The Pharma Innovation Journal 2022; SP-11(7): 1655-1660

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; SP-11(7): 1655-1660

www.thepharmajournal.com
Received: 11-04-2022
Accepted: 03-06-2022

Kavita Bhadu
Assistant Professor, Department of Agronomy, Lovely Professional University, Phagwara, Punjab, India

Bhupendra Kaswan
Assistant Professor, Khalsa College Of Veterinary and Animal Science, Amritsar, Punjab, India

Corresponding Author
Bhupendra Kaswan
Assistant Professor, Khalsa College Of Veterinary and Animal Science, Amritsar, Punjab, India

Organic weed management an important component of organic farming: A review

Kavita Bhadu and Bhupendra Kaswan

Abstract
Weeds are an important biotic constraint to food production which causes significant reduction in crop yield. Their competition with crops for nutrients, light, water etc., reduces agricultural output in terms of quality as well as quantity, and also increases the cost of cultivation involved in the control of weeds. It is also a major constraint on increasing agricultural productivity and farmers' income, particularly in developing countries like India. Therefore, taking this into consideration the importance of weed management is much higher in crop production. Weeds are conventionally controlled by herbicides which led to herbicide persistence and resistance and a shift of weed flora. Application of high dose of inorganic herbicide also causes degradation of soil health, pollution of ground water table and extinct of natural enemies. So, organic weed management is much demanded to get higher crop production. In an organic production system, weeds are one of the most troublesome, time consuming and costly production problems. In an organic production system weeds are managed by non chemical methods.

Keywords: Organic, weed management, non chemical, sustainability, eco-friendly

Introduction
Sustainable crop production is one of the major challenges in today's agriculture where resources are limiting but demands for food grains is increasing day by day. Both abiotic and biotic stresses are responsible factors for losses in agricultural production. As with abiotic causes, particularly the lack or surplus of water in the growing season, high temperatures, high or low irradiance, and nutrient supply; biotic stresses also have the potential to reduce yields substantially (Oerke, 2006) [26]. Weeds are considered the most harmful biotic constraints to agricultural production. Weeds are the major agricultural pests that can destroy a crop if not properly managed.

Weeds are the plants which are undesirable, persistent, damaging and interfere with growth of other crop plants, thus affecting human activities, agriculture, natural processes and economy of the country. In a crop production system, weeds can be considered a significant problem because they compete for the same resources as the crops, such as water, nutrients, sunlight, and space, limiting crop productivity (Harlan 1965) [13]. Weeds also affect the quality of produce. Interfere with and damage harvesting equipment and harbor pests and diseases. Weeds cause harm to crops in many ways and this happens due to the unusual adaptation characteristics of the weeds and their regeneration ability. Therefore, weed management is the major and very important part of crop production.

Today, some farmers have a renewed interest in organic methods of managing weeds since the widespread use of agrochemicals has resulted in environmental-health issues and development of herbicide resistance in weeds. For organic farmers, weeds are the most significant production problems. It is important to understand that an organic farmer must rely on non-chemical weed management. Non-chemical weed management is required for sustainable crop production. This review paper has precise information of various organic weed management methods which provide eco-friendly solutions to organic farmers to solve the weed infestation problems and helps in yield improvement.

The herbicide threat
In the past decades, herbicide use in less developed countries has tended to increase at a faster rate (Moody, 1990) [21]. Glyphosate-based herbicide is the most used broad-spectrum herbicide in the world. Due to its excessive application practices, the widespread presence of glyphosate has been reported in terrestrial and aquatic ecosystems (Hanke *et al.*, 2010) [14]. Spray drift from glyphosate has been found which leads to distorted fruit at a sublethal level of exposure

(Laitinen *et al*., 2007) [19]. Moreover, experts from the World Health Organization's International Agency for Cancer Research have concluded that glyphosate has a carcinogenic effect on humans (Myers *et al*., 2016) [27]. This represents the adverse impact of herbicides on the ecosystem, economy, and human health. This urges us to shift towards organic cultivation practices in the future. Keeping this in mind, I tried to collect some non-chemical or organic methods of weed control in this article.

