public, interest in organic food production and some problems with herbicide use, has led to a range of sustainable techniques being developed for non-chemical weed control. It is important to understand that under an organic farmer must rely on cultural practices, mechanical control and biological methods for weed control. This has made it difficult for conventional farmers to readily take up organic production since putting an end to herbicide use may cause a potential increase in weed population and negatively affect crop yields and profits. However, proper organic weed management or non-chemical techniques can alleviate these potential problems. In this review, various non chemical weed control methods are considered separately from methods of controlling weeds directly and also given the sub-divided to define and discuss more closely the different areas of interest that lie within them.

Citation: Sanbagavalli, S., Somasundaram, E. Ganesan, K. and Marimuthu, S. 2016. "Non - chemical weed management for sustainable agriculture", *International Journal of Current Research,* 8, (12), 43418-43427.

INTRODUCTION

Weeds can be seen everywhere during the growth of the crop, it fiercely battles with crops for water and nutrients, strongly disturbing the normal growth of the crop and resulting in severe yield loss and quality reduction. In order to reduce the losses, weed should be eradicated in the crop's growth period especially in their seedling period (Sharma, 2014). Weeds are considered to be a potential pest causing more than 45 per cent loss in yields of field crops, when compared to 25 per cent due to diseases, 20 per cent due to insects, 15 per cent due to storage and miscellaneous pests and six per cent due to rodents (Verma, 2014). Weed management takes away nearly one third of total cost of production of field crops. In India, the manual method of weed control is quite popular and effective. Of late, labour has become non-availability and costly, due to intensification, diversification of agriculture and urbanization (Kalia and Gupta, 2004). At the same time, the continuous use of the same group of herbicides over a period of time on a same piece of land leads to ecological imbalance in terms of weed shift, herbicide resistance in weeds and environmental pollutions (Sushilkumar *et al*., 2005). Sustainable development is the management and conservation of the natural resource base and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations (Srinivasrao *et al*., 2014). Effective weed management is critical to maintaining agricultural productivity (Ahmed *et al*., 2010). Because of their ability to persist and spread through the multiple reproduction and dispersal of dormant seeds/vegetative propagules, for this reason weeds are virtually impossible to eliminate from any given field (Singh, 2014). These problems have challenged weed scientists to consider alternatives and integrated systems of weed management to reduce herbicide inputs and impacts. Moreover, herbicides are an exhaustible resource, so new approaches to merging soil conservation and non-chemical

Corresponding author: Sanbagavalli, S.
Department of Pulses, Tamil Nadu Agricultural University,
Coimbatore - 641003, India.

weed management are needed. Thus, non-chemical weed management become more important because of organic farming increasing in popularity in many parts of the world (Liebman *et al*., 2001). Non-chemical weed control does not necessarily imply reverting to outdated techniques and an impressive array of modern machinery already exists, some of which are new ideas and others developments of more traditional implements. The role of these machines for effective weed control should now be examined as part of a weed management strategy. Several non-chemical weed control methods and technologies are discussed below.

Non-chemical weed control techniques

Most weed control strategies aim at changing and/or reducing the relative competitiveness of the weed species, thereby favouring growth and development of the crop in comparison with the weed flora (Zimdahl, 2004). Non-chemical weed management strategies have gained renewed interest in recent years as global organic crop production acreage increases. The recent upsurge in environmental awareness of the public, interest in organic food production and some problems with herbicide use, has led to a range of techniques and machines being developed for non-chemical weed control. Some positive impacts of non-chemical weed control would be reduction of environmental impact, the maintenance of low but stable weed population, improvement of soil nutrients and water quality (Upadhyaya and Blackshaw, 2008). Weed control strategies may be categorized in different ways. Often used terminology is biological, chemical, cultural, direct, indirect, mechanical, physical, and/or preventive weed control methods.

Cultural weed management

Cultural management method refers to any technique that involves maintaining field conditions such as growing competitive crops in the rotation (Zimdhal, 2007), intercropping or cover crops (Kumar and Ray, 2011) timely cultivation (Verma and Singh, 2008), mulching, using agronomic practices that promote vigorous crop growth (Das and Yaduraju, 2008), and growing a competitive (Singh, 2014) variety, all contribute to an effective weed management program (Hutchinson and Eberlein, 2003). These practices can also have additional benefits of enhancing soil fertility and facilitating the management of pest and diseases. The ability of crops to compete against weeds could be increased by selecting the right crops and cultivars, considering the weeds present as well as the climate, ensuring rapid and uniform crop emergence through proper seedbed preparation, and by using the right seed and seeding depth, increasing planting density and adapting planting patterns wherever possible to crowd out weeds, adequate and localized resource (water, fertilizer) application, and optimum management of the crop, including insect pest and disease management.

Crop and cultivar choice

Crop cultivars may differ in weed suppressing ability, and which cultivar the farmer prefence may also influence the biomass production of the crop. Important plant competition parameters seem to be early vigour and season growth, straw length, leaf area index, and rate of root system establishment (Drews *et al.,* 2009). The role of crop genotype in weed management has received growing attention over the past several years (Bhan *et al*., 2012). Competitive cultivar can suppress weed seed production, limit future weed infestation, and become a safe, environmentally benign and low cost tool for weed management (Kumar *et al.,* 2013). The cultivar with faster seedling emergence, canopy establishment, early fast growth, maximum number of leaf, tall stature and more tillering capacity have better competitive ability against weeds (Ahmed *et al.,* 2010). Bertholdsson (2011) reported that the weed suppressing ability in wheat varieties depended mainly on early season crop growth and allelopathy.

Planting arrangement

Alteration of planting arrangement can be proposed as an efficient practice to suppress weeds in agroecosystems. This can be achieved by the change of sowing time, planting density, row spacing, row orientation, etc.

Sowing/ planting time

Sowing time is a nonmonetary input, but greatly affects the crop productivity (Verma and Singh 2008). Early planting provides a competitive edge to adapted crop cultivars (Sindhu *et al*., 2010) because crop emerged before the weeds and therefore the weeds did not receive sufficient sun light for their emergence and growth (Cici *et al*., 2008). Whereas, several studies have shown that sowing of rice after onset of monsoon gave higher grain yield and recorded less weed density (Kumar *et al*., 2012) whereas, late planting of wheat reducing *Phalaris minor* infestation (Das and Yaduraju, 2007).

Planting density and row spacing

The practice of increasing crop plant density by using higher seeding rates associated with narrow row spacing can lead to earlier canopy closure, thus shading weeds in their early developmental stages (Vera *et al.* 2006). The studies conducted on barley (*Hordeum vulgare* L.) have shown that higher seeding rates using cultivars with differing competitive abilities enhanced crop competitiveness against wild oat (Harker *et al*., 2009). Row spacing can also affect the crop competitive ability against weeds. In a study, rice grown in 30-cm rows had greater weed biomass and less grain yield than in15 cm and 10-20-10-cm rows and crops in the wider spacing (30cm) were vulnerable to weed competition for the longest period (Chauhan and Johnson, 2011). In another study, Mohammadi, (2012) reported that corn yield improved and weed biomass reduced in response to increasing plant density and decreasing row spacing. Row spacing can also influence the critical period of weed control in crops. It is hypothesized that narrow row spacings may decrease the interval of critical weed competition periods (Chauhan and Johnson, 2011).

