Effect of Herbicides on Living Organisms in The Ecosystem and Available Alternative Control Methods.

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Abstract- Herbicides are used in agricultural areas to reduce harmful of weeds. Herbicides could decimate some weeds and slow down growth in others. Using herbicide has increased significantly since the mid-20th century. In case that herbicides are not used, significant quantitative and qualitative losses will have occurred in agricultural production. However, the side effects caused by the wide and irrational use of herbicides threaten the environment and human health. Although herbicides are the least harmful among pesticides, many studies have shown the serious negative effects of herbicides on the environment and human health. Every year a list of herbicides that cause cancer or leave large residues in the soil and water are published. However, many herbicides have been banned, but only after they have been used in tons and causing environmental pollution. The chemical structure of herbicides degrades quite slowly in nature, which causes its accumulation in the soil and the environment. The effects of these herbicides have reached rivers, lakes, seas and oceans. Also, the effect of chemically degradation herbicides on living organisms under different environmental conditions is still unknown. Due to the widespread use of herbicides, it also negatively affects the use of traditional control methods, which can be also effective in some cases. In this article, some alternative control methods that can reduce the use of herbicides and reduce some of the herbicide's harm to the living organisms of the ecosystem will be included.

Index Terms- Herbicide, Environment, Alternative, Control Methods.

I. INTRODUCTION

Dinitrophenols (DNOC) and Cresols started to be used in 1932, and synthetic hormone-structured herbicides (2,4-D, 2,4-DP, etc.) in 1941. The use of chemical compounds for weeds control has spread rapidly since the late 19th century, and its use has reached the maximum level with the advancement of biochemistry and organic chemistry sciences since the middle of the 20th century. Chemical compounds that eliminate weeds or prevent the growth of weeds are called herbicides. The chemical substances that show the main effect on weeds are called the active substances, and the substances added to facilitate its use and increase its effectiveness are called fillers. All of the herbicides used for agricultural purposes consist of organic substances, namely C, H_2, and O_2. Due to the high number of herbicides used in agricultural production, they are divided into groups according to their usage time, function, or chemical structure. In Turkey, the aim of herbicides using is not to completely destroy weeds, but to reduce the weeds population and to prevent it to compete with crops (Kraehmer, 2012; Güncan, 2013). In a 20-year study conducted in Denmark, it was reported that 80% of 200 weed species grown in the cultivated fields are too weak to compete with the crops and therefore do not affect the yield (Andreasen et al., 1996). In addition, weeds contribute positively to the ecosystem by contributing to biodiversity. Weeds prevent soil damage through erosion that may occur after harvest. The presence of weeds in the soil contributes to the continued life of microorganisms and insects, it also provides habitats for insects used in biological control and it is an important source for bees to use its to produce honey. Some weeds are used as human food sources, some species are used in medical treatment and medicine production. It is also used as animal feed and as a source of genes in ornamental plants. Therefore, a balance must be established between cultivated plants and weeds grown in the same environment, so that weeds are allowed to serve the bio-ecosystem (Kraehmer, 2012; Terfa, 2018). Weeds have been reported to be more harmful in crops than insects, fungi, bacteria, and viruses (Gharde et al., 2018). Weeds cause a significant loss of agricultural production, especially the weeds with rhizome, stolons, and tuber roots; *Elymus repens*, *Sorghum halepense*, *Cyperus rotundus*, and from parasitic plants *Orobanche* spp. and *Cuscuta* spp, these weeds are very difficult to control, so more than one method of control should be applied for these species. Such weeds increase the cost of production, if weed control is neglected, the yield loss can be reach 100%. For example, the high-intensity competition of *S. halepense* caused 88-100% yield loss in the corn crop, 59-88% in soybean, 70% in cotton, and a 69% yield loss in sugar cane (Uludag et al., 2007; Barroso et al., 2016). C*uscuta campestris* has been reported to cause 75% yield loss in tomato yield (Lanini, 2004). Yield loss can reach 100% if *C. campestris* is not controlled in tomato fields (Üstüner, 2018). In India, the total economic loss is estimated at 11 billion USD in 10 large crops due to weeds alone (Gharde et al., 2018). The increasing use of these herbicides day by day carries significant risks for human and environmental health. Nowadays, herbicides take the first place in plant protection drugs produced in the world by 47% on the basis of the active substance. However, in Turkey, the use of herbicides constitutes 24.43% of the pesticides used in the agricultural fields and ranks third among the pesticides used in the protection of crops. In addition, between 2007 and 2008, herbicides ranked first in pesticide categories. Europe is the largest consumer of pesticides in the world. In developed countries, pesticides, mostly of herbicides, are mainly used in corn cultivation (Sitaramaraju et al., 2014). Turkey in 2018, the used pesticides were 59.000 tons, 13.000 tons of them were herbicides, which is equal to 22%. A significant increase in herbicide consumption has been observed and reached 30% in the12 last years. This pesticide used sales amount is approximately 2.5 billion Turkish pounds (Anonymous, 2018). Natural environments are polluted by herbicides, and its destructive effects have started to emerge in soil, water, and environment. In this research, alternative control methods that can limit or reduce the use of herbicides will be mentioned by showing the effects of herbicides on different environments and human health.