Crop weed competition and yield loss due to weeds

Weeds are undesirable plants that infest crops and inflict an adverse impact on crop yield by competing for water, light, space, and nutrients (Reddy *et al*., 2011) [32]. Crops are highly susceptible to weed competition at the early growth stage. Yield loss due to weeds depends on several factors such as density, time of emergence, type of weed, and crop type (Chauhan *et al*. 2020) [9]. Globally, up to 40% yield loss because of weeds has been reported. Worldwide, weed competition causes severe yield reductions in all major crops, such as wheat (23%), soybean (37%), rice (37%), maize (40%), cotton (36%), and potato (30%) (Oerke, 2006) [26].

In general, yield loss due to weeds is caused by a group of different weed species, and these species can differ considerably in their competitive ability (Weaver and Ivany 1998). Basically, it is very difficult to estimate the yield loss due to a single weed species and therefore, it is estimated as the cumulative loss by all the weeds. It was proved that weeds were economically more important than insects, fungi or other pest organisms (Savary *et al*. 1997, 2000) [36]. Globally, weeds caused the highest potential loss (34%), with animal pests and pathogens being less important (losses of 18 and 16% respectively). It has been estimated that on an average, weeds cause 5% loss in agricultural production in most developed countries, while loss is 10% in developing countries and 25% in least developing countries (Oerke, 2006) [26]. Weed infestation during the complete crop season led to a decrease in maize yield by up to 82% to 84% (Babiker *et al*., 2013) [6]. Potential yield loss due to weeds in different major crops of India is presented here in Table 1. (Rao *et al*. 2014) [33]

Table 1: Potential yield loss due to weeds in different major crops of India [Rao *et al*. 2014] [33].

Crop	Yield losses (%)	Crop	Yield losses (%)
Rice	10-100	Pearlmillet	16-65
Wheat	10-60	Sorghum	45-69
Maize	30-40	Fingermillet	50
Sugarcane	25-50	Greengram	10-45
Chickpea	10-50	Groundnut	30-80
Pigeonpea	20-30	Lentil	30-35
Soybean	10-100	Pea	10-50
Cotton	40-60	Potato	20-30
Jute	30-70	Niger	20-30

Weed management

Weeds should be managed in such a way that will encourage the growth of crop plants which are beneficial or in our interest and suppress the remaining unwanted plants (weeds). There are many approaches by which weeds can be effectively and economically controlled in organic farming.

Preventive measures

Prevention is the most important aspect of weed management. Once a harmful weed infestation becomes established, any increase in size and density of weeds creates more expensive management efforts. In India, increasing globalization and unchecked import of food grains and seed materials and from other countries in the past have led to invasion of alien weeds in the country. For successful weed management, it is most important to prevent the distribution of weed seeds from infested to uninfested areas and from one field to another. Use of clean crop seed is the most effective preventive method of weed management. It is also important to recognize and eradicate the invasive weeds in a newly infested field to prevent the buildup of the weed population. The basic principle of managing annual weeds, which reproduce mostly from seeds, lies in killing them before flowering, so as to prevent seed setting and their infestation in the next season.

Cultural methods

Cultural weed control options include crop rotation, increasing the competitive ability of a crop, delayed or early seeding, flooding, solarization, stale seedbed, inclusion of green manure and cover crops, and intercropping. 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 suppress the weeds, adequate and localized resource application, and optimum management of the crop.

Crop rotation

Crop rotation is the practice of growing a series of crops sequentially over time on the same land, thus providing temporal variability (Zhao *et al*. 2020) [48]. Selection of good crop rotation is must to prevent development of diverse weed population. Puddling in rice helps in minimizing Cyperus rotundus in the following chickpea. Similarly, Phalaris minor and *Chenopodium album* in chickpea can be minimized by following puddling in rice (IIPR, 2009) [16]. Inclusion of pulses in the rainy season can reduce the infestation of Phalaris minor and Avena fatua in winter crops.

Weed species in monoculture tend to adapt to management practices and cause yield reductions (e.g., herbicide resistance, early seed shattering, and crop mimicry). In crop rotations, weeds are subjected to diverse weed control methods (no-tillage/till or diverse herbicides, planting dates, fertilization regime), thus preventing weeds from adapting and surviving (Anderson 2007) [3].

Zhao *et al*. (2020) [48] recently performed a meta-analysis on 45 studies and reported a 20% increment in crop yields due to crop rotation. Moreover, another meta-analysis on 54 studies showed that crop rotation leads to a 49% reduction in weed density (Weisberger *et al*. 2019) [46]. Thus, crop rotation helps to reduce weed pressure and increase crop yield.