Row orientation

Light is an important determinant of crop productivity. Crops can be manipulated to increase shading of weeds by the crop canopy, to suppress weed growth, and to maximize crop yield (Borger *et al.,* 2010). In general, cropping systems that reduce the quantity and quality of light in the weed canopy zone suppress weed growth and reduce competition (Borger *et al*., 2010). During early growth stages, there is interference between crop and weed plants because of reflected light. The reflection of far-red photons by the stem of one plant lowers the red to far red photon ratio of light experienced by the stems of neighbouring plants (Shrestha and Fidelibus, 2005). As plants age, the crop canopy closes, and mutual shading further increases the competition for photosynthetic light (Borger *et al*. 2010). According to Alcorta *et al*. (2011) rows oriented east-west allowed less light penetration to the weed canopy zone than north-south rows throughout the growing season and weed species responded to low light levels and the leaf, stem and root dry weight of the weed species in the east-west rows was reduced by 30 per cent compared to the weed species in north-south rows.

Proper crop stand

Planting pattern is a cost effective technique that modifies the crop canopy structure and micro- climate enhances crop competitiveness in weed suppression, improves the resource use efficiency and maximizes crop productivity (Sumathi *et al*., 2010). The plant population of 50 plants/m^2 was found to be significantly superior to 33 and 25 plants/m^2 as it recorded significantly less weed dry matter and highest grain yield compared to other plant population levels (Ghuman *et al*., 2008). Planting pattern with closer spacing of 60 cm ×20cm with 83,333 plants/ha proved to be very effective in suppressing weeds, by recording the least density of grasses, sedges and broad leaved weeds in sweet corn (Sunitha *et al*., 2010).

Crop Rotations

Rotating crops adds diversity to the cropping system, increasing the sustainability of the system. Crop rotation provides the foundation for long-term weed management (Dwivedi*et al*., 2012). Planting a wide variety of crops with varied characteristics reduces the likelihood that specific weed species will become adapted to the system and become problematic (Lundkvist *et al.,* 2008). Crop rotation is a planned sequence of crops growing in the same field year after year. Rotating crops with different life cycles can disrupt the development of weed crop associations, through different planting and harvest dates preventing weed establishment and therefore weed seed production (Das and Yaduraju, 2008) mainly by smothering and allopathic effect. Singh *et al.* (2012) studied that when rice- wheat cropping system is changed, there is reduction in weed density and weed dry weight. In diversified cropping systems, use of different grain crops, forage legumes as green manure and livestock manure to provide organic sources of nutrients and organic matter that can reduce weeds, by affecting weeds through suppression and the release of allelochemicals or by providing substrates for other organisms that inhibit weed seedling growth and potentially influencing the colonization and decay of weed seeds (Gomez *et al.,* 2014).

Intercropping

Intercropping offers potential advantages for increasing sustainability in crop production. Intercropping of short-duration, quick-growing, and early-maturing legume crops with long duration and wide-spaced crops leads to covering ground quickly and suppressing emerging weeds effectively (Kumar *et al*., 2010). Corn-legume intercropping led to a higher soil canopy cover and decreased light availability for weeds, which resulted in a reduction in weed density and dry matter compared with sole crops (Sanjay *et al*., 2011). The cover crop termination method can influence N mineralization and the effectiveness in weed control (Parr *et al*., 2014). Bernstein *et al*. (2014) tested the efficacy of a rye cover crop to suppress weeds for planting soybean under a no-till system and concluded that soybean could be successfully sown in a standing rye cover crop in a no-till soil.

Mechanical and physical weed control

Mechanical weeding is one of the oldest, but the most common methods of weed control and it is an essential component of most organic cropping systems, as there are few alternatives to control intra-row weeds after crop emergence (Kewat, 2014). Most mechanical weed control methods, such as hoeing, tillage, harrowing, torsion weeding, finger weeding and brush weeding, are used at very early weed growth stages (Singh, 2014). Hoeing can be effective on older weeds, and remains selective, many mechanical control methods become difficult after the cotyledon stage and their selectivity decreases with increasing crop and weed age. Thus, if the weeds have become too large, an intensive and aggressive adjustment of the implements is necessary to control the weeds, and by doing this one increases the risk of damaging the crop severely (Carter and Ivany, 2006).

Tillage and inter cultivation

Tillage can affect weed community through the changes in weed seed distribution in the soil. Primary tillage can reduce annual weed populations, especially when planting is delayed to allow weed seeds to emerge before final tillage (Pekrun and Claupein, 2006). The soil seedbank buffers the effect of different tillage practices on the weed flora at least in the short-term (Légère *et al.,* 2005). In Table (1), a method's applicability for management systems is determined by the properties of a management unit (i.e., surface flatness, soil structure, residue quality, residue amount, soil structure, crop presence) at the time of application.

Management units might be generally categorised as: bare (eliminating all residue interference), mulch (allowing some soil disturbance) and no-till (no soil disturbance). A field may have multiple management units types present either spatially (e.g., strip tillage), or temporarily (e.g., notill fallow/planting, followed by inter-row cultivation). Ridge till systems allow crop residues and seeds shattered on the soil surface to be moved to the interrow zones, thus creating a bare ridge unit and a mulch furrow unit (Forcella and Lindstrom, 1988).

Soil solarization

Soil solarization or "solar heating" is a non-chemical disinfestation practice that may serve as a component of a sustainable weed management programme. Solarization effectively controls a wide range of soil-borne pathogens, insects and weeds. Soil solarization is based on the exploitation the solar energy for heating wet soil mulched with transparent PE sheets to 40–55ºC in the upper soil layer (Singh, 2014). Thermal killing is the major factor involved in the pest control process, but chemical and biological mechanisms are also involved (Farid *et al*., 2014) and the thermal killing is determined by the values of the maximum soil temperature and amount of heat accumulated (duration x temperature). Soil solarization is a special technique in which moist soil is covered by polyethylene film (usually black or clear plastic sheet) to trap solar radiation and cause an increase in soil temperatures for several weeks to levels that kill weeds, weed seeds, plant pathogens, and insects for economic crop production (Ascard *et al*., 2007). For effective weed control there should be warm, moist soil and intense radiation needed throughout the day in order to raise the soil temperature, may cause damaging changes in enzyme activity, membrane structure and protein metabolism and ultimately kill weed seeds and seedlings of heat sensitive species (Arora and Tomar, 2012), because the effect of solarization varies with weed species.