II. The Reasons for the Increase in Herbicide Use and the Ways of Spreading in Different Environments

Herbicide use in the world is increasing rapidly due to the high cost of labor and decreasing labor force. Approximately 33% of agricultural products are produced accompanied by using pesticides. Herbicides make up more than 80% of the total pesticide consumption used to protect crops (Ferrero and Tinarelli, 2007; Sitaramaraju et al., 2014). There is a misconception that herbicides are safe for human health and had little impact on the environment. For this reason, the high use of herbicides in agricultural production pollutes the soil, water, environment, and air. As a result, tons of herbicides are applied in agricultural areas every day. Herbicides in Turkey are an indispensable part of crop production (Anonymous, 2018a). The use of herbicides has increased in many cultivated crops around the world (Mahmood et al., 2015). The vast majority of herbicides do not only target weeds but also affect non-target plants and animals during its application (Sitaramaraju et al., 2014). The widespread use of herbicides for many years, with the wrong use methods, high doses, and the spread of herbicides with abiotic factors caused global contamination in various environments and negatively affected all living organisms entering the food chain. We recommend formula 5 D in order to get more effective results in the control against weeds, but also not to harm human health, environment, fish and bees. The 5 D formula proposed in the control against fungal pathogens was adapted from Mutlu and Üstüner (2017) and it was proposed in the control against weeds; 1. Correctly identifying weed species, 2. Using herbicides at the right time, 3. Choosing the right herbicide, 4. Apply in the right dosage and 5. Applying the right spraying method. As in the case of glyphosate, it has been one of the most widely used herbicides in human history and its remains were detected in the diapers and the medical gauze. In addition, it has been discovered that the remains of some new generations of herbicides such as dactal, metolachlor, and trifluralin are found in water, snow, fog, and air samples were taken from the North Pole (Garbarino et al., 2002). There are two ways pesticides enter ecosystems, depending on their solubility. Some pesticides dissolved in water and enter the water environment, and other pesticides are fat-soluble pesticides that are stored in living organisms by a process known as biological cations that cause them to remain in the food chain for a long time (Warsi, 2015). Herbicide particles can not only stay where they are applied but can also spread in other non-target areas through factors such as soil, wind, and water. Thus, it damages microorganisms by making toxic effects on different environments. The adsorption of herbicides to soil ions is affected by the moisture content of the organic matter and the physical and chemical composition of the soil. The plant transmits the herbicide molecules it absorbs to all its organs through conduction bundles. Herbicide can be passed on to the animals fed on the plant and is included in the food chain. Herbicides applied to the soil or plant surface are mixed with the atmosphere by evaporation and can be transported by the wind for long distances. The herbicides move through horizontal and vertical infiltration in the soil. In this case, it is affected by the content of water in the soil, soil structure, clay content in the soil, and organic substances. Herbicides are washed with rain and can mix into groundwater (Jurado et al., 2011). The risk of herbicides is not only limited through infiltration into other environments but also because of its slow decomposition then it can maintain its biological activity in the soil for many years. Residue amount of some herbicides in the soil; It was calculated to be 0.021mg for atrazine, 0.075 for chlortoluron, 0.475 for methabenzthiazuroun, 0.044 for monolinuron, 0.118 mg for terbutryn. A half-life is a time it takes for a certain amount of a pesticide to be reduced by half. In addition, compounds resulting from pesticide degradation may have greater toxicity than the pesticide itself (Kortekamp, 2011). For example, two years after glyphosate and AMPA spraying, it found in water samples at a concentration of 0.1 mg/L (Sitaramaraju et al., 2014).

