

A review on weed management techniques

Abstract

Weeds in the crop field were found to be a major concern. Weeds engage in competition with the primary crop for essential resources such as nutrients, water, space, and sunlight. Utilizing the nutrients that are given to the primary crop, weeds can occasionally completely overtake it. Some weeds are extremely poisonous and dangerous to both people and animals. Herbicide use to manage weeds clearly shows that it has an adverse effect on the ecosystem, water quality, and soil quality. Studies conducted in the field of weeds clearly show this. Furthermore, weeds become resistant to a herbicide when it is used consistently. Numerous techniques, such as mechanical, cultural, chemical, and biological ones, can be used to control weeds. But the application of several herbicides in chemical control is now so pervasive. Chemical fertilizers should not be used excessively as this lowers environmental quality and damages soil health. As a result, a brand-new strategy known as Integrated Weed Management (IWM) was developed, in which all existing strategies are combined to cut down on the use of herbicides alone.

Key words: Weed control, cultural approaches, mechanical methods, biological methods, chemical methods, IWM advancement

Introduction

Weeds have persisted since time immemorial, representing plants that either do not belong to cultivated crops or are intentionally sown in the primary field alongside crop plants. These opportunistic plants not only coexist with the primary crop but also actively vie for essential resources, including food, space, sunlight, and nutrients. This competitive interaction results in notable agricultural production losses, as observed by Das in 2008. The complete eradication of weeds from the main field proves to be an elusive goal due to their diverse modes of propagation, encompassing vegetative propagules, dormant seed dissemination, and other methods (Singh et al., 2014). The effectiveness of weed control is intricately tied to the overall success of agriculture (David et al., 2012). Weeds play a crucial role in the agricultural system, consuming a significant portion of the resources allocated for plant growth, as highlighted by Oerke in 2006. Improper weed management or failure to control weeds at the failure to harvest crops at the appropriate time leads to a considerable decrease in agricultural productivity and an increase in production expenses (Sharma 2014). Weeds can diminish output by up to 90%, and they can cause crop failure. Previously, crop rotation, seed cleansing, tillage practices, and other methods were used to eliminate weeds. Cultural

control involves implementing modifications to the cropping system to mitigate the influence of weeds on the primary crop, as discussed by Dubey in 2014. However, biological control options are constrained, leading to limited adoption. In physical control, manual techniques such as hand weeding or hoeing are employed, while chemical control relies on the use of herbicides, making this method widely favored among farmers. The excessive use of chemical fertilizers and its repercussions on soil and the environment has emerged as a global concern. Throughout history, farmers have implemented various measures to manage weeds, including practices such as seed cleaning, maintenance of clean farm equipment, and ensuring the cleanliness of irrigation channels. Below is a description of different weed control methods:

I. Cultural/ Ecological/ Agronomical methods

It is known as crop management practices. Various cultural practices, including tillage, planting, fertilizer application, and irrigation, play a crucial role in establishing favorable conditions for crops. When employed effectively, these practices contribute to weed control by aiding in the reduction of weed populations. While cultural methods may not independently achieve complete weed control, they complement other techniques. Key components of cultural methods include tillage, fertilizer application, and irrigation. Additionally, factors such as the choice of crop variety, sowing timing, cropping system, and farm cleanliness are instrumental in weed management (Kumar *et al.*, 2014).

1. Field preparation

It is imperative to maintain a weed-free field by preventing the flowering of weeds. This practice is crucial for inhibiting the accumulation of weed seeds in the area.

2. Summer tillage

Engaging in summer tillage or off-season tillage proves to be an effective cultural method in restraining the proliferation of perennial weed populations during crop cultivation. The initial tillage preceding cropping is designed to promote clod formation. These clods, containing weed propagules, desiccate upon drying. Following tillage operations are then aimed at breaking these clods into smaller units, intensifying exposure of the withered weeds to the sun's heat. (Badiyala *et al.*, 2015).



Fig. 1 : Field preparation

3. Crop density

Regarded as a pivotal factor in suppressing weed growth, achieving an optimal plant population in the field is essential. This is because an adequate plant density creates competition against weeds, hindering their growth by either occupying space or utilizing available nutrients, as highlighted by Meena et al. (2010).

