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5' Elements for Integrated Weed Management

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ABSTRACT: Integrated weed management (IWM) is a systematic concept to weed management that incorporates distinct weed controlling approaches to focus on providing the crop a strategic advantage over weeds. Changes in management, such as tillage, time and rate of herbicide application, cover crops, and planting patterns, influence crop yields and weed interaction, according to IWM researchers. Understanding of IWM will be contingent on the recommendation of specific weed-management and crop-productivity-maintaining strategies; such investigation will and should proceed. Predictive techniques would make it easier to include IWM into models of activities that happen in agricultural systems at larger geographical and temporal dimensions, such as in agroecosystems, which are made up of species diversity and their ecosystem. In the current review we have highlighted the five elements which can successfully implement the INM.

Keyword: INM, Diversification in time & space, Selection of Cultivar, Soil management, Control of weeds and Field Monitoring.

INTRODUCTION

The world's population has fast surpassed seven billion people, and by 2050, it is anticipated to reach nine billion (Young and Pierce 2013). Current agricultural production levels are insufficient to feed the world's rising population and satisfying this need might be a major problem for mankind (Westwood *et al*., 2018). Climate change, the shortage of arable land and water supplies, as well as the susceptibility of diseases, pests, and weeds(Wang *et al*., 2019), all contribute to the strain on agricultural systems, with consequences for sustainability, the planet, and the wellbeing of living creatures in the short and long term. Since the beginning of agriculture, weeds have been a constant hazard (Seelan *et al*., 2003).

Weeds compete with crops for sunlight, water, nutrients, and area; thus, farmers must keep weeds under control to keep crop yields high. Most weeds are either mechanically managed with specific agricultural methods or chemically controlled using herbicides (Christensen *et al*., 2019). Intensive mechanisation, on the other hand, promotes soil erosion (Guccione and Schifani 2001), resulting in loss of soil fertility. The goal of contemporary weed control methods is to diminish the number of weeds to minimum. Among different agriculture pests (insects, Fungus and weeds) yield reduction is recorded maximum with weeds it can be controlled successfully by integrated weed management practice. The following five elements of weed control play a major role in weed management (Kudsk and Streibig 2003). The present excessive reliance on pesticides has raised environmental issues as well as human health problems. Herbicide usage has been linked to a deterioration in biodiversity (Storkey *et al*., 2012, Strandberg *et al*., 2017) and lead to the pollution of the ground water by leaching (Rosenbom *et al*., 2015).

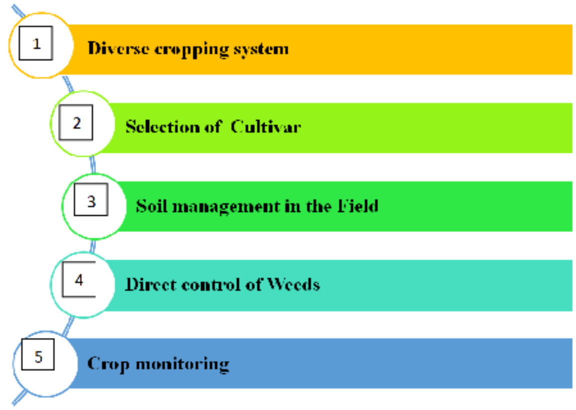
The increased dependence on herbicides has had an indirect impact of Indian agricultural rotations, since the most favoured crops may be planted more often with less need on break crops to disrupt the life cycle of crop weeds. This has efficiently narrowed the biological niche of weeds, encouraging few but more competing weed species, and increasing reliance on a small number of herbicide active components effective against with the prevalent weed species. Apart from weed communities being less varied, certain weed species respond to the increased selection pressure by developing resistance or avoiding herbicide exposure (e.g., changed weed seedling emergence pattern in response to altering soil disturbance) (Heap, 2020). Diversification of weed control is required to minimize the negative environmental effects of herbicides and to limit the rising prevalence of herbicide resistance (Norsworthy *et al*., 2012). An effect is made to compile current knowledge of various tactics and technologies into a general framework for integrated weed management, *i.e*., a systematic integrated strategy that agronomists and weed scientists may utilise to develop new weed control strategies management solutions that are tailored to their individual situations (Mehandi *et al.,* 2015).

