Role of integrated weed management strategies in sustaining conservation agriculture systems

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Conservation agriculture (CA) is an agricultural management practice in which there is minimum soil disturbance, retention of residue for soil cover and rotation of major crops[1]. In contrast, soil in traditional agriculture is intensively tilled to prepare a fine and well-pulverized seedbed. Soil tillage or land preparation is the most energy-consuming operation among all field operations. Compared to traditional agriculture, farmers can save up to 40% of time, labour and fuels in CA[1]. The other benefits of CA include reduction in soil erosion, increased soil moisture conservation, lower surface run-off of herbicides and fertilizers, and improved profits[2]. In addition, the presence of crop residue and the lack of soil disturbance in CA increase biological activity in the soil. However, weeds are the major biological constraints to the adoption of CA. In conventional-tilled farming, weeds can be effectively controlled by tillage operations, which uproot and bury weeds deep into the soil. Due to lack of tillage, weeds grow and flourish in CA if effective weed control measures are not taken. Therefore, attempts to implement CA in many regions in Asia failed due to a yield penalty.

In CA, weeds can be controlled by manual weeding and herbicide use. Labour, however, is becoming scarce and expensive mainly because of migration from rural areas to cities. It is seldom that labour is available at the critical time of weeding. By the time labour becomes available, yield losses have already occurred due to weed competition. Herbicides are being widely used to control weeds in CA, but there is hardly any herbicide that can control different kinds of weeds with one or two applications. Furthermore, there are concerns about developing resistance in weeds, shifts in weed populations due to continuous use of a single herbicide, less availability of new and effective herbicide molecules, increased cost of chemical control and issues related to environmental pollution. Therefore, to increase the sustainability of CA, there is a need to manage weeds by using integrated weed-management strategies. These may include use of preventive measures, stale seedbed technique, adjusting crop sowing time, use of crop residue as mulch, narrow row spacing, high seeding rates, weed-competitive cultivars, adopting crop rotation and judicious use of herbicides (Figure 1).

Preventing weed invasion in a field is a much cheaper and easier option than controlling a heavy infestation. The use of clean crop seeds and machinery (seeding, harvesting and threshing) is the first and most important step in reducing weed infestation in a field. Crop seeds are mainly contaminated with weed seeds where the size and shape of both species resemble each other. Weedy rice or red rice (*Oryza sativa* L.) is a perfect example, which spread in many Asian countries through the use of contaminated rice seeds. In addition, field margins and irrigation canals should be free from weeds.

The use of stale seedbed technique can significantly reduce weed density in a crop in CA systems. Due to lack of soil disturbance, most of the weed seeds remain on the soil surface in these fields. In the stale seedbed practice, a light irrigation is given to stimulate germination of these weed seeds; the weed seedlings that emerge are then killed using a non-selective herbicide (e.g. glyphosate or paraquat). This practice helps in reducing the weed seed bank size in the soil and the crop emerges in a relatively weed-free environment. Some of the weed species sensitive to the stale seedbed technique are *Cyperus iria*, *Digitaria ciliaris*, *Echinochloa colona*, *Eclipta prostrata*, *Leptochloa chinensis*, *Ludwigia hyssopifolia* and *Portulaca oleracea*. In addition, weed seeds present on the soil surface are prone to surface-dwelling seed predators. When combined with other weed-management strategies, seed predation may help reduce herbicide use and labour demand in CA systems.

Adjusting the time of crop sowing can also minimize weed pressure in some crops. Earlier planting of wheat in North India, for example, gives the crop a competitive advantage over *Phalaris minor*, a noxious grassy weed species. Earlier in the season, ecological and environmental conditions are not suitable for seed germination of *P. minor*. The adoption of no-till and early planting of wheat in North India proved profitable to farmers as these helped reduce the problems of *P. minor*.

One of the pillars of CA is retention of residue cover on the soil surface. In addition to moisture and soil conservation, residue as mulch can suppress emergence and growth of many weed species. However, the extent of suppression depends on the quantity and type of crop residue[2–4]. Cereal crops, for example, produce more residue than oilseeds and pulses. Similarly, a crop grown in an irrigated area will produce more biomass than a crop grown in a rainfed area. Growing a cover

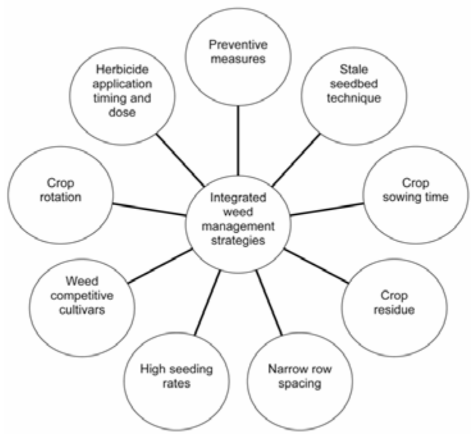

Figure 1. Integrated weed management strategies to manage weeds in conservation agriculture systems.

crop (e.g. cowpea, sesbania, sunhemp, etc.) between two main crops may also help in reducing weed seed bank and weed population in CA systems. The cover crop is then killed using a non-selective herbicide. The dead mulch of the cover crop suppresses weed germination and emergence by releasing allelochemicals and reducing light availability to the weed seeds. The presence of residue not only reduces weed seedling emergence, but may also delay or prolong seedling emergence[5]. The late-emerging seedlings may be less competitive to crops and may have less effect on crop yield. There is a need to invest in research and development to bring affordable machines capable of sowing in loose residue.