4. Fertilizer application

Applying fertilizer in the appropriate quantity, at the right time, and in the right location proves instrumental in weed reduction. This practice ensures that the main crop receives all the necessary nutrients, as emphasized by Dubey in 2014.

5. Maintaining on optimum plant population

Insufficient plant population is susceptible to intense weed infestation, posing challenges for later control. Hence, critical practices such as selecting suitable seeds, employing proper sowing methods, using an appropriate seed rate, and safeguarding seeds from soil-borne pests and diseases are crucial. These measures are vital for establishing a proper and uniform crop stand capable of effectively competing with weeds, as emphasized by Kumar et al. in 2005.

6. Crop rotation

The likelihood of a particular weed species or group persisting increases when the same crop is cultivated continuously. Crop rotation proves to be a valuable strategy in addressing, if not entirely eliminating, challenging weed issues. Managing troublesome weeds, such as *Cyperus rotundas*, may involve incorporating lowland rice into the crop rotation, as suggested by Das et al. in 2012. For instance, rotating crops like wheat, maize, or soybean has been shown to reduce the prevalence of weeds, as observed in studies such as Teasdale et



al. in 2004.**Fig. 2 : Crop rotation**

7. Time of sowing

Initiating early sowing of crops offers a competitive advantage against weeds, as highlighted by Sindhu et al. in 2010. This is because crops emerge before weeds, depriving the latter of sufficient space, nutrients, or light for growth, as observed in studies such as Cici et al. in 2008. For instance, planting rice crops during the monsoon not only results in optimal yields but also reduces the prevalence of weeds.

8. Method of sowing

The choice of sowing methods plays a crucial role in reducing weed populations, as emphasized by Dev et al. in 2013. In the context of wheat crops, zero tillage has been identified as particularly effective in weed control, concurrently leading to increased yields, as demonstrated by Jat et al. in 2013.

9. Growing of intercrops

The practice of intercropping demonstrates superior weed suppression compared to sole cropping, offering an opportunity to employ crops as tools for weed management. Certain short-duration pulses, such as green gram and soybean, have proven effective in smothering weeds without adversely affecting the yield of the main crop, as noted by Shah et al. in 2011.

Additionally, this strategy contributes to a reduction in weeding costs, leading to an enhanced net income by lowering input expenses. For example, intercropping legumes, cucurbits, sweet potatoes, and similar crops not only suppress weed growth but also assist in mitigating the risk of soil erosion.



Fig. 3 : Growing of crops

10. Stale seedbed technique

A stale seedbed refers to a prepared field where the initial one or two weed flushes are eradicated before crop planting. This is accomplished by saturating the well-prepared field with either irrigation or rain, prompting weed germination. At this stage, shallow tillage or the application of a non-residual herbicide, such as paraquat, can be employed to eliminate the dense flush of young weed seedlings, as suggested by Singh in 2014. Subsequently, sowing can take place immediately. This technique creates an environment nearly free of weeds, allowing the crop to germinate successfully, as noted by Sindhu et al. in 2010.



Fig. 4: Uses of stale seedbed approach

11. Blind tillage

The process of tilling the soil after sowing a crop, but before the emergence of the crop plants, is referred to as blind tillage. This technique is commonly used to reduce weed

intensity, particularly in drill-sown crops where the emergence of crop seedlings may be impeded by the formation of a soil crust due to rainfall or irrigation shortly after sowing.

Merits of Cultural Method

1. Cost-effective weed control method
2. Simple and easy to adopt
3. Absence of residual problems
4. Minimal technical skill required
5. No harm to crops
6. Efficient in weed control
7. Maintenance of the crop-weed ecosystem

Demerits of Cultural Method

1. Immediate and rapid weed control is not achievable
2. Weeds are maintained in a suppressed condition
3. Ineffective for controlling perennial and troublesome weeds
4. Practical challenges in adoption

I. Mechanical/ Physical methods

Mechanical or physical methods of weed control have been employed since the inception of agriculture. These methods encompass various techniques such as tillage, hoeing, hand weeding, digging, cheeling, sickling, mowing, burning, flooding, mulching, and more.