Five Elements of Weed Management. Among different agriculture pests (insects, Fungus, and weeds) long term management practices one required to control weeds. Furthermore, an advanced IWM strategy should influence weed population dynamics at various stages of their life cycle by:

1) Preventing weed emergence from seeds or seed material.

2) Reducing the negative effects of emerging weeds on the crop

3) Reducing the replenishment of seed or vegetative bud banks (Kudsk *et al*., 2020).



In the short term, any method can be effective in controlling weeds, but it may differ for species that can adapt to that approach. As a result, a combination of strategies is required to accomplish long-term weed management. Weed scouting, use of decision support systems, and high-tech sensing technologies are examples of cross-cutting monitoring and assessment activities that occur during the planting season and during the crop rotation period. These tools not only assist farmers in making intelligent decisions about which techniques to use, but they also aid in evaluating the effectiveness of previously used tactics and strategies. The elements provide a framework, which can be applied within an individual cropping season, But, more crucially, it can be utilised to make weed control planning easier throughout the entire cropping system. The strategies are generic, but they may be chosen and combined based on local Agro-environmental circumstances, technology and machinery availability, the farmer's socio-economic system, and the individual crops and cropping systems on the field. Agronomists, applied scientists, and advisers may utilise the framework to help farmers rethink weed management on their farms. Each of these aspects' potential contributions, as well as their management alternatives, are now reviewed.

The life cycle and growth habits determine the crop and weed management practices to be adopted both in terms of time and technologies that may be used. Crop diversification will provide opportunities for the adaptation of various weed control strategies which may affect the weed species differently (Liebman *et al.*, 2001). It was observed that agriculture productivity has been reduced due to higher weed diversity linked with varying fertilizer regime (Strokey and Neve 2018). Apart from enhanced weed management and reduced crop competition, diverse weed communities can also provide agroecosystem services including pollen and nectar for wild bees, alternate source of food for beneficial insects, and minimise soil erosion (Blaix *et al*., 2018).A diverse weed population will provide nutrients all around crop cycle and year, however crops can only provide these services during bulk blooming.

***Element 1*- Diversification inSpace and Time**

Cultivating two or more crops in the same field simultaneously for at least part of their growing season is known as intercropping (Wiley, 1990). Intercropping can include numerous cash crops, but it can also include a cash crop and a subsidiary crop, sometimes known as a crop that isn't harvested but is utilised as a living mulch. The spatial arrangement in which all the crops are placed can be used to categorise intercrops. Row, relay, strip intercropping, and mixed intercropping are all examples of intercropping techniques. Intercropping's potential benefit as a weed control strategy was recently proven by a meta-analysis, which found that weed biomass was 58 percent lower in intercrops than in poor weed suppressive crops. An additive design inhibits most weeds as compared to a substitution design (Gu *et al.,* 2021). Live mulches are progressively being used in agricultural crops to control weeds and prevent soil erosion. Maintenance of the live mulch biomass throughout the dry season is critical in these systems, particularly in the arid Mediterranean area, to avoid struggle for water between the living mulch and the crop (Garcia *et al*., 2020). In intercropping system maintaining the population of live mulches one very difficult in arid regions since both the crop compete each other for water to meet the demand. Another issue with live/cover crops is destruction of their crop mechanically due to sowing of succeeding crop as well as aberrant weather condition. In both arable and horticulture crops, crop diversity can be achieved by adopting crop rotation and it will have a direct impact on weed competition. Adoption of various crop management practices such as planted or sown, mechanically, by senescence or frost will have an impact on weeds. Mechanical interventions, such as roller crimpers, along with flames, may help to destroy plants without the use of chemicals of broad-spectrum herbicides like glyphosate (Vincent-Caboud *et al.*, 2019).