Stale seed bed

It is the technique in which the weed seeds are allowed to germinate by rain or wetting and killing them (at 1-2 flushes of the weeds) before sowing seeds of main crops. The main objective with this technique is that most of the weeds that have the potential to germinate, because of their placement in the upper 1" to 2" of the soil, will usually do so within two weeks after the soil is prepared. The technique can be utilized in early spring, when the weather is still too cold for proper seed germination. Several passes are made with a rototiller or plough, and then weed seeds are allowed to germinate as weather permits (Singh *et al.,* 2012). By tilling, the farmer increases the chance of weed seed germination by the same method as one would for favorable vegetable/crops (Gnanavel and Kathiresan, 2014). In stale seedbed technique, after seedbed preparation, the field is irrigated and left unsown to allow weeds to germinate and which are killed by carrying out tillage prior to the sowing (Singh, 2014). This technique reduces weeds emergence, delaying early crop-weed competition and also reduces weed seeds bank (Sindhu *et al.,* 2010). 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, environmental condition (Singh, 2014). Adopting stale seedbed techniques either for 7 or 14 days (by keeping field drained and destruction of weeds by letting in water on 14th day) significantly reduced the population of grassy and broad leaved weeds and improved grain and straw yield of wet seeded rice compared to normal seed bed (Sindhu *et al*., 2010).

Use of weeders

Now a days, use of mechanical weeders in agricultural operations is increasing because of non-availability of labours for weeding. The cost of the weeding operations is also reduced by using the machineries for weeding. The machineries like mini-weeders, power tillers, minitractor drawn rotavator are used for weeding in wider spaced crops like sugarcane, cotton, and orchards. The physiological demand in using weeders was relatively higher than in manual weeding. However the efficiency of the work in terms of area covered was significantly better with the weeder than with manual weeding. The energy demand in manual weeding is only about 27 per cent whereas for weeding with different weeders, the energy goes up to 56 per cent. The strain was relatively less in case of wheel hoe type weeder (Rajasekar, 2002). Since the wider spacing of 5-6 feet is practiced sustainable sugarcane initiatives (SSI), mini-tractor drawn rotavator can be used for effective controlling all types of weeds in sugarcane. Cono weeder is used for controlling the wet land weeds and getting more yields in the system of rice intensification (SRI). The mini weeder and power tillers are used for controlling different types of weeds in cotton crop. Moreover, different types of weeding implements are available for weeding operations in various field and horticultural crops. Small farm implements and machine i.e. power tiller, marker and cono weeder played very imperative role in controlling weeds, enhancement of productivity and reduction in drudgery in SRI (Deshmukh and Tiwari, 2011). The cono weeder incorporation of daincha and azolla resulted in higher weed control during early stages of rice crop.

Hand weeding

Though it is the oldest method of management of weeds, it is still a practical and efficient method of eliminating weeds particularly annual and biennial weeds in cropped and non-cropped situations (Dubey, 2014). Hand weeding is an effective method of weed control for achieving the maximum yield of soybean (Pal *et al.,* 2013). According to Patel *et al.,* (2011) the two hand weeding at 20 and 40 DAS was found more effective in controlling weed population and recorded significantly the lowest dry weight of weeds and higher WCE (80.16 %) at 60 DAS and it harvest crop of summer blackgram in south Gujarat condition. Correspondingly, Abid Khan *et al.* (2012) studied different weed control practices on weeds and growth of chillies and results revealed that hand weeding has been the most effective weed control method that resulted in highest number of fruits/ plant (58.1), fruit length (6.8 cm) and yield of chilli (8775 kg/ha). Farmer's practice of hand weeding twice is found to keep the weed density below the threshold level and increased the yield about 20 per cent than control in hybrid brinjal (Suresh Kumar, 2014).

Power weeder weeding

Weed morphology and growth stage would influence the selection and efficacy of weeding implement. It was found that the physical damage by burial to one cm depth was effective for controlling weeds followed by cutting at the soil surface as noticed by Manuwa *et al.* (2009). The cultivators reduced the labour hours required for weeding by 50-70 per cent compared with hand weeding alone. The time required per weeding run for animal drawn weeding varied between 10 and 20 hours per hectare. While additional (in-row) hand weeding varied between 20 and 60 hours per hectare (Gore *et al.*, 2010). Mechanical weeder, starting 10 days after transplanting, with additional weedings every 10-12 days until the canopy closes to control most weeds and additional weedings were found to boost yield by 500-1000 kg (Satyanarayana *et al.*, 2007). On the other hand, Van *et al*. (2008) already stated that mechanical weeding has a highly variable effect on weed biomass, which is heavily dependent on seasons and species. However, Mohammad (2011) stated that weeding cost in single row conical weeder, two rows conical weeder, rotary weeder and power weeder was reduced by 15.7, 38.51, 22.32 and 48.70 per cent, respectively compared to hand weeding method. The average labour input in mechanical weeder was 36 man hour/ha compared to 112 man hour/ha in hand weeding. Probably, Heinz (2014) reported that the combination of two mechanical weed control treatments followed by ryegrass inter sowing suppressed weeds sufficiently without herbicide applications in leek.

Mulching

Mulching with organic materials aims to cover soils and forms a physical barrier to limit soil water evaporation, control weeds, maintain a good soil structure and protect crops from soil contamination (Ali *et al*., 2013). Polyethylene mulch technology is an efficient and useful method of water saving and weed control, improve soil structure and soil micro-flora (Brar and Walia, 2010), reduce the evaporation of moisture (Chhokar *et al.,* 2009), reduces the leaching of fertilizer and weed problem (Anazalone *et al*., 2010). Thus, it helps in increasing the levels of available nutrients and moisture in the soil (Govindappa and Pallavi, 2014). However, natural materials such as cereal straw, flax straw, nonwoven wool, or pine needles have also been tried, with success varying according to species, environmental conditions, and the nature of the organic materials used (Kasirajan and Ngouajio, 2012). Increased yieldand weed control efficiency due to application of paddy straw in ginger (Kushwah *et al.,* 2013) and in turmeric (Rair *et al*., 2011) and in pepper and in rice (Devasinghe *et al.,* 2011) and in tomato (Dzomeku *et al*., 2009). Bhardwaj (2013) reported that soil under the mulch remains loose, friable and leading to suitable environment for root penetration and conserve more soil moisture. Dead organic mulches generally need to be at least 10 cm thick for effective weed control, and are expected to degrade relatively quickly requiring replacement as frequently as annually (Lanini *et al.,* 2011). Newspapers and black polythene are recommended for the environmental friendly and sustainable control of weeds and realizing good yields of edible pea (Singh, 2010). However, Laurie *et al*. (2015) reported that the application of organic mulch (compost) @ 1 t/ha found to control weed effectively than black plastic mulch in sweet potato and also it is economical method of weed control than inorganic mulch. . Mulch has the potential to discourage weeds and conserve soil moisture to facilitate direct seeding of rice (Ehsanullah *et al.,* 2014).