Anderson (2003) [4] showed that crop rotations could help reduce the seedbank of annual weeds by balancing the seed production frequency. Crop rotation with a non-host of parasitic weeds can help reduce the seedbank of these weeds. Oswald and Ransom (2001) [25] reported crop rotation as one of the most effective methods to reduce Striga infestations in corn and increase corn yields. Samake *et al*. (2006) concluded similar results for *Striga hermonthica* L. in traditional millet and cowpea rotation.

Intercropping

Intercropping has been found to suppress the weeds through formation of good canopies due to a competitive planting pattern. Inclusion of short-duration and quick-growing intercrops in between the rows of long-duration and tall-growing crops has been found to suppress the weed infestation very effectively. As a result of considerable reduction in weed weight due to inclusion of intercrops in long-duration, wide-spaced crops, the weeding requirements have been found to be reduced substantially (Ali, 1988). In pigeon pea-based intercropping, fast-growing short-duration pulses like cowpea, urbean and mungbean suppress weed flora by 30–40% compared with 22% by sorghum (IIPR, 2009) [16].

Talnikar *et al*. (2008) [48] found that weeds caused 79.9% reduction in pigeonpea seed yield if weeds were allowed to grow till harvest. However, the yield losses were only 38.2% in pigeonpea + soybean intercropping system. Similar effect was also reported in chickpea + wheat (Banik *et al*., 2006) [5] and chickpea + mustard (Kaur *et al*., 2014) [18] intercropping systems.

Soil solarization

Soil solarization is a novel technique of weed management through heating of surface soil by trapping the solar radiation using plastic sheets placed on moist soil. Direct killing of weed seed in the soil by lethal soil temperature built under transparent polyethylene mulch is the main mechanism of reducing weed seed population and weed emergence. Soil solarization process increases the soil temperature by 18-12 ^{0}C. Solarization has been found to be highly effective in controlling parasitic weeds like Orabanche spp from 70-100 per cent.

Yaduraju and Ahuja (1990) [47] reported a reduction in the population of grassy and broad-leaf weeds due to soil solarization. However, weeds such as Cyperus rotundus (tubers), Melilotus spp. (hard seed-coat) and Cynodon dactylon (rhizomes) are not controlled by solarization (Patel *et al*., 2005) [27]. This technique is applicable to nurseries and high-value crops like vegetables, and generally cannot be followed for large scale cultivation of field crops because of cost considerations.

Cover Crop

Cover crops are crops planted between the growing seasons to improve soil health, reduce soil erosion, suppress weeds and other pests (Baraibar *et al*. 2018) [7]. Cover crops suppress weed growth by multiple mechanisms such as competition for light, space, water, and nutrients (Thorup-Kristensen *et al* 2003) [41]. After the termination of the crop, it forms a mulch layer on the soil surface, which is proven to reduce weed germination, emergence, and establishment (Teasdale *et al* 2008; Peachey *et al*. 2004, and Wallace *et al* 2017) [42, 28, 45]. Furthermore, cover crops and associated mulch have been shown to release allele chemicals, which further suppress weed growth (Singh *et al*. 2003) [37]. One of the cereals, rye (*Cereale secale* L.), is most commonly used as a winter cover crop in soybean and corn as it provides reasonable weed control and yield (DeVore *et al* 2013) [10].

The diversity and size of the weed seedbank strongly influence the success of weed management practice. Cover crops can reduce weed seedbank by preventing propagule production, reducing seedling establishment, early/delay emergence (Gallandt 2006) [11]. Long-term use of the cover crop before cash crops can help to deplete weed seed bank. However, some studies have noticed no apparent change in weed seedbank (Buchanan *et al*. 2016 and Alonso *et al*. 2018) [8, 2]. Hence, more research efforts are needed to understand the role of cover crops and weed seed bank.

Stale seedbed

In this method, weed seeds in the surface layer of the soil are induced to germinate and emerge before sowing so that a part of the weed population could be eliminated by pre- plant shallow tillage. Sanbagavalli (2010) [39] reported nearly 30 per cent weed seed bank depletion in cotton field and 15 - 20 per cent increased seed cotton yield could be obtained by adopting SSB technique in two consecutive years, when compared to conventional seedbed preparation.