The use of narrow row spacing gives an advantage to the crop by allowing faster canopy closure and less light penetration through the leaves, which help reduce weed competition. Crops such as maize and soybean are traditionally grown in wide rows; however, planting these crops in narrow rows may reduce weed germination and growth by shading[6]. Similarly, a narrow row spacing of 15 cm was found better in suppressing *P. minor* compared with the 23 cm spacing[7]. Narrow row spacing has been suggested to minimize the addition of weed seeds to the soil seed bank and to progressively deplete weed seeds in the long term. CA often has a less favourable microenvironment for crop emergence and therefore higher than normal seeding rates are used to compensate for poor crop establishment. Crop density is an important component of the crop's ability to compete with weeds. Higher seeding rates are used in many crops to suppress weeds and these can be included as a component of weed management strategies in CA systems. The use of high seeding rates may not increase crop yield in weed-free environments, but their use in weedy or partially weedy environments has been found to reduce weed biomass and increase crop yield[8].

Crop species and cultivars differ in their competitiveness with weeds. The use of crop cultivars having early vigour and fast ground cover ability may help in suppressing weeds in CA systems; however, the grain yields of these cultivars should be acceptable to farmers. Traditional and tall cultivars are often more weed-competitive, but they produce lower yields than short-statured modern cultivars. Breeding competitive cultivars with importing allelopathic traits from their wild relatives is a potential technique for improving the weed-competitive ability of commercial cultivars. Compared with shoot traits, relatively little attention has been given to root competition for nutrients and water in crop–weed interactions. Therefore, there is a need to develop weed-competitive cultivars, keeping in mind that both shoot and root traits are equally important in crop–weed interactions.

Growing a single crop or crops under similar management practices allows some weed species to become dominant in the system. Rotation of crops with different management practices, on the other hand, disturbs the growing cycle of weeds and prevents build-up of problematic weeds. It also allows farmers to use different herbicides to control problematic weeds. *P. minor*, for example, is a problematic and noxious weed in the rice–wheat cropping system. Rotating wheat with potato, sunflower or oilseed crops can help in significantly reducing the *P. minor* population. Similarly, rotating one rice crop in rice–rice or rice–rice–rice cropping systems with an upland crop (e.g. soybean or maize) can reduce weedy rice infestation. Weedy rice seedlings are difficult to identify in the rice fields until they are at the flowering stage and there is no selective herbicide to control weedy rice in a rice crop. Crop rotation also improves soil health and reduces build-up of pests. However, the benefits of crop rotation depend on the crop type and market price of the crop.

Herbicide use is an important component of weed management and choosing an appropriate herbicide and timing is critical in CA systems. Weeds present before crop sowing are killed by using non-selective herbicides and then crop is sown. Due to presence of residue, pre-emergence herbicides may not work effectively in CA farming as straw or residue might intercept a considerable amount of soil-active herbicides. There is a need to better understand the interaction effects of pre-emergence herbicides and residue (used as mulch) on weed control. Due to less opportunity of using a pre-emergence herbicide in CA, timing of post-emergence herbicides is critical to avoid any yield loss due to weed competition. There is a need to rotate herbicides with different modes of action and to mix different herbicides to achieve effective weed control. Herbicide mixtures should be used to delay the development of resistance in weeds and improve the weed control spectrum. Farmers should know that excessive herbicide use is not environment-friendly.

Some crop cultivars resistant to non-selective herbicides are available and may prove to be a useful tool in managing weeds in CA systems. Maize, cotton and soybean have commercial cultivars resistant to glyphosate and glufisonate. However, herbicide-resistant crops should not be used as a stand-alone component of weed management and there should be stewardship guidelines for the use of herbicide-resistant crops. Without proper stewardship guidelines, the weed problem may become even worse than now.

As discussed above, various weed management strategies are available to control weeds in CA and a single approach cannot provide effective weed control. To maintain sustainability of CA systems, there is a need to integrate different weed-management strategies. For example, planting a weed-competitive cultivar in narrow rows with high seeding rates and use of residue as mulch and an effective post-emergence herbicide may manage weeds effectively in CA systems. Integrated strategies will also ensure that herbicide use remains profitable and environmentally sound over a long period of time.

1. Hobbs, P. R., Sayre, K. and Gupta, R., *Philos. Trans. R. Soc. London, Ser. B.*, 2008, **363**, 543–555.
2. Chauhan, B. S., Gill, G. and Preston, C., *Aust. J. Exp. Agric.*, 2006, **46**, 1557–1570.
3. Chauhan, B. S., *Weed Technol.*, 2012, **26**, 1–13.
4. Chauhan, B. S., Singh, R. G. and Mahajan, G., *Crop Prot.*, 2012, **38**, 57–65.
5. Chauhan, B. S. and Johnson, D. E., *Adv. Agron.*, 2010, **105**, 221–262.
6. Locke, M. A., Reddy, K. N. and Zablotowicz, R. M., *Weed Biol. Manage.*, 2002, **2**, 123–132.
7. Mahajan, G., Brar, L. S. and Sardana, V., *Indian J. Weed Sci.*, 2004, **36**, 166–170.
8. Chauhan, B. S. *et al.*, *Field Crops Res.*, 2011, **121**, 105–115.

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