Biological weed control

Biological management of weeds involves the deliberate use of host-specific phytophagus arthropods and plant pathogens to reduce the population density of a target species below its economic injury level (Schroeder *et al*., 1993). Three methods of biological weed control in crops can be distinguished: the inoculative or classical approach; the inundative or microbial approach; and the system management or augmentative approach. Classic approach involves the release of a relatively small number of control agents; these agents feed on the weed, reproduce and gradually suppress the weed as their population grows; arthropods are generally used as control agents. Successes with inoculative biological weed control has been recorded in control of *Chondrilla juncea* L. (skeleton weed) in wheat *Triticum aestivum* L. (wheat) in Australia (Espiau *et al*., 1998). Although much attention has been given to the system management or augmentative approach in scientific literature, it has remained largely a theoretical concept (Muèller *et al*., 200).

Insect bio-control agents

Bio-control of weeds is the deliberate use of natural enemies to reduce the densities of the weeds economically or aesthetically tolerable limits. Insects are important in biological control because of their; a) great variety and numbers, b) high degree of host specialization, c) intimate adaption to their host plants, d) availability of a range of natural enemies suited to particular ecological situations and e) the ease with which they can be handled. Biological agents are increasingly being seen as a feasible solution to the problem. The research effort in the use of fish to control excessive aquatic weed growth in irrigation canal has steadily gained ground in recent years (Center *et al*., 1997). The list of weed species controlled by insect agents is given in Table 2.

Bio-herbicides

Weeds can be controlled by pathogens like fungi, bacteria, viruses and virus like agents. Among the classes of plant pathogens, fungi have been used to a larger extent than bacteria and virus or nematode pathogens. A bio-herbicide is a preparation of living inoculums of plant pathogens formulated and applied in a manner analogous to that of an herbicide in an effort to control or suppress the growth of weed species (Gnanavel and Kathiresan, 2014). The potential for successful use of bio-herbicides in managing herbicides-resistant biotypes was demonstrated where growth of an imazaquin-resistant common cockleber biotype originating soybean field was suppressed with the mycoherbicides, *Alternaria helianthi* (Abbas and Burrentine, 1995). *Fusarium oxysporum* was found to be the best resulting in killing of inoculated water hyacinth in about 15 days (Aditi and Kannan, 2011). The list different bio-herbicides available for controlling weeds are given in the Table 3.

Recent development techniques

Rice bran

Rice bran, derived from the outer layers of the caryopsis during milling, including the pericarp, seed coat, nucellus and part of the sub aleurone layer of the starchy endosperm, accounts for 5 to 8 per cent of the rough rice weight. It is reported by Barber and Barber (1980) that rice bran contain valuable components such as oil, protein, macro and micro nutrients, vitamins some essential minerals as well as enzymes, microorganisms, natural toxicant constituent. Rice bran application in combination with deep flooding had a greater chance of successful weed control (Yan *et al*., 2007). Rice bran @ 2 t/ha applied on 3 DAT + hand weeding on 35 DAT is the viable technique for reduced weed density, weed dry weight and increased yield and net return of organic rice (Gnanasoundari, 2013). Application of rice bran at 2 t/ha 3 DAT + HW on 35 DAT recorded siginificantly high values of yield compents which was in confirmed by Kato *et al.* (2010). Higher rates of rice bran application produced lower number of weed and weed weight which showed effective suppression of different weed species (Bhuiyan *et al*., 2014).

Corn gluten meal

Corn flour is a natural substitute for a synthetic "pre-emergence" herbicide and it is environmentally friendly way to control weeds. Christians (2000) determined that CGM rates of 100, 200, 300, and 400 g/m^2 CGM rates reduced average seedling survival for eight vegetables by 48 per cent, 65 per cent, 73 per cent, and 83 per cent, respectively. However, Carol Savonen (2006) noticed that corn meal gluten prevented grass seeds from sprouting. Further research at Iowa State showed that it also effectively prevents other seeds from sprouting, including seeds from many weeds such as crabgrass, chickweed, and even dandelions. Melissa *et al.,* (2002) reported that corn meal gluten @100 g/m^2 is found to be effective in controlling germination of all seeds including weeds in eight vegetable crops like beetroot, carrot, radish, onion, pea and three varieties of lettuce with control. Hence corn meal gluten is recommended for transplanted crops.

Table 1. General applicability of non-chemical weed management tactics in three types of management units within tillage systems

Category	Weed management tactics	Management unit type		
		Bare	Mulch	No till
Cultural	Crop rotation, competitive cultivars	+	+	+
	Crop row spacing, planting density	+	+	+
	Adapt planting time to weed emergence	+	+	+
	Fertilizer rate and placement	+	+	+
	Compost	+	+	
	Reduce weed seed import (machines, seed, manure)	+	+	+
Tillage	Stubble cultivation	+	+	
	Ploughing	+		
	(Repeated) seedbed preparation	+		
Mulches	Cover crops, dead mulch		+	+
	Green mulch, intercrops	+	+	
	Solarisation/plastic mulch	+		
	Artificially applied mulch	+	+	+
Thermal	Flaming	+		
	Hot water/air	+	+	+
	Band steaming	+		
Mechanical	Interrow cultivation	+	+	+
	Rotary hoeing	+	+	
	Hoeing close to the crop row	+		
	Weed harrowing	+		
	Intra-row weeders	+		
	Inter-row mowing/slashing	+		+
	Weed seed collection	+	+	+
Biological	Mycoherbicides	+	+	+
	Resident herbivores and plant or seed pathogens			+
	Maintaining permanent seed predator habitats			+

+: Good possibilities, : serious restrictions, : not applicable. Experimental technologies (e.g., laser cutting, water jet cutting, UV radiation, electroporation) are excluded.