Physical methods

Hand weeding is the oldest method of physical weed management. Farmer's practice of hand weeding twice is found to keep the weed density below the threshold level and increased the yield about 65 per cent than control in brinjal (Umamaheswari, 2016) [43].

Mulching

Covering or mulching the soil surface can reduce weed problems by preventing weed seed germination or seedling growth by various mechanisms *viz*., physical barrier, limiting light transmission below mulches, smothering effect, allelopathy of mulches and altering soil hydro-thermal regimes. Mulches can be made from a number of materials *viz*., living plant ground cover, loose particles of organic or inorganic matter spread over soil. In addition to weed control, these mulches also improve soil fertility by nitrogen addition, reducing soil erosion, soil moisture conservation, increasing microbial population and soil organic carbon status. Plastic mulches and dry plant parts are used as non-living mulch. Gbadamosi *et al*. (2003) [12] found that dry grass mulches were used to control weeds in vegetables, which reduced weed growth upto 78 per cent.

Mechanical methods

Mechanical methods involve removal of weeds with various tools and implements. Intercultural practices are performed with implements used by hand, bullocks or tractor to create favourable conditions for the growth of crops. Most mechanical weed control methods, such as tillage and harrowing are used at very early weed growth stages.

Tillage practices

Tillage influences the weed seed bank dynamics by physical mixing or by turning under the soil. Weed seed burial deep fails to emerge, resulting in low weed intensity in subsequent season. Deep ploughing can also be effective against perennial weed like Cynodon dactylon provided the rhizomes after tilling are collected and destroyed. However, a reduction in tillage will allow accumulation of 40-80% of weed seeds in the top 0-5 cm soil layer resulting in more weed emergence compared to conventional tillage.

Night tillage

Many weeds require a flash of micro-seconds of red light in order to germinate. Night tillage may help to reduce weed germination to a significant extent. Moradi Talebbeigi *et al*. (2016) [23] reported that night tillage reduced the weed

population of common lambsquarter (*Chenopodium album* L.) and foxtail (*Setaria* spp.) by 38.6 and 22%, respectively than day tillage.

Use of weeders

Machineries like mini-weeders, power tillers, and mini tractor-drawn rotavator are used for weeding in wider spaced crops like sugarcane, cotton, and orchards. Cono weeder is an implement which is used for controlling the wet land weeds and getting more yields under the system of rice intensification.

Pneumatic weed control

This is a new technology implemented to manage weed from the field. An implement has been developed that injects the compressed air into the soil and removes the small weed from either side of the crop row. The compressed air uproots the weeds from both sides of the crop furrow.

Thermal weed management

Thermal weed management involves heat energy to kill the weeds and their seed production through different direct and indirect techniques. Heating results in the coagulation of proteins and bursting of protoplasm due to expansion, which kills the tissue. Plant tissues are susceptible to high temperatures, which can disrupt physiological functions. Heat can be applied in different ways to control weeds: direct flaming (Knezevic *et al*., 2011) [17], Solarization (Horowitz *et al*., 2017) [15], laser radiations (Mathiassen *et al*., 2006) [20], steam (Rask and Kristoffersen, 2007) [31], and electrocution (Parish, 1990) [29]. These methods of weed control can be used to kill weeds in organic farming. Weeds can also be killed by exposure to very low temperature, e.g. by exposing aquatic weeds to low air temperature by removing water from a pond or lake or by freezing terrestrial weeds using dry ice or liquid nitrogen.

Infra-Weeder

The Infra - weeder weed control equipment uses infrared heat to kill undesired vegetation. Infra-weeder equipment uses a propane- fuelled ceramic heating element that develops temperatures up to 1800 degrees Fahrenheit (1000 degrees Celsius), which applies infrared radiation to weeds.

Biological methods

Biological weed management involves the use of host-specific phytophagus insects and plant pathogens to reduce the population density of a target species below its economic injury level. Some examples of biological weed management include; control of Parthenium by *Zygogramma bicolorata*; Lantana spp. by *Telenomia scrupulosa*; water hyacinth by *Neochetina eichhornea* and *N. bruchi*;. Fish under aquatic system and competitive crop plants also proved to be the successful biological control agents for aquatic weeds.