Cropping system diversity in time is primarily driven by changing crop rotation for both arable and horticultural crops. While the intrinsic features of certain crops (for example, competitive aptitude) will have an impact, Changes in crop rotation have a direct impact on weed communities. Changes in management procedures connected with various crops, such as sowing time and pattern, soil cultivation, fertilisation, and harvest time, will be indirect. As a result of crop rotation weed growth characters fluctuate from year to year, or even season to season. Weeds that develop in one crop will be less well suited to the following crop or will be chosen against by the crop's cultivation management procedures. According to a recent meta-analysis, crop diversification in terms of crop species helped weed control more than crop diversification in terms of planting dates (Weisberger *et al*., 2019)

Incorporating a cover crop across two cash crops is a second sort of time-based agricultural diversification offers soil cover during a time because when soil would otherwise be barren or covered by natural plants. Cover crops are often planted to offer ecological systems such as enhanced soil fertility, control of soil-borne pest and disease, and erosion reduction. Depending on the properties of the chosen species, leaching and run-off, as well as enhanced soil structure, may occur. moreover, cover crops have the potential to suppress germination in the next cash crop, you can help with weed control (Schipanski *et al*., 2014).

***Element 2*- Selection of Cultivar**

There are two types of crop-weed interactions: a) competition for physical space and competition for resources including light, water, and nutrients (Bastiaans & Kropff 2017) and b) Allelopathy is the direct or indirect effect of chemicals released by plant or micro-organism on the growth and yield of other plant is known as allelopathy (Einhellig, 1995). Allelopathic interactions have been employed for millennia to favour the crop and prevent weed infestation without identifying the chemical basis of the phenomena. As herbicide alternatives shrink in the face of herbicide-resistant weeds, interest in allelopathy as a weed management strategy has grown. Alkaloids, Terpenes, phenols, sugars and non-proteinaceous amino acids are examples of allelochemicals (Lin *et al*., 2007). Plants having allelopathic capability are considered sustainable weed management options and a way to reduce dependency on pesticides (Appiah *et al*., 2015), therefore minimising herbicide resistance selection pressure. Allelopathic plants have also contribute to the discovery of novel herbicidal chemicals with novel MOAs (Duke, 2010).

One approach to reduce the need for direct weed management is to use weed-suppressive and tolerant crops and cultivars. Suppressive crop types of lower weed fitness, whereas tolerant varieties retain high yield levels under weed pressure but may not necessarily lessen weed pressure, perhaps leading to a weed population build-up (Hansen *et al*., 2008). As a result, suppressive cultivars should be included in an IWM approach since they aid in weed population management (Andrew *et al*., 2015). The possibility of combining cultivars with different phenotypes to limit the available functional space for weeds has also been investigated with some indication for reduced weed functional richness in barley cultivar combinations (Pakeman *et al*., 2020). However, there were no discernible impacts of cultivar mixing on weed biomass. The weight of data suggests that cultivars' potential as a key tool in IWM. This might be due to the lack of genetic variation among current, high-yielding cultivars, and suppressive features should be included in future crop breeding attempts. A system that rates cultivars based on their ability to manage weeds, on the other hand, would encourage the adoption of weed suppressive varieties (Mehandi *et al.,* 2013). Adjusting the sowing date, seed rate, sowing pattern, sowing depth, and the use of transplanted crops are further management strategies that might shift the crop-weed competitive relationship in the crops favour. The method of delayed planting in winter grains is employed to control grass weeds (Moss, 2017). Increased seeding rates have been shown to improve cereal weed resistance under low fertiliser input conditions (Lemerle *et al*., 2004), and the benefits of increased seeding rates have been noticed in combination with wider row spacing and inter-row weeding (Kolb *et al*., 2012).