Table 2. List of weed species controlled by insect agents

S.No.	Weed species	Agents used to control
1.	*Salvinia molesta*	*Cyrtobagous salviniaePaulinia acuminata*
2.	*Eichhornia crassipes*	*Neochetina eichhorniaeN.bruchiOrthogalumna terebrantisSameodes albiguttalis*
3.	*Alternanthera philoxeroides*	*Agasicles hygrophila*
4.	*Ludwigia adscendens*	*Altica cyanea*
5.	*Pistia stratiotes*	*Namangana pectinicoris*
6.	*Opuntia spp.*	*Dactylopius ceylonicusD. opuntiaeDactylopius tomentosus, D. indicus*
7.	*Lantana camara*	*Ophiomyia lantanaeCrocidosema lantana, Teleonemia scrupulosa*
8.	*Parthenium hysterophorus*	*Zygogramma bicolorata*
9.	*Cyperus rotundus*	*BactraverutanaAthesapaeutacyperi*
10.	*Orabanche spp.*	*Phytomyza orobanche*
11.	*Tribulus terrestris*	*Microlarinus lypriformis, M. lareynii*
12.	*Solanum elaegnifolium*	*Frumenta nephalomicta*
13.	*Hydrilla, Azolla, Lemna, Potamogeton*	*Ctenopharyngodon idella*
14.	*Algae*	*Tilapia sp*

Table 3. List of microorganisms used in bio-herbicides and their target weeds and ecosystems

Microorganism	Target weed	Ecosystem	Commercial Product
Foliar/Stem Fungal pathogens			
Biopolaris sorghicola	Sorghum halepense		Biopolaris
Colletotrichum gleosporioides aeschynomene	Aeschynomene viriginica	Rice, soybean	Collego
Colletotrichum gleosprioides f.sp. malvae	*Malva pusilla*	Wheat, horticultural crops	Biomal, Mallet
Colletotrichum gleosprioides f.sp.cuscutae	*Cuscuta* spp.	Soybean	Lubao
Colletotrichum gleosprioides	*Hakea sericea*	Mountain meadows	Hakatak
Colletotrichum truncatum.	Sesbania exaltata	Soybean, cotton, rice	Coltru
Colletotrichum coccodes	Abutilon theophrasti	Maize, soybean	Velgo
Phytopthora palmivora	*Morrenia odorata*	Citrus groves	De Vine
Alternaria cassiae	*Cassia obtusifolia*	Soybean	CASST
Alternaria destruens	Dodders	Cranberry	Smolder
Puccinia canaliculata	Cyperus esculentus	Rice, horticultural crops	Dr.Biosedge
Cercospora rodmani	*Eichhornia crassipes*	Water ways, impoundments	ABG 5003
Chondrostereum purpureum	*Prunes serotina*	Forest	Biochon
Cylindrobasidium leave	*Acacia spp.*	Forest, rangelands	Stumpout
Nectria ditissima	Red alder	Forest	PFC-Alderkill
Foliar Bacterial Pathogens *Xanthomonas campestris pv.poae*	*Poa annua*	Turf, athletic fields	Camperico
Streptomyces hygroscopicus	General vegetation	Row and horticultural crops	Biolophos

In onions, CGM applications of 400 g/m^2 to spring-transplanted onions produced fair (72.1per cent) overall weed control and good (82.7per cent) broadleaf weed control through the first 46 Days After Planting (DAP), without reductions in yields from crop injury (Webber *et al.,* 2007). Average over application rates and compared to the non-treated control, emergence rates of weeds were 17, 27, and 34per cent for kochia, common lambsquarters, and barnyard grass, respectively in CGM amended soil under greenhouse condition (Jialin and Don, 2014)

Limitation to use of non-chemical weed control

Despite the identified ecological/environment and health benefits associated with non-chemical methods of weed control, it usage among the smallholder farmers are limited by a number of factors ranging from farmers perception to socio-economic considerations. Some of the identified limitations are:

There is the problem of farmers' acceptability of non-chemical technologies because of perceived ineffectiveness (Okrikata and Anaso, 2008). Farmers' inability to evaluate the negative impact of synthetic chemicals on the environment and human health (Oruonye and Okrikata, 2010). Non-chemical weed control relies primarily on tillage and hand weeding, practices which are labor intensive and expensive (Gianessi and Reigner, 2007). Lack of available labor, and high wage rates prohibit use of these techniques for agricultural production. Tabaglio *et al*. (2013) posited that farmers understand, but often do not practice IPM/IWM for personal and socioeconomic reasons. The greater and wide adoption of IWM may be achieved by greater attention to the farmer's perspective, needs, belief structure, aspiration and belief structure (Kumar *et al.,* 2012).

Need for further research

First, different weed control techniques should be integrated together to reduce the risk of a selective pressure leading to the predominance of certain species. Repeated use of any weeding method is apt to cause a shift in the weed flora to resistant or tolerant species. Such shifts would reduce the effectiveness of certain weed control strategy. As a kind of strategy, brushing and harrowing can be used occasionally to clean-up heavily infested areas, but may damage vulnerable soil surface and degrade conditions of soil moisture. Thermal weed control can be applied at regular intervals throughout the season to keep weeds at a reasonable level. Second, it is necessary for further development and improvement of the existing weed management methods to increase the energy utilization efficiency. Likewise, it deserves further investigations and development of the weed detecting technologies originally developed for precision chemical application, such as spectral discrimination for weed detection in field, and usage of them into non-chemical weed control. However, the cost of sophisticated equipment would need to be balanced against faster operation speed, consumption in water and energy, and reduced labor costs. Third, it is necessary to study and adjust the energy dose to various weed floras, according to the plants' morphology, flowering period, and environmental conditions. For example, for weed control along the roads, weed control level is often determined by aesthetic considerations and different pavement modes. Therefore, weed control strategies dividing the infested areas into different levels should be considered in order to classify the weed control level according to the required quality, usage and placement. The levels could be ranged from no weed control at all to a very high level of weed control. The purpose of the strategies is to help the farmers or local administrators to plan weed control schedule and give priority to the urgent areas so that the weed management could go from the present relative short-term operational planning to long-term strategy planning.

Conclusion

The above stated review reveals that weeds have to be controlled for successful crop production. Significant crop losses due to weeds are simply not acceptable in a world where two billions more people will have to be fed in the next 40 years. 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. In addition to the growing concern for protection of environment, maintain biodiversity and protection of human and animal health, this approaches are also good ways of climate change mitigation. Each sustainability or at least one less acre as a source acre converted to organic, sustainable methods could be practiced which was stabilize the soil fertility and reduce the environmental pollution.

REFERENCES

Abbas, H.K., W.L. Barrentine., 1995. Alternaria helianthi and imazaquin for control of imazaquin susceptible and resistant cockleber (*Xanthium strumarium*) biotypes. *Weed Sci., 43*: 425-428.

Abid Khan, S. Muhammad., H. Zahid., M. Abdul., 2012. Effect of different weed control methods on weeds and yield of Chillies (*Capsicum annuum* L.). *Pak. J. Weed. Sci. Res.,* 23(4):12-14.

Aditti, P., C. Kannan., 2011. Isolation and pathogenicity of some native fungal pathogens for the biological management of water hyacinth. *Indian J. Weed Sci.,* 43 (3&4): 178-180.

Ahmed, A., S.K. Thakral., A. Yadav., R.S. Balyan., 2010. Grain yield of wheat as affected by different tillage practices varieties and weed control methods. National Symposium on Integrated Weed Management in the Era of Climate Change, held at NAAS, New Delhi on 21-22 August, p. 19.