III. The Effect of Herbicides on Human Health

Every year, many herbicides were banned in some countries due to its harmful effects on human health, but this is done after tons of herbicides were applied and spread to the environment. Many herbicides had caused serious human diseases so it had banned. This does not mean that the herbicides allowed to use are innocent because its direct and indirect effects are difficult to identify complex and costly. The effect of some banned herbicides such as paraquat may lead to diseases and cause deaths (Kortekamp, 2011). The future risks posed by the dangerous properties of the herbicides currently in use cannot be evaluated in terms of human health. In the world in 1999, the number of deaths caused by pesticide poisoning reached about one million persons. World Health Organization reported that poisoning cases cussed by pesticides are generally 3 million persons per year (OECD, 2008, WHO, 2016). Herbicides have two types of toxicity, acute and chronic toxicity. Many herbicides have moderate to weak acute toxicity. It is estimated that the chronic effects of herbicides can be very important and threaten human life like in (2,4-D) (Weisenburger, 1993). While testing the herbicidal in terms of the possibility of cancer-causing in Syria, they achieved a positive result in the hamster embryo assay (Maire et al., 2007). In addition, it has been reported that using pesticides is associated with prostate cancer in farmers, causing endocrine disruption, decreased sperm count, or increased abnormalities in sperm. In the case of dioxin pollution and exposure to 2,4-D in admixture with other pesticides, a wide range of results was found in cancer risk research (Garabrant and Philbert, 2002; Soloneski and Larramendy, 2011). It also caused chromosomal aberrations in plants, mice, and human cells, including human lymphocytes for occupationally exposed workers to pesticides (Garaj-Vrhovac and Zeljezic, 2001; Ateeq et al., 2002). The 2,4-dichlorophenoxyacetic acid (2,4-D) and 3,6-dichloro-2-methoxy benzoic acid (Dicamba) from the herbicides belong to the Auxinic group, the world's most common post-emergence herbicides are that used to control broadleaf weeds in grain crops (Reinbothe et al., 1996). Based on its toxicity, both of these herbicides are classified as class II members (moderately dangerous) by WHO (2016). It has been determined that each of the herbicides 2,4-D and Dicamba can cause DNA damage in CHO cells and human lymphocytes when the chromosomal and DNA levels were analyzed. Dicamba and 2,4-D have been reported to cause SCEs in mammalian cells and it has clastogenic activity. (Soloneski and Larramendy, 2011). Dicamba (2-Methoxy-3,6-dichlorobenzoic acid) has been listed by the US EPA as an increased toxin, has a negative reproductive effect and Cholinesterase inhibitor (Anonymous, 2002). Glyphosate is the chemical substance that is the best-selling herbicide in human history and the world and constitutes 60% of the broad-spectrum herbicide sales (Dill et al, 2010; Atwood and Paisley-Jones, 2017). Glyphosate can cause chronic health effects in laboratory animals. Nutritional experiments with glyphosate lifetime have shown weight reduction, effects on liver and kidney, and damage to the eye lens. These effects were only at the higher doses tested. Tests with rabbits have shown dose-dependent negative effects on sperm quality (Cox, 1991; WHO, 1994; Annett et al., 2014; Mesnage et al., 2015). Clinical studies have shown that workers who previously used glyphosate had a higher incidence of non-Hodgkin lymphoma, a rare form of cancer compared to those who did not use glyphosate (Eriksson et al., 2008). Also, most toxic tests have been done only on glyphosate and a limited number of tests have been made on formulated products (Cox, 1991). A glyphosate activity that damages DNA in the liver and kidneys of mice has also been observed (Soloneski and Larramendy, 2011). Polyoxymethylene Amine, an additional ingredient added to most formulations, has been found to be more acutely toxic than glyphosate itself (Claudia et al., 2014).

IV. The Effect of Herbicides on the Environment

Herbicides are spread in different environments by various methods mentioned earlier. Thus, herbicides affect the organisms of these environments, causing a toxic effect and can then directly affect people. It is found that 40% of the world economy is directly linked to ecosystem services due to indirect effects (SCBD, 2010). 60% of ecosystem services have deteriorated in the past 50 years (Anonymous, 2005).

IV.1. The effect of herbicides on non-target plants

Herbicides, especially broad-spectrum herbicides, affect plant biological diversity and damage environmental balance. In addition to the possibility of killing crops, herbicides can reduce plant yield and increase susceptibility to diseases. For example, glyphosate significantly increases the severity of various plant diseases, and lead to weakening plant capacity to resist against pathogens, and immobilizes soil and plant nutrients (Johal and Huber, 2009). Due to these effects and increased weed tolerance and resistance, farmers have to use fungicides and supplemental herbicides in cereals, causing excessive ecological effects. It can also lead to the complete extinction of weeds that have an impact on agricultural ecosystems. Therefore, agricultural biodiversity and ecosystem functions such as biological control, pollination, and functional soil structures are increasingly compromised, as well as the almost complete elimination of weeds. This ecological degradation also posed a particular threat to endangered plant species (Schütte, 2003). The US Fish and Wildlife Service identified 74 endangered species that could only be threatened by glyphosate (Anonymous, 1986). Seed quality of cultivated plants exposed to glyphosate has been significantly reduced (Locke et al., 1995).