***Element 3*- Soil management in the field**

This element includes primary tillage, secondary tillage, Nutrient, and water management. Traditionally, primary tillage is done at depths ranging from 15 to 35 cm (Kouwenhoven *et al*., 2002). Ploughing, particularly mould board ploughing, is thought to be one of the finest mechanical methods for controlling weed populations (Kouwenhoven *et al*., 2002), since it can bury weed seeds at a depth where they are unable to develop and eventually decay. Ploughing depths greater than 0.20 m produce the best results (Brandsaeter *et al*., 2011). Primary tillage with a chisel, disc, mouldboard, dual layer, and powered rotary ploughs can offer a foundation for IWM, particularly when perennial weeds are present (Brandsaeter *et al*., 2011). The method of tillage affects the distribution of weed seeds in the soil; seeds are more evenly dispersed all across the soil with a mouldboard plough, whereas seeds are mostly found in the topsoil layers with non-inversion tillage (Scherner *et al.,* 2016). Ploughing (inversion tillage) contributes to weed management in different ways depending on the crop rotation & weed species (Ruisi *et al*., 2015). Rotational ploughing may be the best strategy, although the results will vary depending on the crop rotation and weed species.

Secondary tillage activities are shallow than primary tillage operations and are used to prepare the seed bed and include inputs like fertilisers. They will manage any weeds if these procedures are done close to sowing. Weed seedlings have sprouted, while fresh weed seeds are being stimulated at the same moment. The early germination of crop creates additional flushes of weed seedlings growth. The use of shallow tillage operations on a regular basis can reduce weed densities by removing sprouting seedlings (De Cauwer *et al*., 2019). Emerging seedlings are commonly killed with non-selective herbicides, but if the goal is to reduce herbicide use, emergent weed seedling control can also be accomplished with superficial cultivation or non-mechanical instruments (e.g., flame weeding) to stop additional flushes of weed seedling germination and emergence (De Cauwer *et al*., 2019). Tillage should be shallower than the initial operation to minimise germination of future flush of weed seeds while employing mechanical weeding equipment (Lamour and Lotz 2007).

During different stages of their life cycles, plants struggle for the resources they share (such as water and nutrients) (Holst *et al*., 2007). Weed species such as *Chenopodium album* in maize respond differently to changes in soil water level & availability of nutrients to crop plants (Krahmer, 2016).This knowledge can be used to improve the crop's growing environment while making them less conducive for the crop's principal weed species by directing resources in time and location. Soil moisture is one of the key environmental variables regulating seed germination and seedling of weed emergence in field crops along with temperature (Chauhan, 2012). In other words, in both conventional and reduced tillage systems management of nutrients and water can be used to manage weeds.

***Element 4*- Direct control of weeds**

When indirect approaches to restrict weed development are insufficient to overcome agricultural yield losses and/or a grow of a weed population that could pose issues in subsequent crops, direct weed management instruments are necessary. Chemical herbicides, microbiological herbicides, mechanical tools, heat equipment, and electro weeders are some of the direct control instruments available to farmers, and they can be further subdivided based on their scale of operation (Riemens *et al*., 2008).

Herbicides have been the basis of direct control of annual weeds since the mid-twentieth century, and broadcast application, either pre- or post-emergence, has been the favoured form of treatment until recently. Glyphosate, which is administered pre-sowing, pre-harvest, or in the stubble, is the most effective way to manage perennial weeds (post-harvest). One technique to overcome dosage reductions is to use band spraying in the crop rows, which may be used in conjunction with inter-row cultivation. If selective herbicides are not available, inter-row spraying of non-selective herbicides combined with mechanical instruments competent of intra-row weeding may be an option. Although site-specific herbicide application can help reduce herbicide use even further (Martin *et al*., 2016), these techniques are still under research and have only just been commercially accessible.

Mechanical weeding using harrows, inter-row cultivators, or mowers is a well-known technology that was widely employed in agriculture before herbicides took over and is now the most popular alternative to herbicide use for direct weed management. Inter-row cultivation techniques have advanced dramatically in recent years, and machine vision algorithms can now discriminate crop plants from soil and weed plants using a mix of light reflectance and crop row pattern recognition (Fennimore *et al*., 2016). This enables for weed management extremely near to the crop row, as well as control of intra-row weeds with certain inter-row weeders (Kennedy *et al*., 2020). Farmers can also use non-chemical approaches as well. Thermal weed management by burning, hot water/foam, and steaming has been extensively explored, but results are inconsistent, and thermal approaches are costly and need energy inputs 100–1000 times greater than tillage treatment (Coleman *et al*., 2019).