Bio-herbicides

Bio-herbicides are biological control agents applied in similar ways of chemical herbicides to control weeds. Most commonly the micro-organism used is fungus and in this case bio- herbicide is also called a myco-herbicide.

Table 2: Commercial mycoherbicides (Sanbagavalli *et al* 2020) [38]

Trade Name	Pathogen	Weed controlled
Devine	*Phytophthora palmivora*	Strangle vine in citrus
Collego	*Colletotrichum gloeosporioides*	Joint vetch in rice and soybean
Biopolaris	*Bipolaris sorghicola*	Johnson grass
LUBAO 11	*Colletotrichum gloeosporioides f.sp. cuscutae*	*Cuscutta* spp.
ABG 5003	*Cercospora rodmanii*	*Eichhornea crassipes*

Caprylic and capric acid uses

Caprylic acid is a plant extract derived from coconut oil and palm seed Kernel (Penner *et al*., 2011) [30]. A mixture of caprylic acid (47% v/v) and capric acid (32% v/v) functions as a contact, post-emergent nonselective herbicide. The desiccant mode-of-action burns down annual and perennial weed species. It is sold under the trade name Suppress® Herbicide EC. HomePlate® is another post-emergent herbicide derived from caprylic and capric acids at 44% and 36% v/v, respectively. Both are approved for use in organic systems, and are "allowed with restrictions" for use in and around all food crops.

7. Allelopathy in weed management

Allelopathy could be used to suppress weeds by using companion or rotational crops, mulching with plant residues, applying plant extracts. Muhammad *et al*., (2013) [24] reported that sunflower plant extract application was found to be reduce the weed population. Parthenium incorporated into soil reduces the growth of Cynodon dactylon. Leachate of dry menthe (cumin) controls most of the weeds. Velvet bean suppress purple nut sedge.

Integration of non - chemical weed management options

A sound weed management plan should have a strategy to prevent the introduction and dissemination of weeds, enhance the ability of crops to compete with weeds, and combine a variety of weed management options to prevent weeds from adapting to any one of the control practice. So for this we go for integrated approach of weed management and we need to use different methods combinedly for effective management of weeds in an organic farm. Following Table 3 shows different weed management practices and how these practices manage weeds we can use any combination as per our need.

Table 3: Effect of different organic weed management practices on weeds

Weed management practice	Effect on weed
Tillage	Kills growing weeds; damages perennial roots & rhizomes; buries seeds too deeply to emerge; brings weed seeds to surface.
Stale seedbed	Flushes weeds from the soil before planting.
Crop cultivar choice	Suppress weeds, Competitive cultivars improves competitive ability of crop against weeds
Cover crops/Intercrops	Suppress weeds, improves soil health
Crop rotation	Disrupt the development of crop weed association
Using transplants	Competitive advantage to crop
Planting arrangement (Sowing time/Plant density/row spacing & row orientation)	Competitive advantage to crop/Suppress weeds by shading
Organic nutrient sources for fertility enhancement	Faster-growing weeds due to slow release of nutrient sources.
Post - planting cultivation	Removes weeds from the crop.
Drip irrigation	Directs water to the crops rather than to weeds.
Mulch	Smothers / delays emergence of weeds
Allelopathy	Suppress weeds

Conclusion

Increasing environmental awareness, interest of public in organic food production and some problems associated with herbicide use, has led to develop a range of sustainable techniques for non-chemical weed control. Management of weeds in organic systems is a long and complex process. It is important to understand that under an organic farming, weeds could never be eliminated but only managed. We can conclude that if various components of integrated weed management are implemented systematically, we can provide a good weed management with higher economic returns in organic farming.

