Review Article

“Weed management indices and its relevance in weed science research”

ABSTRACT

Weeds are one of the most important biotic factors cause significant loss in crop productivity. Weed competes with crops for various resources, resulting in severe yield loss, although it largely depends on the management strategies adopted. For the effective management of weeds, various methods are adopted *viz;* cultural, mechanical, chemical and biological methods. All these methods are used based on their performance. Henceforth, it is imperative to evaluate the efficacy of suitable management strategies. To evaluate the performance many weed indices are being used. Understanding of these indices is still indispensable. Weed indices provides a logistic support in impact assessment, interpretations and drawing appropriate conclusions in weed management research.

Key words: Weeds, weed management, weed indices, herbicides, efficiency, persistence

Introduction

Weeds are the major problem in agricultural production systems, acting at same tropic level as the crop. Weeds capture a part of the available resources that are essential for plant growth (**Oerke, 2006; Ryan *et al.*, 2009; Smith *et al.*, 2010**). Diverse climatic conditions in India favor the most adopted weeds to prevail and cause severe crop yield losses. Weeds also degrade quality of the produce, raise cost of production; harbor and serve as alternate hosts to several insect pests and diseases (**Rao *et al.*, 2020**). Among the pests, weeds cause maximum yield losses (34%), although it largely depends on the management strategies adopted. The problem of weeds is exacerbated by modern farming practices, such as monoculture, fertilizer application, and the use of heavy machinery, which create ideal conditions for weed growth and spread (**Gaweda *et al.*, 2020**). Inevitably, leaving weeds uncontrolled will sooner or later lead to considerable reductions in crop yield and increase production cost (**Sharma, 2014**). Weed compete with crops for light, water, space and nutrients, that’s by reduce crop yield and quality and lead to billions of dollars in worldwide crop losses annually (Kaur et al., 2024; Kumar et al., 2019). Because of their ability to persist and spread through the many reproduction and dispersal of dormant seeds/ vegetative propagules, for this reason weeds are virtually impossible to eliminate from any given field (**Singh 2014 and Sharma 2014**). In the presence of weeds, any attempt to improve the crop production and productivity is futile until not taken the action to control weeds. In modern agriculture, for the effective management of weeds, various methods are adopted *viz;* cultural, mechanical, chemical and biological methods. All these methods are used based on their performance. Continuous monitoring and refinement in management strategies is essential for alleviating adverse effects of weeds on agricultural productivity and environmental health **(Rao and Nagmani, 2013)**. Herbicidal methods are used to control weeds in crop as pre or post emergence application which reduces the population of weeds significantly. Sometimes, the pesticides apart from harming target species also affect the non target living being like microflora or fauna or biochemical reaction in soil and plant which may sometimes enhance yield (Phytotonic effect) or sometimes produce detrimental effect (phytotoxic) on plant. Under changing climatic senario, it is needful to conserve ecosystem and biodiversity along with sustained production (**Kumar *et al*. 2019)**. To quantify weed persistence, crop resistance and phytotonic as well as phytotoxic effect of herbicidal treatments, mathematical formula based on plant growth characters may be used. These mathematical formula are termed as indices. To evaluate or analyze their performance so many weed indices are used. Weed indices provides a logistic support in impact assessment, interpretations and drawing appropriate conclusions in weed management research (Thesiya et al., 2024; Esposito et al., 2021; MacLaren et al., 2019).

1. Weed Control Efficiency (WCE): Mani *et al*. (1973) suggested weed control efficiency as a derived parameter out of weed population/density per unit area for studying treatments' performance in weed control researches. Weed control efficiency usually indicates the percentage reduction in weed population or dry weight of weeds under different methods/ treatments of weed control compare to untreated plot (weedy). Although weed density may not be a reliable estimate of weed competition/ control in crops, the trend in methods'/treatments' efficiency may be visualized in terms of their superiority or inferiority.

$$\boldsymbol{WCE}\ (\%) = \frac{\boldsymbol{WDC - WDT}}{\boldsymbol{WDC}} \times \mathbf{100}$$

Where, WD_C: Weed density (number/m^2) in control (un-weeded) plot, WD_T: Weed density (number/m^2) in treated plot. Unit of the WD_C and WD_T should be same of uniform.

Normally the value of weed control efficiency ranges from zero to hundred. Its value in weedy check or unweeded plots occurs 0 (zero) and in case of weed free plots it occurs 100 (hundred). Therefore the higher value of weed control efficiency of a treatment indicates that this treatment is highly effective in control of weeds. However, in certain cases WCE can also be negative (-ve) for a treatment which is worse than the weedy check. It happens in the field experimentation. It could be worked out for both sole and intercropping situations.

In a crop/season, WCE of a treatment particularly herbicide normally decreases over time or as the date of observation advances. For example, upon application of a herbicide, WC'E obtained initially at 30 or 40 DAS is usually the highest and then it decreases gradually as the crop growth advances towards maturity and becomes the lowest in maturity. This all happens due to weed population normally goes on decreasing over time under weedy/unweeded situation (control plots) and, on the contrary, it likely increases under herbicide-treated plot at the later period of crop growth since herbicide loses its activity. If plots are not periodically weeded out or put some treatments superimposed with the former in a sequential manner, WCE decreases across growth stages of a crop.

2. Weed Control Index: Mishra and Tosh (1979) replaced weed density in **Mani *et al*. (1973)** formula by dry weight to calculate weed control index. It is also a derived parameter and compares different treatments of weed control on the basis of weed dry weight across them. It is more reliable estimate of weed competition control in crops than weed control efficiency.

$$\boldsymbol{WCI} = \frac{\textbf{WDMC}-\textbf{WDMT}}{\textbf{WDMC}} \times \mathbf{100}$$

Where, WDM_C: Weed dry weight (unit/m^2) in control plot, WDM_T: Weed dry weight (unit/ m^2) in treated plot

The value of WCI normally ranges from 0 (zero) to 100 and, on principle, weedy check always has WCI value as zero and weed-free check treatment as 100. Therefore, higher the value of WCI of a treatment, greater is the weed control by that treatment. However, in certain cases WCI can also be negative (-ve) for a treatment which is worse than the weedy check. It happens in the field experimentation. It could be worked out for both sole and intercropping situations.

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3. Weed index (WI)/ Weed competition Index (WCI): Gill and Vijayakumar, (1969) suggested weed index as a derived parameter from the crop yields obtained across the treatments of weed control researches. It is nothing but a measure of the crop yield loss accrued across treatments in comparison to a weed free plot or in certain cases the minimum weed- infested plot like two or three hand weeding (if as good as weed free check) adopted in an experiment It is the ultimate parameter towards appraisal of the superiority or inferiority of several treatments and is worked out in almost all weed control researches.

$$WI = \frac{\mathbf{YWF - YT}}{\mathbf{YWF}} \times \mathbf{100}$$

Where, Y_{WF}= Crop yield in weed free plot, Y_{T}= Crop yield in treated plot

The value of WI generally does not have a definite range. Weedy check will have the highest value since its yield is likely to be the lowest. However, sometimes certain treatments appearing as poor as weedy-check, may have similar lower values. In an extreme situation of the weedy check when there is no yield obtained, WI becomes 100. Weed-free check, however, will have 0 (zero) value. Certain treatments particularly some herbicide (eg pendimethalin, atrazine) yielding higher than that obtained under season- long weed-free situation, may have WI values negative (-ve), which indicates superiority of that treatment than even weed free check. WI could be worked out for both sole and intercropping situations over different treatments employed.

4. Relative dry weight (RDw): In the above two formulae (WCE and WC), the composite culture of weed species is taken into consideration and the effect of a single weed species is ignored or hardly evaluated. Therefore, the relative dry weight can be chosen as a parameter of study just to evaluate, in terms of dry weight accumulated, the effect of a particular weed species to the overall total effect of composite weed community. Accumulation of dry matter will reflect to a great extent the vigour and competitive ability of weed species individually.

$$\boldsymbol{RDW} = \frac{\textbf{Dry weight of weed species per unit area}}{\textbf{total dry weight of composite weed in that unit area}} \times \mathbf{100}$$

5. **Weed Smothering Efficiency (WSE):** Weed smothering efficiency (WSE) is a modification of **Mani *et al.* (1973)** formula and suits best under an intercropping situation. Intercrops chosen are generally for their weed smothering action. Thus WSE may be a good indicator of weed smothering abilities of different intercrops adopted in certain crops of prime interest. There is no scope for working out WSE under sole cropping. To have more accuracy, observation may be collected from 2-3 spots within a plot or treatment per replication and averaged out.

$$\boldsymbol{WSE} = \frac{\textbf{Mdw}-\textbf{Idw}}{\textbf{Mdw}} \times \mathbf{100}$$

Where, **Mdw:** Average dry weight of weeds in main/ sole crop, **Idw**: Average dry weight of weeds in intercropping situation.

6. Weed persistence index (WPI): recently WPI suggested by **Mishra and Misra, (1997**), which have got enough relevance to study the aspect of weed management on comparative basis/scale. WPI indicates relative dry matter accumulation of weeds per count in comparison to control. Weed persistence index, which demonstrates the resistance of escaped weed against the particular weed control measure, reflected variability.

$$WPI = \left(\frac{Weed\ population\ in\ control\ plot}{Weed\ population\ in\ treated\ plot}\right) \times \left(\frac{Weed\ population\ in\ control\ plot}{weed\ population\ in\ treated\ plot}\right)$$

7. Crop resistance index (CRI): It refers to the relationship between a proportionate increase in crop biomass and a proportionate decrease in weed biomass in the treated plots (**Mishra and Mishra, 1997)**. In other hands we can say, the crop resistance index indicates increased vigor of crop plant due to weed management measures.

$$\boldsymbol{CRI} = \left(\frac{\boldsymbol{Crop\ dry\ weight\ in\ treated\ plot}}{\boldsymbol{Crop\ dry\ weight\ in\ control\ plot}}\right) \times \left(\frac{\boldsymbol{Crop\ dry\ weight\ in\ control\ plot}}{\boldsymbol{Crop\ dry\ weight\ in\ treated\ plot}}\right)$$

8. Pest/weed management index (WMI): This index indicates the yield increase with respect to control because of weed management options taken and percent control of weeds by the respective treatment. It can be calculate by the formula that suggested by **Mishra and Mishra (1997).**

$$WMI = \left(\frac{Percent\ crop\ yield\ over\ control}{Percent\ control\ of\ weeds\ /other\ pests}\right)$$

9. Agronomic management index (AMI): It combines yield and weed control effects, similar to WMI. It also considers the change in weed dry weight in relation to the control plot. These indices provide valuable insights into the effectiveness of herbicide treatments and their impact on both crop yield and weed management strategies. To calculate the AMI **Mishra and Mishra (1997)** suggested a formula:

$$AMI = \left(\frac{(Percent\ crop\ yield\ over\ control) - (Percent\ control\ of weeds/other\ pests)}{Percent\ control\ of weeds/other\ pests}\right)$$

10. Integrated weed management index (IWMI): It is a composite indicator that combines the **Weed Management Index (WMI)** and the **Agronomic Management Index (AMI)** to provide a comprehensive assessment of the effectiveness of weed control measures alongside agronomic practices. This index of weed management suggested by **Mishra and Mishra (1997),** it has got popularity in current weed management approaches. The lowest values of IWMI indicate better weed control and the higher value of IWMI indicates opposite. It is calculated as the arithmetic mean of the two indices, represented mathematically as:

$$IWMI = \frac{\mathbf{WMI+AMI}}{\mathbf{2}}$$

Where, WMI: Weed management index, AMI: Agronomic management index

11. Herbicide efficiency index (HEI): The Herbicide efficiency index (HEI) is useful to assess the potential of an herbicide treatment in killing weeds while considering its impact on the crop. To calculate this index **Krishnamurthy *et al*., (1975)** derived a formula:

$$HEI = \frac{\frac{(YT - YC)}{YC} \times 100}{\frac{WDMT}{WDMC} \times 100}$$

Where, Y_T: crop yield from treated plot, Y_C: crop yield from control plot, WDM_T: weed dry matter weight in treated plot, WDM_C: Weed dry matter weight in weedy check plot.

12. Weed intensity (WIn): Rana and Kumar (2014) suggested weed intensity indices that refers to the proportion of weeds in relation to the total plant population (weeds + crops) in a given area, expressed as a percentage.

$$WIn = \frac{Weed\ density}{Density\ of\ weed + crop} \times 100$$

CONCLUSION

From this study it may be concluded that these indices indicates the potential of herbicides and weed management strategies for killing weeds and their phytotoxicity on the crop. Also helps in determining economic threshold level of management strategies, weed persistence in soil, impact of herbicides on environment and their impact on both crop yield and weed management strategies. To quantify weed persistence, crop resistance and phytotonic or phytotoxic effect of herbicidal treatments by using mathematical formula can be easily identified, and may be taken into consideration for further studies.

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