IV.2. The effect of herbicides on animals

Herbicides affect animals directly or indirectly. As a result of the use of pesticides; herbicides, and fungicides there are decrease in the numbers of rare animals and some species of endangered birds (Anonymous, 2010). Herbicides can affect arthropod community dynamics separately from their effects on the plant community and also affect the biological control factors in agroecosystems (Evans et al., 2010). Glyphosate caused high death levels of frogs in its effect study. Herbicide application is reported to lead to a decrease in chicken and bird population (Taylor et al, 2006). In addition, it has been reported to occur degradation of frog genetics due to atrazine (Hayes, 1990). Exposure of chicken eggs to 2,4-D reduced incubation time and has been reported to cause feminization and infertility in pheasant chicks (Duffard et al., 1981).

IV.3. The effect of herbicides on soil

Herbicides are retained by soils of different degrees, depending on the interaction between the properties of the soil and herbicides. The most effective soil feature is organic matter content. As the organic matter content increases, the adsorption of herbicides also increases. Whenever the soil colloids were even smaller, its adsorption increases herbicide. Accordingly, the amount of herbicide molecules adsorbed is high (Andreu and Pico', 2004). Active persistence period of some herbicides applied to soil; Acetachlor 3-12 months, Alachlor 1.5-3 months, Atrazine 4-18 months, Bromacil 9-18 months, Cholorxuron 3-6 months, Chlordbiamid 12-24 months, Dichlobenil 12-24 months, Isoxaben 6-12 months, Metsulfuron 2 -12 months, Oxadiazon and Terbacil 9-18 months, Trifluralin 5-10 months (Börner et al., 1979, Monaco et al., 2002). Factors such as soil organisms, soil structure, transformation, and organization of organic substances that provide the nutrition of plants are negatively affected by herbicides. Many herbicides can destroy microorganisms in the soil. On the other hand, microbial disruption can lead to the formation of more toxic and permanent metabolites. Although microbial soil complexes can adapt to changing environmental conditions, the application of herbicides has been reported to cause significant changes in populations (Sitaramaraju et al., 2014). Herbicides prevent the plant from taking advantage of this, as atmospheric nitrogen disrupts the conversion function to nitrate because it had a negative effect on the microorganisms that performed this process. Triclopyr inhibits soil bacteria that convert ammonia to nitrite, and 2,4-D has been found to reduce nitrogen fixation of bacteria that live in the roots of bean plants (Fabra et al., 1997). Glyphosate reduces the *Arbuscular mikorhizal* fungi communities, which negatively affects the microbes present in the soil that benefit from this fungus with nutrition. Glyphosate has been reported to be toxic to beneficial soil bacteria such as Bacillus family, by inhibiting soil minerals (manganese, iron, etc.) and free-living nitrogen stabilizing bacteria which make plants biologically usable (Johal and Huber, 2009; Zaller et al., 2017). Earthworms play an important role in the soil ecosystem. It operates in the soil as a bioindicator and may show deterioration in soil quality in the early period. A study in Argentina reported that glyphosate has harmful effects on Earthworm's population (Casabé et al., 2007).