References

1. Ali M. Weed suppressing ability and productivity of short- duration legumes intercropped with pigeonpea under rainfed conditions. Tropical Pest Management. 1988;34(4):384-387.
2. Alonso-Ayuso M, Gabriel JL, García-González I, Del Monte JP, Quemada M. Weed Density and Diversity in a Long-Term Cover Crop Experiment Background. Crop Prot. 2018;112:103-111.
3. Anderson RL. Managing Weeds with a Dualistic Approach of Prevention and Control. A Review. Agron. Sustain. Dev. 2007;27:13-18.
4. Anderson R. An Ecological Approach to Strengthen Weed Management in the Semiarid Great Plains. In Adv. Agron; Elsevier: Amsterdam, The Netherlands, 2003;pp:33–62.
5. Banik P, Midya A, Sarkar BK, Ghose SS. Wheat and chickpea intercropping systems in an additive series experi- ment: advantages and weed smothering. European Journal of Agronomy. 2006;24(4):325–332.
6. Babiker M, Salah E, Siraj O, Mukhtar A. The Critical Period of Weed Control in Maize (*Zea mays* L.) in Sudan. 2013.
7. Baraibar B, Hunter MC, Schipanski ME, Hamilton A, Mortensen DA. Weed Suppression in Cover Crop Monocultures and Mixtures. Weed Sci. 2018;66:121-133.
8. Buchanan AL, Kolb LN, Hooks CRR. Can Winter Cover Crops Influence Weed Density and Diversity in a Reduced Tillage Vegetable System? Crop Prot. 2016;90:9-16.
9. Chauhan BS. Grand Challenges in Weed Management. Front. Agron, 2020, 1.
10. DeVore JD, Norsworthy JK, Brye KR. Influence of Deep Tillage, a Rye Cover Crop, and Various Soybean Production Systems on Palmer Amaranth Emergence in Soybean. Weed Technol. 2013;27:263-270.
11. Gallandt ER. How Can We Target the Weed Seedbank? Weed Sci. 2006;54:588–596.
12. Gbadamosi AA, Iremiren GO, Aladesama R. Effects of weeding regimes and atrazine application on soil factors of growth performance of maize in rain forest area of Nigeria. Journal of Agriculture, Forestry and Fisheries. 2003;3:58-62.
13. Harlan JR, de Wet JMJ. Some Thoughts about Weeds. Econ. Bot. 1965;19:16-24.
14. Hanke I, Wittmer I, Bischofberger S, Stamm C, Singer H. Relevance of urban glyphosate use for surface water quality. Chemosphere. 2010;81:422-429.
15. Horowitz M, Regev Y, Herzlinger G. Solarization for weed control. Weed Sci. 2017;31:170-179.
16. IIPR. 25 Years of Pulses Research at IIPR. ICAR-Indian In-stitute of Pulses Research, Kanpur, Uttar Pradesh, India, 2009.
17. Knezevic S, Datta A, Stepanovic S, Bruening C, Neilson B, Gogos G. Weed control with flaming and cultivation in corn. Phytopathology. 2011;101:81-92.
18. Kaur R, Kumar A, Sharma BC, Brijnandan Kour P, Sharma N. Weed indices in chickpea + mustard inter-cropping system. Indian Journal of Weed Science. 2014;46(4):333-335.
19. Laitinen P, Sari RS, Siimes K. Glyphosate translocation from plants to soil-Does this constitute a significant proportion of residues in soil. Plant Soil. 2007;300:51-60.
20. Mathiassen SK, Bak T, Christensen S, Kudsk P. The effect of laser treatment as a weed control method. Biosyst. Eng. 2006;95:497-505.
21. Moody K. Pesticide use in rice culture: Paper presented at the workshop on the Environmental and Health Impact of Pesticide Use, International Rice Research Institute, Los Banos, Philippines, 1990.
22. Myers JP, Antoniou MN, Blumberg B. Concerns over use of glyphosate-based herbicides and risks associated with exposures: a consensus statement. Environ health, 2016;15:19.
23. Moradi Talebbeigi R, Pirasteh – Anosheh HH, Ahmadi Lahijani MJ, Emam Y. Evaluation of effects of wheat residues and day or night tillage on yield of SC 704 corn cultivar (*Zea mays* L.). Bum/ Shinasi – I kishavarzi. 2016;5(3):255-262.
24. Muhammad Naseem, Muhammad Aslam, Muhammad Ansar, Muhammad Azhar. Allelopathic effects of