1. Tillage

Tillage serves to eliminate weeds from the soil, leading to their demise. This process may weaken plants by causing injuries to roots and stems, reducing their competitiveness and regenerative capacity. Additionally, tillage buries weeds, disrupting their growth. Tillage operations, including plowing, discing, harrowing, and leveling, are employed to promote soil turnover, weed germination, and the exposure of seeds to sunlight, facilitating their effective destruction later on. In the case of perennial weeds, both above-ground and underground growth are harmed and eliminated through tillage(Kumar *et al.*, 2011).



Fig. 5: Tillage operations

2. Hand weeding

This method involves the manual removal or pulling out of weeds by hand or by using implements like khurpi, which resembles a sickle. Likely one of the oldest weed control methods, hand weeding remains a practical and efficient approach for eliminating weeds in both cultivated and uncultivated areas. It is particularly effective against annuals and biennials and is limited to controlling the upper portions of perennial weeds, as noted by Angiras et al. in 2008.



Fig. 6:Hand weeding technique

3. Hand Hoeing

The hoe is considered one of the most suitable and extensively used weeding tools, offering quick and cost-effective results. It is often added to the cultivator for tending to row crops. Hoeing is particularly effective against annuals and biennials, as it can completely destroy their weed growth. However, when dealing with perennials, hoeing primarily targets the top growth with minimal impact on underground plant parts, leading to the possibility of re-growth



Fig. 7:Hand Hoeing

4. Sickling

Sickling, a manual process employing a sickle, is utilized to remove the top growth of weeds by hand. The aim is to prevent seed production and starve the underground parts of the weeds. This method is particularly prevalent in sloped or hilly areas, where only the tall weed growth is sickled, leaving the root system intact to anchor the soil and prevent soil erosion, as highlighted by Gupta O.P. in 2007.

5. Digging & Cheeling

Digging proves to be highly beneficial, especially in the case of perennial weeds, as it targets the removal of underground propagating parts from the deeper layers of the soil. Cheeling is a manual process carried out using a cheel hoe, which resembles a spade with a long handle. This technique involves cutting and shaping the above-ground growth of weeds.

6. Mulching

Mulch refers to a protective covering of material maintained on the soil surface. Mulching has a smothering effect on weed control by preventing light from reaching the photosynthetic portions of plants, thereby inhibiting their top growth (Verma & Singh, 2008). This method is highly effective against annual weeds and certain perennial weeds such as *Cynodon dactylon*. Mulching can be achieved using dry or green crop residues, plastic sheets, or polythene film. For optimal effectiveness, the mulch should be thick enough to prevent light transmission and eliminate photosynthesis (Goswami and Saha 2006).



Fig. 8: Mulching in agriculture

7. Mowing & Slashing

Mowing is primarily employed in non-crop settings such as canal bunds, farm roads, parks, and lawns, while slashing may find application in both cropped and non-cropped situations (Senarathne et al., 2011). Occasionally, mowing using sickle mowers or rotary mowers is recommended for weed control in widely-spaced fruits and plantation crops. It proves effective in managing tall annual weeds, but not perennial weeds, as mowing and slashing cut only the top growth and do not address the horizontal, prostrate, and underground growth of perennial weeds. (Das T.K. 2009).

8. Burning & Flaming

Burning is a cost-effective method for eliminating mature, unwanted vegetation in non-cropped areas such as range lands, field bunds, roadsides, and ditch banks. This technique is employed to (a) dispose of vegetation, (b) eradicate the dry tops of matured weeds, and (c) eliminate green weed growth in situations where cultivations and other common methods are impractical. Flaming involves the momentary exposure of green weeds to high temperatures (up to 1000°C) through the flames emanating from burning liquid petroleum gas. A hood

cover directs the flames onto weeds between rows, killing the cell protoplasm of plants (Singh, 2014). Flaming is commonly used in various Western countries for the selective control of inter-row weeds in crops like onions, soybeans, sorghum, etc.

9. Flooding

Flooding proves effective against weed species that are sensitive to prolonged submergence in water. This method kills plants by reducing the availability of oxygen necessary for their growth. The success of flooding depends on the complete submersion of weeds for extended periods. Flooding is an efficient weed control method, particularly for some perennial weeds such as *Cyperus* spp., *Cynodon dactylon*, and *Convolvulus arvensis*.