Alcorta M., M.W. Fidelibus., K.L. Steenwerth., A. Shrestha., 2011. Effect of Vineyard Row Orientation on Growth and Phenology of Glyphosate-Resistant and Glyphosate-Susceptible Horseweed (*Conyza canadensis*). *Weed Sci.,* 59(1):55-60.

Ali, M., A. Riaz., A. Zahoor., A.M. Rehan., 2013. Effect of Different Mulches Techniques on Weed Infestation in Aerobic Rice (*Oryza sativa* L.). *J. Agric. Environ. Sci.,* 13 (2):153-157.

Anazalone, A., A. Cirujeda., J. Aibar., G. Pardo., C. Zaragoza., 2010. Effect of biodegradable mulch materials on weed control in processing tomatoes. *Weed Tech.,* 24(3): 369-377.

Arora, A., S.S. Tomar., 2012. Effect of soil solarization on weed seed bank in soil. *Indian J. Weed Sci.,* 44(2): 122-123.

Ascard, J., P.E. Hatcher., B. Melander., M.K. Upadhyay., 2007. Thermal weed control. In Upadhaya, M.K and

Blackshaw, R.E. 2007. Nonchemical weed management. Principles, concepts and technology. CABI, London, UK.

Barber, S., C.B. De Barber., 1980. Rice bran: chemistry and technology. In: Rice: Production and Utilization. (ed B.S. Luh) Avi Publishing, Westport. pp. 790-862.

Bernstein, E.R., D.E. Stoltenberg., J.L. Posner., J.L. Hedtcke., 2014. Weed community dynamics and suppression in tilled and no-tillage transitional organic winter rye-soybean systems. *Weed Sci.,* 62: 125e137.

Bertholdsson, N.O., 2011. Use of multivariate statistics to separate allelopathic and competitive factors influencing weed suppression ability in winter wheat. *Weed Res.,* 51(3): 273-283.

Bhan, M., U.P.S. Bhadauria., S. Sharma., 2012. Effect of varieties for weed and drought tolerance in different irrigation regimes. In: Proceeding of 3rd International Agronomy Congress, Held at IARI, New Delhi, pp. 58-57.

Bhardwaj, R.L., 2013. Effect of mulching on crop production under rainfed condition : A review. *Agric. Rev.,* 34 (3): 188-197.

Bhuiyan, M.K.A., A.J. Mridha., G.J.U. Ahmed., S.A. Islam., M.A.A. Mamum., 2014. Effect of rice bran application for eco-friendly weed control, growth and yield of lowland rice in Bangladesh. *Int. J. Agron. Agril. Res.,* 5(3): 40-44.

Borger, C.P.D., A. Hashem., S. Pathan., 2010. Manipulating crop row orientation to suppress weeds and increase crop yield. *Weed Sci.,* 58:174-178.

Brar, A.S., U.S. Walia., 2010. Rice residue position and load in conjunction with weed control treatments interference with growth and development of *Phalaris minor* and wheat (*Triticum aestivum* L). *Indian J. Weed Sci.,* 42 (3&4): 63-67.

Carol Savonen., 2006. Effect of corn meal gluten on weeds. Oregon State University Extension service. *Weed Sci.,* 26: 128-131.

Carter, M.R., J.A. Ivany., 2006. Weed seed bank composition under three long-term tillage regimes on a fine sandy loam in Atlantic Canada. *Soil and Tillage Res.,* 90: 29-38.

Center, T.D., J.H. Frank., F.A. Dray., 1997. Strangers in paradise. In: Biological control. (Eds. Simberl off DDC Schmitz and TC Brown) Island Press. Washington DC. 245-266.

Chauhan, B.S., D.E. Johnson., 2011. Row spacing and weed control timing affect yield of aerobic rice. Field Crops Res., 121: 226-231.

Chhohar, R.S., S. Samar., R.K. Sharma., M. Singh., 2009. Influence of straw management on Phalaris minor Retz. Control. *Indian J. Weed Sci.,* 41(3&4): 150-156.

Christians, N.E., 2000. A natural herbicide from corn meal for weed-free lawns. IPM Practitioner., 17(10): 5-8.

Cici, Z.H., S. Adkins., J. Hanan., 2008. A canopy architectural model to study the competitive ability of chickpea with sowthistle. *Annals of Bot-London.,* 101: 1311-1318.

Das, T.K., N.T. Yaduraju., 2007. Effect of irrigation and nitrogen levels on grassy weed competition in wheat and comparative ecophysiology of *Phalaris minor* and *Avena sterilis* in wheat. *Indian J. Weed Sci.,* 39: 178-184.

Das, T.K., N.T. Yaduraju., 2008. Effect of soil solarization and crop husbandry practices on weed species competition and dynamics in soybean- wheat cropping system. *Indian J. Weed Sci.,* 40(1&2): 1-5.

Deshmukh, G., R.K. Tiwari., 2011. Impact of weeders for weed management in systems of rice intensification (SRI). *Indian J. Weed Sci.,* 43(3&4): 243-244.

Devasinghe, D.A., U.D. Premarathne., U.R. Sangakkara., 2011. Weed Management by Rice Straw Mulching in Direct Seeded Lowland Rice (*Oryza sativa* L.). *Tropical Agril. Res.,* 22 (3): 263-272.

Drews, S., D. Neuhoff., U. Köpke., 2009. Weed suppression ability of three winter wheat varieties at different row spacing under organic farming conditions. *Weed Res.,* 49(5): 526-533.

Dubey, R.P., 2014. Integrated weed management- an approach. In Training Manual Advance Training in Weed Management, held at DWSR, Jabalpur, India on 14-23 January, pp. 19-21.

Dwivedi, S.K., G.K. Shrivastava., A.P. Singh., R. Lakpale., 2012. Weeds and crop productivity of maize + blackgram intercropping system in Chhattisgarh plains. *Indian J. Weed Sci.,* 44: 26-29.

Dzomeku, I.K., G.K. Mahunu., T.B. Bayorbor., P. Obeng-Danso., 2009. Effects of mulching on weed control and yield of hot pepper and tomato in the Guinea Savannah zone. *Ghana J. Hortic.,* 7: 53-61.

Ehsanullah, R., M. Qamar., A. Kalim., Z. Rehman., A. Iqbal., Ghaffar., G. Mustafa., 2014. Growth and economic assessment of mulches in aerobic rice (*Oryza sativa* L.). *J. Agric. Res.,* 52(3): 395-405.

Espiau, C., D. Riviere., J.J.S. Burdon., B. Gartner., S. Daclinat., P. Chaboudez., 1998. Host-pathogen diversity in a wild system. *Chondrilla juncea- Puccinia chondrillina*. *Oecologia.* 113: 133-139.

Farid Golzardi., Yavar Vaziritabar., Yazdan Vaziritabar., Shabnam Sarvaramini., Seyedeh Zohreh Ebadi., 2014. Solarization period and thickness of polyethylene sheet effects on weed density and biomass. *Indian J Fundamental and Applied Life Sci.,* 4 (S3): 587-593.