sunflower water extract on weed control and wheat productivity. Pak. J Weed Sci. Res; 2013;15(1):107-116.
25. Oswald A, Ransom JK. Striga Control and Improved Farm Productivity Using Crop Rotation. Crop Prot. 2001;20:113-120.
26. Oerke EC. Crop losses to pests. Sci: J Agric. 2006.
27. Patel RH, Shroff J, Dutta S, Meisheri TG. Weed dynamics as influenced by soil solarization – A review. Agricul- tural Reviews. 2005;26(4):295-300.
28. Peachey RE, William RD, Mallory-Smith C. Effect of No-till or Conventional Planting and Cover Crops Residues on Weed Emergence in Vegetable Row Crop. Weed Technol. 2004;18:1023-1030.
29. Parish S. A review of non-chemical weed control techniques. Biol. Agric. Hortic. 1990;7:117-137.
30. Penner D, Coleman R, Michael J. Novel formulations on an organic acid herbicide. Journal of ASTM International. 2011;8(5):1-5.
31. Rask AM, Kristoffersen P. A review of non-chemical weed control on hard surfaces. Weed Res. 2007;47:370-380.
32. Reddy TY, Reddi GHS. Principles of Agronomy. Kalyani Publishers, Noida, India, 2011, PP:527.
33. Rao AN, Wani SP, Ladha JK. Weed management research in India - an analysis of the past and outlook for future. In: Souvenir (1989-2014). DWR publication No. 18. Directorate of Weed Research, Jabalpur, India. 2014, 1-26.
34. Samaké O, Stomph TJ, Kropff MJ, Smaling EMA. Integrated Pearl Millet Management in the Sahel: Effects of Legume Rotation and Fallow Management on Productivity and *Striga hermonthica* Infestation. Plant Soil. 2006;286:245–257.
35. Savary S, Srivastava RK, Singh HM, Elazegui FA. A characterisation of rice pests and quantification of yield losses in the rice–wheat system of India. Crop Protection. 1997;16:387-398.
36. Savary S, Willocquet L, Elazegui FA, Castilla NP, Teng PS. Rice pest constraints in tropical Asia: quantification of yield losses due to rice pests in a range of production situations. Plant Diseases. 2000;84:357-369.
37. Singh HP, Batish DR, Kohli RK. Allelopathic Interactions and Allelochemicals: New Possibilities for Sustainable Weed Management. CRC Crit. Rev. Plant Sci. 2003;22:239-311.
38. Sanbagavalli S, Kandasamy OS, Anbumani S. Weed flora studies in stale seed bed technique of weed management. Paper presented in: National conference on Challenges in Weed Management in Agro - Ecosystems: Present status and future strategies, Organised by Dept. of Agronomy, TNAU, Coimbatore. Held during 30th, 2010, 302.
39. Sanbagavalli S, Jeeva M, Somasundaram E. Eco-friendly weed management options for organic farming: A review. The Pharma Innovation Journal. 2020;SP-9(11):15-18.
40. Talnikar AS, Kadam GL, Karande DR, Jogdand PB. Integrated weed management in pigeonpea [*Cajanus cajan* (L.) Millsp.]. International Journal of Agricultural Sciences. 2008;4(1):363–370.
41. Thorup-Kristensen K, Magid J, Jensen LS. Catch Crops and Green Manures as Biological Tools in Nitrogen Management in Temperate Zones. In Adv. Agron; Elsevier: Amsterdam, The Netherlands, 2003, PP:227-302.
42. Teasdale JR, Abdul-Baki AA, Bong Park Y. Sweet Corn Production and Efficiency of Nitrogen Use in High Cover Crop Residue. Agron. Sustain. Dev. 2008;28:559-565.
43. Umamaheswari M. Influence of non-chemical weed management on organic Brinjal (CO 2) (*Solanum melongena* L.,). M.Sc (Agronomy) thesis submitted to the Department of Agronomy, TNAU, and Coimbatore. 2016.
44. Weaver SE, Ivany JA. Economic thresholds for wild radish, wild oat, hemp-nettle and corn spurry in spring barley. Can. J. Plant Sci. 1998;78:357-361.
45. Wallace J, Williams A, Liebert J, Ackroyd V, Vann R, Curran W, *et al*. Cover Crop-Based, Organic Rotational No-till Corn and Soybean Production Systems in the Mid-Atlantic United States. Agriculture. 2017;7:34.
46. Weisberger D, Nichols V, Liebman M. Does Diversifying Crop Rotations Suppress Weeds? A Meta-Analysis. PLoS ONE 2019;14:e0219847.
47. Yaduraju NT, Ahuja KN. Weed control through soil solarization. Indian Journal of Agronomy. 1990;35(4):440-442.
48. Zhao J, Yang Y, Zhang K, Jeong J, Zeng Z, Zang H. Does Crop Rotation Yield More in China? A Meta-Analysis. Field Crops Res. 2020;24:107659.