Fig. 9: Flooding in the field

10. Chaining & Dredging

Chaining and dredging are methods employed against aquatic weeds. Chaining involves pulling a heavy chain through the bottom of a ditch, utilizing two tractors moving on either bank of the ditch. The heavy chains cut and uproot the roots, causing them to float to the surface, where they are then collected. On the other hand, dredging is the mechanical removal of weeds along a channel, encompassing their roots and rhizomes covered in mud. This technique is utilized for the removal of both submerged and emerged aquatic weeds. (Rana *et al.*, 2015).

11. Soil solarization

This method involves harnessing solar energy for weed desiccation in fallow fields during hot summer months. The concept is based on the idea that light from the sun, in the form of short electromagnetic waves, easily penetrates colorless translucent polyethylene films (20-25 mm). This light reaches the soil, raising its temperature by 10-12°C within 2-4 weeks and reaching up to 55-60°C. This elevated temperature is effective in controlling most weed species whose seeds are present in the top 5 cm of the soil layer (Arora and Tomar, 2012).

Merits of Mechanical Method

- 1) Oldest, efficient, and cost-effective method
- 2) Allows coverage of large areas in a shorter time
- 3) Environmentally safe method
- 4) Requires no specialized skills
- 5) Enables weeding in between plants
- 6) Effectively controls deep-rooted weeds

Demerits of Mechanical Method

- 1) Labor-intensive
- 2) Potential for crop damage
- 3) Requires specific and optimal conditions



Fig. 10 : Biological control of Weed

I. Biological control

Biological control involves the utilization of natural living organisms, such as insects, herbivorous fish, other animals, disease organisms, and competitive plants, to limit the growth of weeds. While it may not eradicate weeds entirely, it can significantly reduce weed populations. This method is not universally effective for all types of weeds, and it is particularly useful for controlling introduced or invasive weed species (Bellgard Stanley, 2008). Notable examples include the control of *Opuntia* spp. (Prickly pear) in Australia and lantana in Hawaii using specific insect bioagents (Tiwari et al., 2013). Biological control is an eco-friendly method and is generally cost-effective. In India, this method is commonly employed to control *Parthenium hysterophorus* (Kumar and Ray, 2011).

Table 1: Promising bioagents of weeds

| Weed | Bioagent | Reporting country | Kind of bioagents |
|---------------------------------|------------------------------|-------------------|---------------------|
| <i>Chondrilla juncea</i> | <i>Puccinia chondrillina</i> | Australia | Plant pathogens |
| <i>Cirsium arvense</i> | <i>Septonia cirsii</i> | - | Plant pathogens |
| <i>Cyperus rotundus</i> | <i>Bactra vendana</i> | India, USA | Shoot boring moth |
| <i>Hydrilla verticillata</i> | <i>Hydrilla pakistanae</i> | USA | Shoot fly |
| <i>Orobanche cernua</i> | <i>Sclerotinia spp</i> | USA | Plant pathogens |
| <i>Parthenium hysterophorus</i> | <i>Zygomma bicolarata</i> | India | Leaf eating insect |
| | <i>Epiblema strenuana</i> | Australia | Stem galling insect |
| | <i>Conotrachelus spp</i> | Australia | Stem galling insect |
| <i>Rumex spp</i> | <i>Uromyces rumicis</i> | USA | Plant pathogens |
| | <i>Gastrophysa viridula</i> | USA | Beetle |
| <i>Tribulus terrestris</i> | <i>Microlarinus lareynii</i> | USA | Pod weevil |

Merits of biological control

- 1) Causes minimal harm to the environment
- 2) No residual effect
- 3) Relatively cost-effective with a comparatively long-lasting impact
- 4) Does not affect non-targeted plants and is safe to use
- 5) Highly effective in controlling weeds in non-cropped areas
- 6) Some fish, snails, and other animals can convert weed vegetation into a food source

Demerits of biological control

- 1) Multiplication is expensive
- 2) Control is slow
- 3) Limited success in control
- 4) Availability of very few host-specific bio-agents at present

II. Chemical methods

Herbicides or inorganic chemicals are employed to destroy weeds in this weed control method. Herbicides can be sprayed on leaves or applied to the soil. Farmers have increasingly turned to chemical solutions since the Green Revolution to suppress weed growth and boost their profits. Herbicides, while often effective in weed control, come with several drawbacks, as they can harm the environment and soil. They become weed-resistant as a result of their prolonged use. Therefore, their ideal application is good, but using these chemicals extensively harms the ecosystem, raising alarms of impending danger.