Forcella, F., M.J. Lindstrom., 1988. Movement and germination of weed seeds in ridge-till crop production systems. *Weed Sci.,* 36 (1): 56-59.

Ghuman, R.S., L.S. Brar., U.S. Walia., 2008. Role of variety and plant geometry on weed management in Transplanted rice (*Oryza sativa* L.). *Indian J.Weed Sci.,* 40(3&4): 137-141.

Gianessi, L., N. Reigner., 2007. Barriers to widespread conversion from chemical pest control to non-chemical methods in U.S. Agriculture. Accessed from http://www. croplifefoundation.org.

Gnanasoundari, P., 2013. Weed management in organic rice production. M.Sc. (Ag.) Thesis. Tamil Nadu Agricultural University, Coimbatore.

Gnanavel, I., R.M. Kathiresan., 2014. Eco-friendly weed control options for sustainable agriculture- a review. *Agri. Review.,* 35(3): 172-183.

Gomez, R., M.L. Liebman., G. Munkvold., 2014. Weed seed decay in conventional and diversified cropping systems. *Weed Res.,* 54: 13-25.

Gore, A.K., G.D. Gadade., J.K. Jadhav., 2010. Performance of mechanical weeders on vertisols of Marathwada region in Soybean. In: Biennial conference of Indian Society of Weed Science on Recent Advances in Weed Science Research-2010, 25-26 February. IGKV, Raipur, Chhattisgarh, p 106.

Govindappa, M., S.C. Pallavi., 2014. Importance of mulching as a soil and water conservative practice in fruit and vegetable production-review. *Intl. J.Agri. Innov. Res.,* 3(4): 1014-1017.

Håkansson, S., 2003. Weeds and Weed Management on Arable Land – An Ecological Approach (first edition), CABI Publishing, Wallington, Oxon, UK.

Harker, K.N., J.T. O'Donovan, R.B. Irvine., T.K. Turkington., G.W. Clayton., 2009. Integrating cropping systems with cultural techniques augments wild oat (*Avena fatua*) management in barley. *Weed Sci.,* 57: 326-337.

Heinz, M.S., 2014. Inter planting rye grass in winter leek: Effect on weed control, crop yield and allocation of N-fertilizer. *Crop Protection.* 15(7): 641-648.

Hutchinson, P.J.S., C.V. Eberlein., 2003. Weed management. J.C. Stark and Love, S.L. Eds. In: Potato Production Systems. Moscow, ID: University of Idaho Agricultural Communications. pp. 241-283.

Jialin, Y., M. Don., 2014. Response of Seven Weed Species to Corn Gluten Meal and White Mustard (*Sinapis alba*) Seed Meal Rates. *Weed Tech.,* 28(1): 259-265.

Kainz, M., G. Gerl., B. Lemnitzer., J. Bauchenss., K.J. Hülsbergen., 2005. Effects of different tillage systems in the long-term field experiment. Ende der Nische, Beiträge zur 8. Wissenschaftstagung Ökologischer Landbau, Kassel University Press, 4 pp. Online at http://orgprints.org/3651/

Kalia, A., R.P. Gupta., 2004. Disruption of food web by pesticides. Indian. J. Ecol., 31: 85-92.

Kasirajan, S., M. Ngouajio., 2012. Polyethylene and biodegradable mulches for agricultural applications: a review. *Agron Sustain Dev.,* 32:501-529.

Kato, S., D. Abe., T. Miki., S. Iwaishi., T. Harakawa., K. Inubushi,, 2010. Effect of application methods of organic manure at transplanting time on rice yield and suppression of paddy weeds in organic rice cultivation. *Hort. Res.,* 64:25-34.

Kewat, M.L., 2014. Improved weed management in Rabi crops. National Training on Advances in Weed Management. pp. 22-25.

Kumar, M., A.K. Ghorai., S.R. Singh., B. Majumdar., D.K. Kundu., B.S. Mahapatra., 2012. Effect of stale seedbed and subsequent herbicides application on weeds and rhizospheric microorganism in Jute. In: Proceeding of 3rd Int. Agron. Cong., Held at IARI, New Delhi, pp. 304-305.

Kumar, P., Y. Singh., U.P. Singh., 2013. Evaluation of cultivars and herbicides for control of barnyard grass and nutsedge in boro rice. *Indian J. Weed Sci.,* 45: 76-79.

Kumar, R., R. Gopal., M. Jat., R.K. Gupta., 2010. Conservation Agriculture Based Strategies for Sustainable Weed Management in Maize (*Zea mays*). Training Manual, Maize for Freshers. Directorate of Maize Research, New Delhi, India.

Kumar, S., P. Ray., 2011. Evaluation of augmentative release of *Zygogramma bicolorata* for biological control of Parthenium. *Crop Protection*. 30: 587-591.

Kushwah, Y.C., P.K. Dwivedi., S.S. Jain., 2013. Effect of mulching materials on growth and yield attributes and enhancing farm income through ginger cultivation under rainfed rice based production system. *Veg. Sci.,* 40 (1): 96-98.

Lanini, W.T., G.T. McGourty., L.A. Thrupp., 2011. Weed management for organic vineyards. In: McGourty, G. (Ed.), Organic Winegrowing Manual. University of California, Agriculture and Natural Resources, Richmond, pp. 69-82.

Laurie. M., M. Maja., H. Ngobeni,, 2015. Effect of different types of mulching and plant spacing on weed control, canopy cover and yield of sweet potato (*Ipomoea batatas* L.). *American J. Exptl. Agril.,* 5(5): 450-458.

Légère, A, F.C. Stevenson., D.L. Benoit., 2005. Diversity and assembly of weed communities: contrasting responses across cropping systems. *Weed Res.,* 45: 303-315.

Liebman, M., C.L. Mohler., C.P. Staver., 2001. Ecological Management of Agricultural Weeds Cambridge University Press, Cambridge.

Lundkvist, A., L. Salomonsson., L. Karlsson., A.M. Dock-Gustavsson., 2008. Effects of organic farming on weed flora composition in a long term perspective. *European J Agronomy.* 28(4): 570-578.

Manuwa, S.I., O.O. Odubanjo., B.O. Malumi., S.G. Olofinkua., 2009. Development and performance evaluation of a row-crop mechanical weeder. *J. Engg. Appl. Sci.,* 4(4): 236-239.

Melissa, C., Mc Dade., N.E. Christians., 2002. Corn gluten meal- a natural pre-emergence herbicide: Effect on vegetable seedling survival and weed cover. *Weed Sci.,* 50(6): 688-699.

Mohammad, A.R., 2011. Field performance evaluation of mechanical weeders in the paddy field. *Sci. Res. Essays.* 6(25): 5427-5434.

