Herbicide Resistant Weeds; Incidences, Management, and the Impact on Alfalfa Agroecosystem: A review

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Abstract: This review aims to shed the light on the economic role of alfalfa cultivars as alfalfa is considered the most important perennial forage legume in animal husbandry as well as the impact of herbicide-resistant weeds on alfalfa agro-ecosystem. Furthermore, some aspects of the herbicide-resistant history, incidences, cases in both developing and developed countries, and the most effective herbicide resistance management approach to applying.
Keywords: Alfalfa, herbicide-resistant, incidences, management.

Introduction:

As indicated by Radović et al. (2009), the perennial legume of alfalfa is considered the "queen" of forages as it is very economical regarding its high nutritive value and high production of biomass reaching approximately (20 t ha^{-1}) of dry matter yield and over (80 t ha^{-1}) of high green yield and high crude protein levels. Alfalfa is also considered the most widespread crop worldwide as it is now cultivated in more the 80 countries on all continents covering an area of about 35 million ha with low irrigation requirements.

The word "Herbicide" comes from the combination of two Latin words: herb, which means undesirable plant, and the word cide, which means killer. Therefore, herbicides are defined as plant killers or chemical materials that can kill unwanted weeds (Ware, 2000). Therefore, herbicides are capable of decreasing the need for labor and have a major contribution to developing the yield of economically valued crops. However, knowing the properties and the usage of each herbicide is necessary for weed management and control (Strehlow *et al.,* 2020). Based on Qasem (2013), herbicide resistance is the inherited ability of an unwanted weed to survive the application of an herbicide to which the original population was sensitive. Although most cases of herbicide

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resistance have occurred in developed countries, many weeds that have developed resistance are having a great economic impact on important crops such as alfalfa.

According to Atwood & Paisley-Jones (2017), the dominating agrochemical companies (Syngenta, Monsanto, Aventis, BASF, Dow Agro-Sciences, DuPont, and Bayer) have reported sales of about 24.7 billion USD in 2012 alone with the developed countries (North America, Europe, and Japan) alone representing nearly 70% of the global agrochemical market. Valavanidis (2018) stated that glyphosate is the most commonly used herbicide in the world, which accounts for nearly 11% of the total value of agrochemical market sales.

Incidences and History of Herbicides Resistance:

Back to the beginning of the seventeenth century (1821), Copper Sulfate ($CuSO_4$) was the first multiple-use herbicide utilized ever in combatting weeds, fungi, algae, and bacteria. In Northern Europe, 1855 acids were applied to combat unwanted weeds in onion farms. In 1896, a solution of $CuSO_4.5H_2O$ has proven its eclecticism to kill *Sinapis arvensis* in mono-cultural crop fields. Heavy metal salts to defeat weeds were first introduced by the USA. In 1914, petroleum oils were discarded into the irrigation channels to demolish the existence of undesirable weeds and it is still used until today in some developing countries. The first organic herbicide (2 methyl 4,6-dinitrol phenol) was made in 1932 by France to fight weeds in bean crops. In 1941 the well-known herbicide (2,4-dichlorophenol acetic acid) was made, introduced, and commercialized by the USA to combat the genus of *aspidistra spp* (Shaner, 2014).

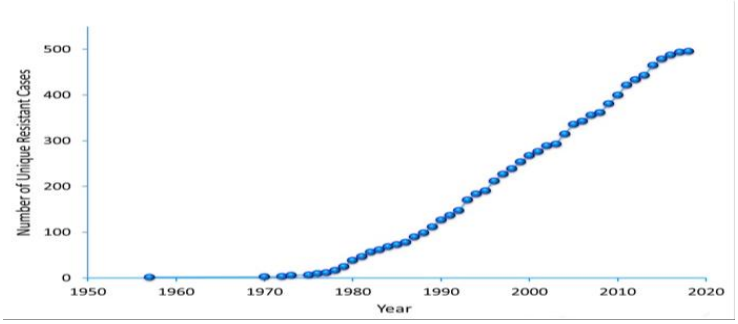

Figure (1): Global increase in resistant cases (Mendes, 2020).

The first herbicide resistance case was reported in the USA in the late 1950s. In 1964, it was reported that *Convolvulus spp* has developed resistance to (2,4-dichlorophenol acetic acid) in the state of Kansas, USA. Resistance to triazine herbicides was recorded in the capital city of Washington in 1970. In the 1980s, the number of reported herbicide-resistant cases began steadily increasing worldwide. Resistance to at least

one or more of 25 herbicide families has been confirmed through field studies in more than 65 weed species. Currently, more than 500 resistance cases were observed in non-cropland and approximately 100 different crops in 70 developed and developing countries (Beckie, 2020).

Herbicide Resistant Cases in Developing Countries:

The first herbicide resistance case to 2,4-Dichlorophenoxyacetic acid was reported in *Daucus carota* 1957. However, weed resistance to herbicides began to receive attention only after the first case of triazine resistance in *Senecio vulgaris* in 1970. A few years later, resistance cases to triazines were most common, as 64 species have evolved resistance to the triazine family. On the other hand, only four confirmed species have evolved resistance to glyphosate. Nowadays, there are 157 confirmed resistant species (Valverde, 2003).

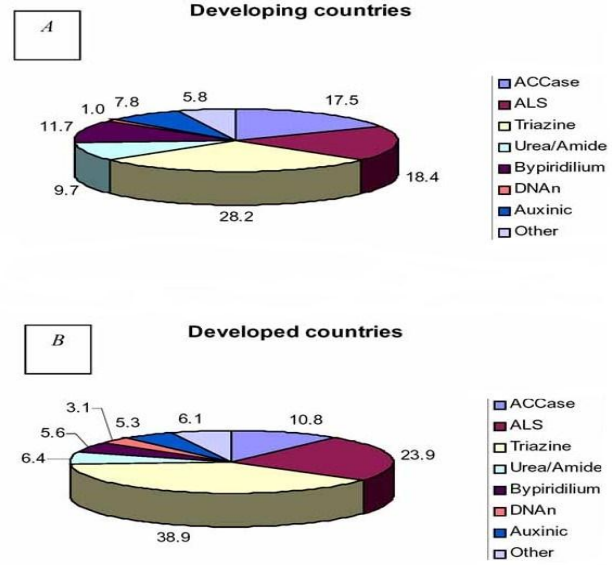

Figure (2): Cases of herbicide resistance in developing and developed countries (Heap, 2001).

Based on data obtained by Heap (2001), developing countries alone contribute approximately 22% of the total herbicide resistance cases worldwide. However, the most important herbicide families that have evolved resistance are Triazine, ALS, and ACCase, representing about 64.1% and 73.6% of the resistance incidences in both developing and developed countries respectively.

Herbicide Resistance Management:

If resistance to an herbicide is confirmed, different herbicide resistance management approaches need to be immediately applied for the questionable species as follows:

1. Completely stop using the herbicide in question and any other herbicides with the same mechanism of action.
2. If the resistant weed is limited to small areas, prevent seed production and spread.
3. Use another herbicide if the weed is still small enough to control or remove the resistant weed by hand or destructive tillage.
4. Avoid using any equipment used in the infested field.
5. Scout fields before and after herbicide application to monitor the effectiveness of the herbicide program.

Applying to the resistance management steps declared above would help in delaying and preventing resistance from occurring and recurring in the long term (Evans *et al.,* 2016).

The Impact of Herbicide Resistant Weeds on Alfalfa Agro-system:

Controlling weeds that compete with crops is necessary for better yield and productivity. To minimize the impact of weeds on crop productivity growers resort to the application of herbicides. Moreover, herbicide usage enables beneficiaries to minimize destructive tillage techniques resulting in reduced soil erosion. Due to these benefits, the rate of biotech herbicide-tolerant crop usage has become quite rapid. For example in Argentina, glyphosate-tolerant soybeans were planted on over 98% of soybean acres within 5 years of introduction (Green, 2016).

On the other hand, if any single herbicide is used repeatedly, the development of resistant weeds may occur more rapidly as in Figure (3).In most herbicide-resistant cases, the same herbicide can continue to be useful because of the spectrum of weeds present. The majority of weed scientists recommend adding another herbicide to the primary herbicide to have better control over herbicide-resistant weeds.

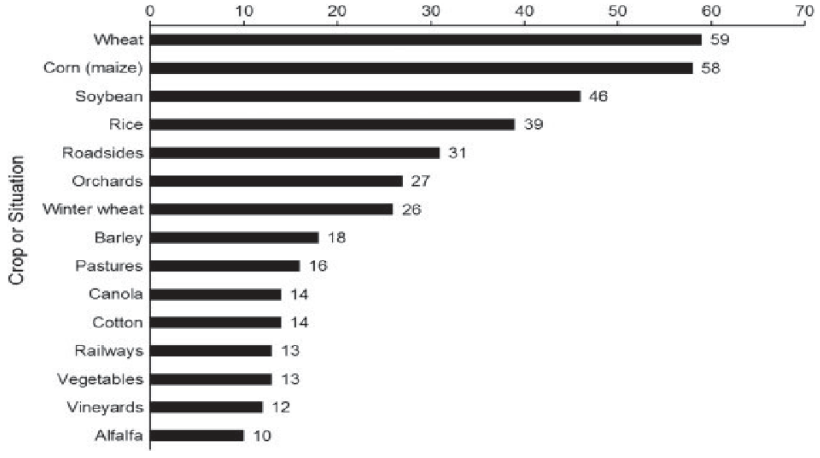

Figure (3). Number of herbicide-resistant species by crop (Heap, 2014)

Conclusion:

Briefly, no single herbicide or management tactic can solve a particular herbicide-resistance problem. Both to prevent and manage resistance, once it occurs, requires a basic knowledge of the biology of the weeds and their population dynamics. A fundamental understanding of the forces that select resistant individuals and the processes by which resistance is accelerated or delayed, plus the experience gained over a broad range of growing conditions and countries, should better prepare us to combat herbicide resistance.

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