III. Integrated Weed Management (IWM)

The primary challenge for agricultural and weed scientists is developing a technique that is cost-effective, highly efficient, time-efficient, and requires minimal labor. Weeding operations have an extremely high production cost since they must be done by hand, which raises the overall cost of production. The country loses a lot of money every year as a result of poor weed management techniques. The cost of manufacturing can be reduced by employing effective weed management strategies. Developing a labor-free weed control strategy is essential for achieving sustainable crop production goals. In this context, a new approach called Integrated Weed Management (IWM) has been developed, combining two or more weed management techniques. IWM is an efficient, low-input weed management method that has become a crucial component of agricultural systems (Riemens et al., 2007). This approach can be seen as a long-term weed management strategy that integrates chemical, biological, mechanical, and cultural techniques (Kewat 2014). For instance,

utilizing manual weeding in addition to pre- and post-emergence herbicides on wheat crops produced the best results when compared to using pesticides on their own. Farmers should adopt integrated weed management as it is environmentally friendly and involves the use of inorganic chemicals in minimal amounts. This approach ensures the optimal use of chemicals in combination with cultural and mechanical methods for weed control. Although chemical weed control methods are effective, ideal, and practical, it is essential to consider integrated weed management for a more sustainable and balanced approach to weed control in agriculture.

Advantages of IWM

1. Shifts the balance of crop-weed competition in favor of the crop
2. Prevents the transition of weeds toward perennial nature
3. Helps prevent the development of resistance in weeds to herbicides
4. Eliminates the risk of herbicide residue in soil or plants
5. Minimizes environmental pollution
6. Leads to higher net returns in agriculture

Conclusion

Weeds pose a significant biotic constraint to production in various cropping systems. Relying on a single method of control is often insufficient for long-term weed management and may lead to the development of resistance. Despite the application of specific control methods, weeds continue to cause substantial yield losses. To address this challenge and feed the growing global population, there is an increasing need to minimize yield losses through the development and implementation of effective and sustainable Integrated Weed Management (IWM) programs.

References

- Arora, A. and Tomar, S. S. 2012. Effect of soil solarization on weed seed bank in soil. *Indian J. Weed Science*.**44** (2): 122-123.
- Cici, Z. H., Adkins, S. and Hanan, J. 2008. A canopy architectural model to study the competitive ability of chickpea with sow thistle. *Annals of bot- London*.101: 1311-1318.
- Das, T. K. and Yaduraju, N.T. 2008. Effect of soil solarization and crop husbandry practices on weed species competition and dynamics in soybean- wheat cropping system. *Indian J. Weed Science*.**40** (1&2): 1-5.

- Das, T. K., Tuti, M. D., Sharma, R., Paul, T. and Mirja, P. R. 2012. Weed management research in India: An overview. *Indian Journal of Agronomy*.**57** (3 IACS Special Issue): 148-156.
- David, A., Mortensen, J., Egan, F., Bruce, D. M., Matthew, R. R. and Smith, R. G. 2012. Navigating a Critical Juncture for Sustainable Weed Management. *Bio. Science*.**62**: 75-84.
- Dev, D., Vivek, Singh, S. P. and Kumar, R. 2013. Weed management studies in wheat with herbicide under different establishment methods. *Indian J. Agronomy*.**58** (2): 215-219.
- 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.
- Elzein, A, Kroschel, D. J. and Leth, V. 2006. Seed treatment technology: An attractive delivery system for controlling root parasitic weed *Striga* with mycoherbicide. *Bio-control Science and Technology*. 16: 3- 26.
- Jat, R. K., Banga, R. S. and Yadav, A. 2013. Resource conservation techniques and pendimethalin for control of weeds in durum wheat cultivars. *Indian J. Weed Science*.**45**: 93- 98.
- Goswami, S. B. and Saha, S. 2006. Effect of organic and inorganic mulches on soil-moisture conservation weed suppression and yield of elephant foot yam. *Indian J. Agronomy*. **51**(2): 154-156.
- Kewat, M. L. 2014. Improved weed management in Rabi crops. National Training on Advances in Weed Management pp. 22- 25.
- Kruidhof, H., Bastiaans, M. L. and Kropff, M.J. 2008. Ecological weed management by cover cropping: effects on weed growth in autumn and weed establishment in spring. *Weed Research*. 48: 492- 502.
- Kumar, S. and Ray, P. 2011. Evaluation of argumentative release of *Zygodontia bicolorata* for biological control of *Parthenium*. *Crop Protection*. 30: 587-591.
- Meena, R. S., Singh, M. K. and Singh, B. 2010. Effect of seed rate and weed management on weed and yield of late sown zero-till wheat. National Symposium on Integrated Weed