In recent years, harvest weed seed technologies, in which weed seeds are gathered and killed during harvest have gotten a lot of interest. The technique which was first created in Australia is now being researched in other regions around the world (Walsh *et al*., 2018). Efficacy is determined by the proportion of seeds left on the weed plants at harvest, which varies by weed species and year (Bitarafan and Andreasen, 2020). Surprisingly, the emergence of herbicide-resistant plants has forced the rediscovery of the oldest weed management technology, manual weeding, as a means of limiting the spread of resistant weed strains (Inman *et al*., 2017).

***Element 5*- Field Monitoring**

Unlike a conventional herbicide-based weed management technique, IWM employs a variety of approaches, each of which has been found to have inconsistent and context-specific results. Evaluation processes are critical throughout the season for the farmer to determine the best weed control approach and adapt to the effectiveness of the strategies used. There are a variety of approaches and support tools available now, and technology is rapidly evolving to allow Integrated Weed Management including site-specific management at several levels. Before weed emergence, the farmer might use the field history to develop a preliminary weed control strategy. Many farmers are familiar with their fields and weed infestation levels, especially the most prevalent and difficult plant species. However, not all farmers apply this information in a systematic and active way. Some farmers utilise paper weed maps, while others employ a digitalized field management system that allows them to monitor observations on a variety of parameters. During season whenever the weed population is observable, the farmer can employ scouting plans to change the approach to the real weed situation, either on their own or in conjunction with a decision support system. In generally, manual reconnaissance is not done in a systematic manner, and there is a scarcity of literature on the subject. Scouting tactics are vital and have an impact on efficiency, as seen in Groundnut fields (Robinson *et al*., 2007).

A manual direct control programme can be developed when a weed map is established, or the information can be transmitted to a decision support system for further automation. The approaches and goals of the various systems are quite different. While some prompt decision support system focused on determining the need for weed management, others tried to improve herbicide selection, dosage rate, timing, and sprayer equipment (Gonzalez-Diaz *et al*., 2020). Several new methods have been launched, with some decision support system focusing on assisting the farmer rather than presenting a list of exact solutions (Sanderskov *et al*., 2020). There are few decisions support system available for weed management in perennial crops and orchards, however in Spain, decision support system for Integrated pest management in apple and olive orchards were created and evaluated for detection of common diseases, insects, and weeds. It is critical to assess the tactics used and the plan in order to verify that management techniques are effective (Gupta *et al.*, 2016). The data on successful and unsuccessful weed removal is equally relevant for future weed management. Farm management systems assist the farmer in keeping track of his or her operations.

Decision support system work effectively for specific major pests, weeds, and illnesses in general. The number of characteristics necessary and the potential relationships grow too complicated to provide easy forecasts for entire populations or several pests. Rather developing decision support system that precisely forecast or explain system behaviour under various weed control situations, future decision support system should assist farmers in developing their IWM approach.

CONCLUSION

This review spotted the five elements *viz*., diverse cropping system, cultivar selection management of soil at field conditions, controlling of weeds directly with herbicides and proper crop monitoring which plays vital role in effective integrated weed management. By proper alteration of spacing and the time of cropping the growth of weeds and the competition between the crop and the weed can be reduced. Adopting weed-recessive and crop-tolerant cultivars/varieties also involved in INM with prior position. Other management practices like late planting, high seed rates, maximizing the spacing between the rows and between the crop (plants). Soil management practices like primary tillage, secondary tillage, harrowing, mowing etc., also plays crucial role in INM by altering the soil structure through which the weed-roots distribution and fixation in the soil were disturbed, by altering the soil layers with tillage operations the weeds and weed growth will be reduced. The chemical approach with herbicides having appropriate combinations according to the type of weeds and type of crop provides the successful Integrated Nutrient Management.

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