IV.4. The effect of herbicides on the aquatic environment

Herbicides can infiltrate the aquatic environment in many ways and cause harmful effects on living organisms. It has been determined that herbicides used in agricultural areas affect aquatic life and this kind of pollution is observed both in the laboratory and in the fields (Daam et al., 2009). Approximately 1% of the applied herbicide is estimated to leak into the surrounding environment and rain precipitation can increase this rate up to 3% (Bengtson et al., 2005). In the Netherlands, herbicides have been found to be used at concentrations above legal standards. Herbicide pollution has been reported in water and sediment samples taken in Australia (Magnusson et al., 2008; Knauer et al., 2010). In addition, studies have reported that herbicides such as atrazine, simazine, alachlor, metolachlor and trifluralin are found in surface water and groundwater close to agricultural areas (Añasco et al., 2010). Aquatic plants provide about 80% of dissolved oxygen and are essential for survival of organisms in the water. Herbicides have been observed to kill aquatic plants, thereby lowering O_2 levels and ultimately reducing fish numbers in the water (Helfrich et al., 2009). Atrazine and alachlor have a serious effect on algae and diatoms, which are the main organisms in the food chain in the aquatic environment. It has been reported to cause degradation of compounds in cells, preventing photosynthesis and inhibiting plant growth, even at low levels from herbicides using (Anonymous, 2000). Due to the application of herbicides close to the fish environment, the reproductive potential of many aquatic organisms, including fish, has decreased (Helfrich et al., 2009). Trifluralin has been shown to be highly toxic to fish, causing to form spinal deformities in fish. It has also been found to be highly toxic to marine organisms such as shrimps and mussels (Anonymous, 1996). 2,4-D herbicides in *Sockeye salmon* have been reported to cause physiological stress responses and reduce rainbow trout's ability to collect food, and are harmful to shellfish and other species (Cheney et al., 1997). Herbicides containing Glyphosate or glyphosate have been reported to cause adversities such as fish irregular swimming and lack of oxygen (Liong et al., 1988).

V. The Plants and Weeds That Have Resistant to the Herbicide

The introduction of herbicide-resistant cultivated plants may cause more herbicides to enter the agricultural system. In addition, the use of genetically modified organisms (GMO) products, their potential effect on the environment and human health, the release of these products will lead to an increase in the use of herbicides, thereby increasing their environmental hazards. Weeds can become more resistant to these herbicides, which will cause farmers to increase the herbicide dose and increase environmental pollution. Due to the lack of results regarding the use of herbicide-tolerant crops, a five-year ban has been proposed on the release of herbicides in many countries. This prohibition will provide the time needed to assess the risk status of herbicide-tolerant crops (Buffin and Jewell, 2001; Bennett et al, 2004). If Glyphosate is widely applied in GMO agriculture, almost no alien species may remain (Buffin and Jewell, 2001). Since GMO plants are produced in herbicide companies, it will increase the use of herbicides produced by these companies, thereby speeding up the resistance of these plants for herbicide. In recent years, in Turkey, many weed species are known to be resistant to many Active substances; such as *Avena sterillis*, *Sinapis arvensis*, *Cyperus difformis*, *Phalaris brachystachys* and *Echinochloa crus-galli* (Aksoy et al., 2007; Anonymous, 2017). In one study, approximately 500 weed species were determined to be herbicide-resistant species, more than 100 weed species were resistant for two types of herbicides, more than 50 weed species had resistant for three types of herbicides, and more than one weed species were had resistant for 11 types of herbicides. As a result of excessive glyphosate use, the number of resistant weeds was determined as 424 species (Heap, 2019).

VI. Indirect Effects of Herbicides

Herbicides can indirectly affect the population of birds, mammals, insects, and other animals with changes in the nature of their habitats, as they cause large changes in vegetation. Some herbicide compounds have been found to have toxic metabolites that can remain in nature for a long time (Knauer et al., 2010; Hossain, 2015). Economic damage to herbicides in non-target species (including plants, humans) is estimated to be 8 billion dollars annually. In fact, the relatively common use of herbicides can be particularly problematic. The best way to reduce herbicide contamination in our environment is to use harmless ones such as biological, biotechnical, physical, mulch methods that are safer for weed control (Aktar et al., 2009).

VII. SOME ALTERNATIVE METHODS FOR WEEDS CONTROL

There are many non-chemical processes and methods used to reduce weed damage. Some of these methods are widely used, while others are less commonly used. Natural chemicals such as plant essential oils have a very important effect on weed control. Eucalyptus essential oils containing chemical compounds (oxygenated sesquiterpenes, monoterpene hydrocarbons, sesquiterpene hydrocarbons, and oxygenated monoterpenes) were found to be 80% effective in the control against weeds, especially *Amaranthus retroflexus*, *Rumex crispus*, and *Convolvulus arvensis* (Üstüner et al., 2018). Some methods may be successful against certain weeds. Therefore, integrated weed management; many methods are known as mulch, solarization, tillage in hot months, hand and machine hoe (IWM) suggest using more than one method in the integrated program. These methods can be counted as cultural, mechanical, thermal and biological.

VII.1. Cultural weed control

Includes, crop rotation, increasing crop competitiveness, planting time, irrigation type, cover crops, and intermediate hoeing (Shrestha, 2006).

VII.1.1. Competitive variety selection

Cultivating a competitive crop is an effective method of reducing weed growth due to the crop's intervention. Crop competition is an important and cost-effective tactic to increase weed suppression and optimize crop yields (Blackshaw et al., 2008). