Mysore J. Agric. Sci., 53 (3) : 1-9 (2019)

Weed Shift Analysis : A Way for Effective Weed Management

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ABSTRACT

Weed shift is the change in the composition and relative frequencies of weeds in a weed population. Weed shift occurs when weed management practices do not control an entire weed community or population. The management practices could be use of herbicide and other practices such as tillage practices, manure application, cropping system, harvest schedule and recently the climate change issues that bring about a change in weed species composition. Some weed species which are susceptible are killed by weed management practices, where as tolerant weeds are not affected by the management practices and still there exists another category which do not encounter the management practices. Those species that are not controlled can grow, reproduce and increase in their population resulting in weed shift. In case of chemical weed control, no single herbicide controls all weeds, the weeds which are not controlled by use of same herbicide over period of time are tolerant weeds / resistant weed which thrive and proliferate in the system resulting in gradual shift to tolerant weeds species. While the weeds which are susceptible to the particular herbicide, are gradually eliminated with continuous use of same herbicide. Weed shift does not necessarily have to be shift in the different species, there could be shift with in a weed species to late emerging weed species that emerge after application of herbicide. Weed shift and resistance can be effectively reduced by adopting weed management principles. Frequent monitoring is much required. It helps to know the reasons or the way for entry of new weed species and its effects to the crops and also helps to know the fault in management measures. It provides a better way to find out the best weed management measures for effective control of weeds without entry of any new species with higher yield and economic returns.

Keywords: Weed shift, Weed management and Herbicides

WEED is a plant growing where it is not desired or the plants that are unwanted in a given situation and may be harmful, dangerous or economically detrimental. Weeds are a serious threat to primary production and biodiversity. They reduce farm and forest productivity, displace native species and contribute significantly to land and water degradation. The costs of weeds to the natural environment are also high, with weed invasion being ranked second only to habitat loss in causing biodiversity decline.

Shifts in weeds are not new. Weed shifts have happened as long as humans have cultivated crops. Weedy and invasive species can easily adapt to changes in production practices in order to take advantage of the available niches. Weeds are well equipped to flourish in disturbed agricultural systems. Weeds are genetically diverse and can readily take advantage of the variety of conditions created by any crop production system. A Weed Shift refers to a change in the relative abundance or type of weeds as a result of a management practice. The management practice could be herbicide use or any other practice that brings about a change in weed species composition. In the case of chemical weed control, no single herbicide controls all weeds, as weeds differ in their susceptibility to a herbicide. Susceptible weeds are largely eliminated over time with continued use of the same herbicide leaving tolerant weeds, which often thrive and proliferate with the reduced competition. So over time, there is gradual shift or increase in tolerant weed species. A weed shift does not necessarily have to be a shift to a different species. For example, with a foliar herbicide like Roundup, there could also be a shift within a weed species to a late-emerging biotype that emerges after application. Bruckner *et al*. (1997) surveyed weeds in maize in the Szigetkoz area between 1st July and 31st September 1996 and the findings were compared with those of surveys conducted in 1990. An increase in the average cover and frequency of occurrence of *Panicum miliaceum*, *Mercurialis annua* and *Ambrosia artemisiifolia* were observed. Many species not recorded in 1990 were registered (*Eragrostis minor*, *Amaranthus graecizans*, *Digitaria sanguinalis* and *Geranium pusillum*). Such changes in weed flora composition over time are referred to as weed shifts. A weed shift may be defined as 'the change in the composition or relative frequencies of weeds in a weed population (all individuals of a single species in a defined area) or community (all plant populations in a defined area) in response to natural or human-made environmental changes in an agricultural system'. The behavior of a weed population depends on the nature of the environment experienced by individual plants. Increase in the size of a population is achieved through reproduction of the individuals that survive to maturity and by gains from immigration. Survival may occur by persistence in a dormant state (as seeds in the soil) or by escape from control as seedlings or plants (through chance or due to genotype as in herbicide resistance). It is therefore, the reproductive contribution of these survivors is important in the growth of the population. Plant species may be pre-adapted to be weeds in the sense that species possesses a suite of a life history characteristics which enables rapid population growth in the particular habitat conditions created and maintained by human activity. Pre-adapted weeds have been defined as those species that

i) are resident in a natural plant community within dispersal distance of the crop (or other habitat)

ii) come to predominate within the crop as a consequence of a change in crop and weed management practices.

The successful invasion of a crop by a species from natural habitat, wasteland or hedgerow therefore, depends on the match of life history characteristics of the weed to the habitat template provided by the cropping system (Rana and Rana, 2015). In contrast to a weed shift, weed resistance is the inherited ability of a weed to survive an herbicide dose that kills the wild type of that species. In other words, resistance occurs when there is a genetic change so that a weed that is normally controlled by an herbicide is no longer controlled. In this article occurrence of weed shifts, reasons for weed spectrums change, weed resistance, production practices that influence shifts and preventive measures to reduce weed shifts are discussed.

1. Occurrence of weed shifts

Community shift in response to herbicide use : With the use of clodinafop in wheat, weed flora was mainly composed of *Poa annua*. Similarly in maize continuous use of pre-emergence atrazine give subsequent flushes of *Commelina banghalensis*, *Bracharia ramosa* and *Ageratum conyzoides*. In the Corn Belt and winter wheat areas of the western United States, changes in weed communities were noted within 10 years of the introduction of 2.4-D for the control of broadleaf weeds. In corn, summer annual grass species increased as broadleaf species were controlled. In wheat, winter annual grass species replaced broadleaf species as the predominant troublesome species.

Effect of tillage on community shift : Any reduction in tillage intensity or frequency may therefore have an influence on weed management to a greater extent. Changes from conventional tillage to reduced tillage systems often cause weed community shifts that include increase in summer annual grasses, small-seeded summer annual broadleaves, winter annual, biennial and perennial species, while it decreases in large-seeded summer annual species.

Singh *et al*. (2010) reported that in rice, weed flora of the experimental field in the initial two years (2005 and 2006) consisted of *Echinochloa colona*, *Ischaemum rugosum*, *Fimbristylis milicea*, *Cyperus iria*, *Alternanthera triandra*, *Cynotis axillaries* and *Croton bonplandianum*, but in 2007, *Setaria glauca* emerged as new weed and *Fimbristylis miliacea* got disappeared. Further, it was observed that overall weed population under zero and conventional tillage was almost similar. However, remarkable increase in population of *Cyperus iria* under zero tillage was recorded as compared to conventional tillage during three years of experimentation (Table 1 & 2).

Long-distance introduction of weed species : *Phalaris minor* in wheat and invasion of grasslands and pastures and other non-cropped areas with Lantana and Parthenium are typical examples of introduced weeds in India which have become dominant in both cropped and non cropped areas. Common lambsquarters, a weed believed to be native to Europe and Asia, is now found throughout the United States. In much of Pennsylvania, common lambsquarters has become predominant in the weed community. The shift occurred because the species grows aggressively, is difficult to control, and is a prolific seed production. Long-distance dispersal has also resulted in the introduction of many noxious weeds to the United States, some of which have caused weed community shifts (including field bind weed in the western plains, leafy spurge in rangeland, and multiflora rose in pasture).

Weed shift shifts in response to herbicide use (herbicide-resistant populations) : In the mid-west, in many populations of common waterhemp (pigweed species), biotypes differed in susceptibility to ALS-

TABLE 1

Effect of tillage and weed control on weed population /m^2 at 60 DAS, during wet season of 2006

Treatment	Grasses		Broad leaf				Sedges		Total
	EC	Ir	Ca	AT	Cb	Other	Ci	Fm	
Zero tillage									
W1	1.0	-	6.0	-	15.0	-	1	-	23.0
W2	-	-	22	3	-	-	1	-	26.0
W3	6.0	1	27	17	2	-	10	6	69.0
Zero tillage									
W1	-	3	7	3	5	-	4	-	22.0
W2	-	-	19	6	-	-	-	-	25.0
W3	10.0	1	40	5	5	-	3	2	67.0
Conventional tillage									
W1	-	-	-	-	30	-	7	-	37.0
W2	-	-	17	3	-	-	1	-	21.0
W3	4	7	22	-	5	-	-	30	68.0
Conventional tillage									
W1	5	-	2	3	4	-	3	-	17.0
W2	-	-	20	4	4	-	-	-	28.0
W3	2	1	50	1	5	-	10	2	71.0

Raipur Singh *et al*.,2010

W_1-Hand weeding twice (farmer's practice), W_2-Recommended herbicide, W_3-Weedy check, DAS - Days after sowing,
E. colona- Echinochloa colona , Ir - Ischaemum rugosum, Ca - Cynotis axillaris, AT-Alternathera triandra, Cb -Croton bonplandianum Ci - Cyperus iria, Fm - Fimbristylis miliacea

TABLE 2

Effect of tillage and weed control on weed population/m^2 at 60 DAS, wet season 2007

Treatment	Grasses		Broad leaf					Sedges	Total
	EC	Ir	AT	Ca	Cb	Sg	Other	Ci	
Zero tillage									
W_1	-	-	1.3	1.0	-	-	-	2.3	4.7
W_2	-	0.7	3.0	4.0	3.0	0.7	0.7	2.3	14.3
W_3	1.3	5.3	14.7	6.3	6.0	3.0	1.3	41.0	79.0
Zero tillage									
W_1	-	0.7	0.7	1.7	1.7	-	1.0	13.7	19.3
W_2	-	0.3	3.3	3.7	1.7	0.7	1.3	6.7	18.6
W_3	2.3	2.7	6.0	10.3	8.3	1.0	3.0	64.3	98.0
Conventional tillage									
W_1	-	-	2.0	2.7	2.0	-	1.0	2.3	10.0
W_2	1.3	-	6.7	2.0	1.0	-	2.0	11.7	24.7
W_3	1.7	1.7	14.7	25.7	3.3	1.0	5.7	29.0	82.6
Conventional tillage									
W_1	-	-	0.7	1.0	1.0	0.7	0.7	3.3	7.3
W_2	-	-	6.3	3.7	1.3	0.7	1.3	3.3	16.6
W_3	1.3	4.0	16.3	19.7	3.7	2.7	3.0	34.7	85.3

inhibiting herbicides. With the recurrent spraying of ALS-inhibiting herbicides, populations shifted from susceptible to highly resistant biotypes. It is note that a concurrent shift in many weed communities also occurred. Other species were controlled with these highly effective herbicides and the waterhemp numbers increased as a proportion of the entire weed community. Other ALS-resistant pigweed species have also developed in several areas of the United States, including the northeast. Most recently, glyphosate resistant weeds such as horseweed (marestail) and pigweed species are a problem in different regions of the U.S. as a direct result of glyphosate use in herbicide resistant crops.

The shift in the weed flora due to continuous use of herbicides, the data on species wise weed density/ m^2 along with category of weeds (sedges, grass and broad leaf/m^2) at 50-60 DAP during *kharif* 1999, summer 2002 and *kharif* 2006 are given in Table 3.

During initial year in 1999 *kharif*, the densities of sedge, grass and broad leaf weeds were similar

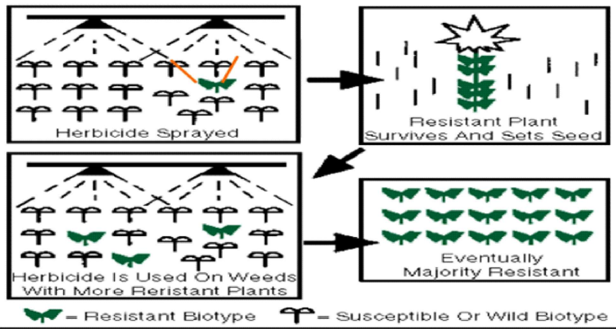

Fig. 1 : Development of herbicide resistance.

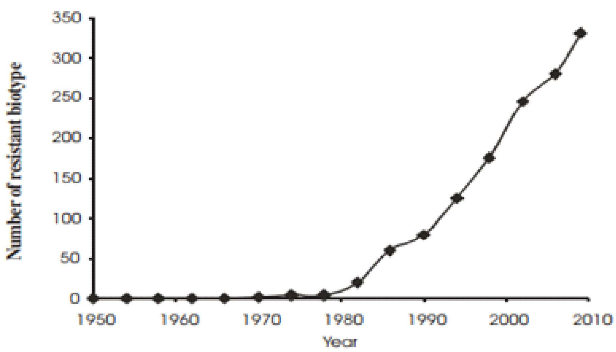

Fig. 2 : Worldwide Chronological increase in herbicide resistant weeds (http://www.weedscience.org)

TABLE 3

Long-term effect of herbicides on weed shift (major weed species' density, No.m2) at 50-60 DAP in 1999 *kharif* 2002 summer and 2006 *kharif* 2002 summer and 2006 *kharif* in transplanted rice

Treatments	*Kharif* 1999 - 50 DAP (1st Crop)												
	Sedge			Grass			Broadleaf						Total
	Fm	Cdf	Total	Pt	Eg	Total	Lp	Rv	Ea	Sa	Go	Total	Weeds
T 1 - Butachlor + 2,4 - D EE + FYM	5.6	0.8	6.4	1.6	2.0	3.6	8.4	7.2	6.4	3.6	15.6	46.0	56.0
T 2 - Butachlor + 2,4 - D EE + FYM #	12.0	0.8	12.8	2.0	1.2	3.2	9.6	3.6	16.8	11.2	9.2	60.0	76.0
T 3 - Hand weeding + FYM	9.6	8.8	18.4	0.4	2.0	2.4	12.8	12.4	5.6	3.6	12.0	63.6	84.4
T 4 - Butachlor + 2,4 - D EE + FYM	6.0	0.8	8.4	1.6	2.0	3.6	4.8	8.4	6.0	8.8	8.0	43.6	55.6
T 5 - Butachlor + 2,4 - D EE + FYM #	8.0	2.4	11.6	0.8	2.0	3.6	5.6	2.8	12.0	4.8	4.0	41.6	56.8
T 6 - Hand weeding + FYM	9.6	1.6	10.8	0.4	2.0	2.4	4.0	2.8	3.6	0.4	14.0	36.8	50.0

Treatments	Summer 2002 - 50 DAP (6th crop)													
	Fm	Cdf	Ci	Total	Eg	Pt	Total	Ea	Sa	Rv	Go	Lp	Total	Weeds
T 1 - Butachlor + 2,4 - D EE + FYM	42.0	6.0	33.0	81.3	12.0	2.0	14.0	24.0	52.8	4.0	4.0	4.0	103.2	198.5
T 2 - Butachlor + 2,4 - D EE + FYM #	21.2	3.2	13.0	34.0	1.0	0.0	3.2	22.8	20.0	0.0	2.0	11.0	66.0	103.2
T 3 - Hand weeding + FYM	33.2	2.0	26.8	62.0	5.5	0.0	9.2	10.0	10.0	2.0	9.0	4.0	58.0	129.3
T 4 - Butachlor + 2,4 - D EE + FYM	26.0	6.0	32.0	64.0	27.2	8.0	35.2	6.0	27.0	2.0	9.0	12.8	60.0	159.8
T 5 - Butachlor + 2,4 - D EE + FYM #	14.8	1.2	0.0	16.0	14.0	4.8	19.2	14.0	29.0	0.0	0.0	4.0	57.2	92.0
T 6 - Hand weeding + FYM	44.8	10.0	50.0	105.2	10.0	2.0	20.0	15.2	18.0	0.0	6.0	6.0	59.2	184.0

Treatments	*Kharif* 2006 - 60 DAP (15th Crop)														
	Sedge					Grass		Broadleaf							Total weeds
	Cdf	Sc	Fm	Ci	Total	Ec	Total	Ea	Sa	Lp	Rv	Lv	Go	Total	
T 1 - Butachlor + 2,4 - D EE + FYM	6.0	15.0	10.0	10.0	42.8	0.0	0.0	0.0	23.0	5.0	6.0	0.0	0.0	34.0	76.8
T 2 - Butachlor + 2,4 - D EE + FYM #	10.0	12.0	6.0	6.0	35.0	0.0	0.0	3.0	15.0	10.0	3.0	0.0	0.0	34.5	69.5
T 3 - Hand weeding + FYM	19.3	16.0	4.0	0.0	43.3	8.0	11.0	0.0	3.0	15.0	9.0	9.0	24.0	60.0	114.3
T 4 - Butachlor + 2,4 - D EE + FYM	8.0	0.0	15.0	0.0	25.3	0.0	3.0	2.0	6.0	11.0	8.0	7.0	17.0	58.0	86.3
T 5 - Butachlor + 2,4 - D EE + FYM #	6.0	5.0	11.0	0.0	23.0	2.0	4.0	0.0	16.0	11.0	0.0	3.0	7.0	37.0	64.0
T 6 - Hand weeding + FYM	3.0	24.0	11.0	8.0	46.8	2.0	2.0	0.0	8.0	7.0	8.0	3.0	25.0	58.0	106.8

T_1 and T_4 = Butachlor 0.75 kg + 2,4-D EE 0.4 kg/ha as pre-em.,3 days after planting applied in sequence (3 DAP)during both *kharif* and summer seasons; # = T_2 and T_5 = butachlor and 2,4-D EE applied in sequence as in T_1 and T_4 during *kharif* followed by pretilachlor 0.75 kg/ha as pre-emergent 3 DAP (only during summer season); +FYM = 75% NPK through fertilizer + 25 % through FYM; - FYM = 100% NPK through fertilizers only (100 kg N, 50 kg P2O5, 50 kg K2 O/ha in *kharif* and 125 kg N, 62 kg P2O5, 62 kg K2O/ha in summer, FYM - 0.6%N, 0.5% P and 1.2% K; K = *kharif*, S = summer season;

Fm = *Fimbristylis miliacea*, Cdf = *Cyperus difformis*, Ci = *Cyperus iria*, Sc = *Scirpus spp*., Eg = *Echinochloa glabrascens*, Ec = *Echinochloa colona*, Pt = *Panicum tripheron*, Lp = *Ludwigia parviflora*, Ea = *Eclipta alba*, Go = *Glinus oppositifolius*, , Rv = *Rotala verticillaris*, Sa = *Spilanthus acmella*, LV= *Lindernia veronicaefolia*.

between two butachlor + 2, 4-D EE treatments. However, after 6 crop rice during summer 2002, the density of sedge (particularly *Fimbristylis miliacea* and *Cyperus iria*) was three to eight times higher in application of butachlor + 2,4-D EE both during *kharif* and summer as compared to plot receiving butachlor + 2,4-D EE during *kharif* and pretilachlor in summer. While such increase was three to ten folds in grasses (*Echinochloa glabrascens* and *Panicum tripheron*) density in the former treatment as compared to the later treatment (Ramachandra Prasad *et al*., 2008)

Weed shift due to climate change : Over the past decades, climate change has induced transformations in the weed flora of arable ecosystems of the world. For instance, thermophile weeds, late-emerging weeds and some opportunistic weeds have become more abundant in some cropping systems. The composition of arable weed species is indeed ruled by environmental conditions such as temperature and precipitation. Climate change also influences weeds indirectly by enforcing adaptations of agronomic practices. Therefore, a need for more accurate estimations of the damage potential of arable weeds to develop effective weed control strategies while maintaining crop yield.

Climate change is expected to increase the risk of invasion by weeds from neighboring territories. With the competitive ability, weeds often find an opportunity to establish new populations when natural or desirable plant species decline. Climate change may also favor expansion of range of weeds that have already established but are currently restricted in range. The range expansion can be attributed to evolutionary adaptation.

Alien weeds are usually non-native, whose introduction results in wide-spread economic or environmental consequences e.g. *Lantana camara*, *Parthenium hysterophorus*, *Eichhornia crassipes, etc.,* in India. These weeds have strong reproductive capability and are better dispersers and breeders. With these characteristics, they are benefitted from climate change. Invasive weed *Parthenium hysterophorus* has tremendous growth response to elevated CO_2.

2. Reasons for Weed Spectrums Change

Weeds are well equipped to flourish in disturbed agricultural systems. Weeds are genetically diverse and can readily take advantage of the variety of conditions created by any given crop production system. Many common weed species also have the ability to rapidly establish themselves in a field in just a couple of years' time. This is primarily due to ability of some weeds to produce large quantity of viable seeds (if it is an annual) or vegetative tissues such as rhizomes (if it is a perennial) in a single growing season. Most weed species also have the attribute of seed or bud (if it is a perennial) dormancy. This allows a diversity of weed species to exist for long periods of time in the soil. Thus, when changes in the cropping system occur that are favorable for their germination and development, a particular weed species is able to respond fairly quick and rapidly (often within three to five growing seasons) and establish itself in the cropping system. Therefore, one key for reducing the predominance of any given weed species is to increase the diversity of crops within the cropping system or at least the diversity of weed management practices within the cropping system.

Weed shifts occur when weed management practices do not control an entire weed community or population. The management practice could be herbicide use or any other practice such as tillage, manure application, or harvest schedule that brings about a change in weed species composition. Some species or biotypes are killed by (or susceptible to) the weed management practice, others are not affected by the management practice (tolerant or resistant) and still others do not encounter the management practice (dormant at application). Those species that are not controlled can grow, reproduce and increase in the community resulting in a weed shift. Any cultural, physiological, biological or chemical practice that modifies the growing environment without controlling all species equally can result in a weed shift.

3. Weed Resistance

In contrast to weed shift, weed resistance is a change in the population of weeds that were previously susceptible to an herbicide, turning them into a population of the same species that is no longer controlled by that herbicide. While, weed shifts occur with any agronomic practice (crop rotation, tillage, frequent harvest or use of particular herbicide), the evolution of weed resistance is only the result of continued herbicide application. The use of a single class herbicide application continuously over time creates selection pressure so that resistant individuals of a species survive and reproduce, while susceptible ones are killed.

A weed shift is far more common than weed resistance, and ordinarily take less time to develop. If an herbicide does not control all the weeds, the tendency is to quickly jump to the conclusion that resistance has occurred. A common misconception is that weed resistance is intrinsically linked to genetically engineered crops. However, this is not correct. The occurrence of weed shifts and weed resistance is not unique to genetically engineered crops. Weed shifts and resistance are caused by the practices (for example repeated use of single herbicide) that may accompany a genetically engineered crop and not the genetically engineered crop itself.

Transgenic herbicide resistance crops have greater potential to foster weed shifts and resistant weeds since a grower is more likely to use single herbicide in transgenic herbicide resistance crops. The increase in acrege of these crops could increase the potential for weed shifts and weed resistance in the cropping systems utilizing transgenic herbicide resistance crops. Weed species shifts and herbicide resistant weeds are the direct result of a lack of diversification in weed management systems (Rana and Rana, 2015).

4. Production Practices that Influence Shifts

Effectiveness of weed management program : The effectiveness of the overall weed management program will be the single most important factor affecting weed shifts. If the program is not managing all weed species, species that are not effectively controlled will increase. Farmer diligence and ability to make adjustments in a weed management program will directly influence the occurrence of weed shifts.

Speed of weed shift occurrence : The speed at which weed shifts occur will depend on various factors. The ability to prevent the introduction of new weeds to an area, the buffering capacity of the soil seed bank, weed characteristics described previously and the farmer's ability to quickly adjust a weed management strategy when a shift is first observed will all influence the speed at which a shift occurs or if a shift occurs at all. With poor management, a field could shift predominant weed species very quickly. Weed species shifts are a long-range risk, generally taking 5 to 7 years for significant weed species shifts to occur. The temptation of the short-term gains of using the Roundup Ready technology across all corn and soybean acres is strong and short-term gains are often adopted because "a Rupee today is worth more than a Rupee tomorrow".

Interface areas : A cropped field will likely include places where no herbicide is applied (skips) or where reduced rates are applied (field edges, places with a lack of overlap). These areas may or may not influence weed shifts. In some cases, these areas may allow genotypes that were not subjected to the selection pressure to survive and reproduce. However, these areas may be so small that they have a negligible effect on overall field effects.

5. Preventive Measures to Reduce Weed Shifts

Weed identification : Effective weed management practices begin with proper identification to assess the competiveness of the weeds present and to select the proper herbicide if one is needed. A weed management strategy to prevent weed shifts and weed resistance requires knowledge of the composition of weeds present. Identification of young seedlings is particularly important because seedling weeds are easier to control.

Frequent monitoring for new species : It is difficult to detect an emerging weed shift or weed resistance problem if fields are not frequently monitored for weeds that escapes current weed management practices. Identification and frequent monitoring can detect problem weeds early and guide management practices including herbicide selection, rate and timing.

Quarantine laws : Checking the interstate or intrastate movement if weed seeds or other propagating materials movement through food grains or from any other materials.

Judicious herbicide rate and timing : In weed management programme, the grower must be sure to use the proper herbicide rate for the particular weeds species as they may sometimes are tolerant to lower doses. Also, the time of application of the herbicide dose is important *i.e.,* treat the weeds when they are small, because after crossing certain stage they may be tolerant to that particular herbicide or dosage.

Crop rotation : One of the most effective practices for preventing weed shifts and weed resistance is crop rotation, which allows growers to modify selection pressure imposed on weeds. Crops differ in their ability to compete with weeds. Some weeds are a problem in some crops, while they are less problematic in others. Rotation therefore would not favor any particular weed spectrum. Crop rotation also allows the use of different weed control practices, such as cultivation and application of herbicides with different sites of action. As a result, no single weed spices or biotype should become dominant.

Agronomic Practices : In addition to crop rotation, several management practices may have an impact on the selection of problem weed populations. If problem weeds germinate at a specific time of year, crop seeding date can be shifted to avoid these weed populations. Delaying irrigation can reduce germination of certain summer annual weeds. However, this practice only works on some soil types and water stress resistant crops only. Harvest management can assist in eliminating or suppressing problem weed populations in some cases, but harvest must occur before weed seed production to prevent weed proliferation.

Rotation of Herbicides : Weed shifts occur because herbicides are not equally effective against all weed species and herbicides differ greatly in the weed spectrum they control. A weed species that is not controlled will survive and increase in density following repeated use of one herbicide. Therefore, rotating herbicides is recommended. Rotation of herbicides reduces weed shifts, provided the rotation herbicide reduces weed shifts and provided the rotational herbicide is highly effective against the weed species that is not controlled with the primary herbicide. The grower should rotate to an herbicide with a complimentary spectrum of weed control, along with a different mechanism of action and therefore a different herbicide binding site. Weed susceptibility charts are useful to help develop an effective herbicide binding site and herbicide rotation scheme. In addition, publications on herbicide chemical families are available to assist growers in choosing herbicides with different mechanisms of action.

Rotating herbicides is also an effective strategy for resistance management. Within a weed species there are different biotypes, each with its own genetic makeup, enabling some of them to survive a particular herbicide application. The susceptible weeds in a population are killed, while the resistant ones survives, set seed, and increase over time. Using an effective herbicide with a different mode of action from the one to which the weeds are resistant, would, control both the susceptible and resistant biotypes. This prevents reproduction and slows the spread of the resistant biotype. Frequency of Rotation depends on weed species and escapes. There is no definitive rule on how often herbicides should be rotated. It is better to rotate at least once in the middle years or more often for perennial crops. It can also be modified depending upon the actual observations of evolving weed problems. The key point, which cannot be overemphasized, is the importance of thorough monitoring for weed escapes. Producers should stay alert to the appearance of weed species shifts and evolution of resistant weeds. Weed resistance should be confirmed by controlled studies conducted by a weed scientist. However in these situations, it is imperative to prevent reproduction of a potentially resistant biotype. Treat weed escapes with alternative herbicides or other effective control measure.

Identifying new weeds through frequent monitoring is very much required which helps to know the reasons or the way for entry of new weed species and its effects to the crops and also helps to realize the faults in management measures. It provides a better way to find out the best weed management measures for effective control of weeds without entry of any new species with higher yield and economic returns.

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(*Received :* August, 2019 *Accepted :* September, 2019)