Mohammadi, G.R., 2012. Living mulch as a tool to control weeds in agro ecosystems: A Review. In: Price, A. J. (Ed.), Weed Control. Tech Press, Croatia. pp. 75-100.

Muèller, H., P.C. Scheepens., M.P. Greaves., 2000. Biological control of weeds in European crops: recent achievements and future work. *Weed Res.,* 40: 83-98.

Okrikata, E., C.E. Anaso., 2008. Influence of some inert diluents of neem kernel powder on protection of sorghum against pink stalk borer (*Sesamia calamistis*) in Nigerian Sudan savanna. *J. Plant. Protect. Res.,* 48(2): 161-168.

Oruonye, E.D., E. Okrikata., 2010. Sustainable use of plant protection products in Nigeria and challenges. *J Plant Breeding and Crop Sci.,* 2(9): 267-272.

Pal, D., S. Bera., R.K. Ghosh., 2013. Influence of herbicides on soybean yield, soil micro flora and urease enzyme activity. *Indian J. Weed Sci.,* 45(1): 34-38.

Parr, M., J.M. Grossman,, S.C. Reberg-Horton., C. Brinton., C. Crozier., 2014. Roller-crimper termination for legume cover crops in North Carolina: impacts on nutrient availability to a succeeding corn crop. *Soil Sci. Plan.,* 45:1106-1119.

Patel, V.M., V.S. Patel., J.D. Thanki., 2011. Effect of irrigation levels and weed management practices on weed growth and yield of summer blackgram (*Phaseolus mungo* (L.) Hepper) under south Gujarat condition. *Green farming*. 2(2): 182-184.

Pekrun, C., W. Claupein., 2006. The implication of stubble tillage for weed population dynamics in organic farming. *Weed Res.,* 46: 414-423.

Rair, A.B.S., G.S. Chhina., H.S. Chatha., 2011. Response of turmeric (*Curcuma longa* L.) to plant architecture and mulching in term of growth and rhizomes yield in Punjab. *Progressive Agric.,* 2: 450-452.

Rajasekar, S., 2002. Design, development and performance of tractor drawn multirow rotary weeder. M.E (Ag.) thesis. Tamil Nadu Agricultural University, Coimbatore.

Rask, A.M., P. Kristoffersen., 2007. A review of non-chemical weed control on hard surfaces. *Weed Res.,* 47: 370-380.

Sanjay, K., G.K. Dwivedi., A.P. Shrivastava., S.S. Kolhe., 2011. Weed population, nitrogen removal by weeds and crop yield under maize+ blackgram intercropping system in Chhattisgarh plains. *Indian J. Weed Sci.,* 43 (3&4): 203-210.

Satyanarayana, A., T.M. Thiyagarajan., and N. Uphoff., 2007. Opportunities for water saving with higher yield from the system of rice intensification. *Irrigation Sci.,* 25: 99-115.

Schroeder, D., H. Mueller-Schaerer., C.S.A. Stinson., 1993. A European survey weeds in 10 major crop systems to identify targets for biological. *Weed Sci.,* 33: 449-458.

Sharma, A.R., 2014. Weed management in conservation agriculture systems- problems and prospects. National Training on Advances in Weed Management. pp. 1-9.

Shrestha, A., M. Fidelibus., 2005. Grapevine row orientation affects light environment, growth, and development of black nightshade (*Solanum nigrum*). *Weed Sci.,* 53: 802-812.

Sindhu, P.V., C. George Thomas., and C.T. Abraham., 2010. Seedbed manipulations for Weed Management in Wet Seeded Rice. *Indian J. Weed Sci.,* 42(3&4): 173-179.

Singh, A., R. Kaur., J.S. Kang., G. Singh., 2012. Weed dynamics in rice- wheat cropping system. *Global J. Bio. Agri. and Health Sci.,* 1(1): 7-16.

Singh, M., 2010. Evaluation of different mulches for weed management in Pea (Pisum sativum). *Indian J. Weed Sci.,* 42(1&2): 60-62.

Singh, R., 2014. Weed management in major kharif and rabi crops. National Training on Advances in Weed Management. pp. 31-40.

Srinivasarao, M., A. Halder., M. Pramanick., 2014. Efficacy of glyphosate 71% SG (Ammonium salt) on weed management in tea. *The Ecoscane.* 6: 91-95.

Sumathi, V., D. Subramanyam., D.S. Koteswara Rao., D.S. Reddy., 2010. Effect of planting pattern and weed management on weed flora and yield of rabi sunflower. *Indian J. Weed Sci.,* 42(3&4): 212-216.

Suresh Kumar, K., 2014. Integrated Weed Management in Hybrid Brinjal, M.Sc., Thesis, AC&RI, Tamil Nadu Agricultural University, Madurai.

Sushilkumar., K. Vishwakarma., N.T. Yaduraj., 2005. Chemical control of lotus (*Nelumbo nucifera* Gaertn) in fish culture pond and its impact on water quality. *Indian J. Weed Sci.,* 37(3&4): 293-295.

Tabaglio, V., A. Marocco., M. Schulz., 2013. Allelopathic cover crop of rye for integrated weed control in sustainable agroecosystems. *Italian J. Agron.,* 8: 5-10.

Upadhyaya, M.K., R.E. Blackshaw., 2008. Non-chemical weed management: principles, concepts, and technology. CAB International/North American Office, 875 Massachusetts Ave., Seventh Floor, Cambridge, MA.

Van, D.W., R.Y. Bleeker., P.O. Achten., L.A.P. Lotz., F. Fogelberg., B. Melander., 2008. Innovation in mechanical weed control in crop rows. *Weed Res.,* 48:215-224.

Vera C.L., S.M. Woods., J.P. Raney., 2006. Seeding rate and row spacing effect on weed competition, yield and quality of hemp in the Parkland region of Saskatchewan. *Can. J. Plant Sci.,* 86: 911-915.

Verma, S.K., 2014. Enhancing sustainability in wheat production though irrigation regimes and weed management practices in eastern Uttar Pradesh. *The Ecoscane.* 6: 115-119

Verma, S.K., S.B. Singh., 2008. Enhancing of wheat production through appropriate agronomic management. *Indian Farming.* 58(5): 15-18.

Webber, C.L., J.W. Shrefler., M.J. Taylor., 2007. Impact of corn gluten meal applications on spring transplanted onion (*Allium cepa*) injury and yields. *Int. J. Veg. Sci.,* 13: 5-20.

Yan, Y.F., J.D. Fu., B.W. Lee., 2007. Rice Bran Application under Deep Flooding Can Control Weed and Increase Grain Yield in Organic Rice Culture. *J. Crop Sci. Biotech.,* 10(2): 79-85.

Zimdahl, R.L., 2004. Weed-Crop Competition. A review. (2nd edition), Blackwell Publishing Ltd., Iowa, USA.

Zimdahl, R.L., 2007. Fundamental of weed science. Academic Press, Burlington, MA.

****