Management in the Era of Climate Change, held at NAAS, New Delhi on 21-22 August, pp. 14.

Mohler, C. L., Dykeman, C., Nelson, E. B. and Ditommaso, A. 2012. Reduction in weed seedling emergence by pathogens following the incorporation of green crop residue. *Weed Research*. 52: 467- 477.

Oerke, E. C. 2006. Crop losses to pests. *The J. Agricultural Science*. 144: 31-43.

Riemens, M. M., Widge, R. V. D., Bleeker, P.O. and Lotz, L. 2007. Effect of stale seedbed preparation and subsequent weed control in lettuce on weeds. *Weed Research*. 47: 149-156.

Shah, S. N., Shroff, J. C., Patel, R. H. and Usadadiya, V. P. 2011. Influence of intercropping and weed management practices on weed and yields of maize. *International J. Science and Nature*. 2: 47-50.

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

Sindhu, P. V., Thomas, C. G. and Abraham, C. T. 2010. Seedbed manipulations for weed management in wet-seeded rice. *Indian J. Weed Science*. 42(3&4): 173- 179.

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

Teasdale, J. R., Mangum, R. W., Radhakrishnan, J. and Cavigelli, M. A. 2004. Weed seedbank dynamics in three organic farming crop rotations. *Agronomy J*. 96: 1429-1435.

Tiwari, A., Meena, M., Zehra, A. and Upadhyay, R. S. 2013. Efficacy of *Alternaria alternata* as bioherbicide against weed species. Int. Conf. on Global Scene. Of Trad. Syst. of Medi., Ayurveda, Agriculture and Education, RGSC, Barkachha BHU, 21-22 January, pp. 498-01.

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

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

- Yadav, D. B., Yadav, A. and Punia, S. S. 2010. Long term effect of green manuring and herbicidal use on weed dynamics and productivity of rice-wheat cropping system. Nat.Symp. on IWM in the Era of Climate Change, held at NAAS, New Delhi on 21-22 August, pp. 9.
- Angiras N.N and S.S. Rana 1998. Integrated weed management in direct seeded puddle sprouted rice (*Oryza sativa* L.). *Indian Journal of Agronomy* **43**(4): 644-649.
- Angiras NN, Suresh Kumar and SS Rana 2008. Efficacy of new herbicides alone and in integration with hand weeding to manage weeds in onion (*Allium cepa*). *Himachal J. Agric. Res.* **34** (2): 109-112.
- Badiyala D, S.S Rana, Neelam Sharma and Rajinder Kumar 2015. Major weeds in cropped lands of Himachal Pradesh. Department of Agronomy, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur.
- Bellgard Stanley 2008. The biological control of weeds. Landcare Research Private, Auckland, Newzealand.
- Das TK. 2009. Weed Science- Principles and Application. Jain Publishers
- Gupta OP. 2007. Weed Management- Principles and Practices. Agrobios
- Kumar Deep, N.N. Angiras, Y Singh and S.S. Rana. 2005. Influence of integrated weed management practices on weed competition for nutrients in wheat. *Indian Journal of Agricultural Research* **39**(2): 110-115.
- Kumar Suresh, S.S Rana and N.N Angiras 2011. Influence of seeding and weed control methods on the productivity of puddle seeded rice. Himachal. *Journal of Agricultural Research* **37**(2): 149-156.
- Rana S.S and N.N. Angiras. 1999. Influence of integrated weed management practices on weed competition for nutrients in puddle sown rice. *Indian Journal of Weed Science* **31**(3&4): 169-171.
- Rana S.S, D Badiyala, Neelam Sharma and Rajinder Kumar 2015. Major weeds in the non-cropped lands of Himachal Pradesh. Department of Agronomy, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur.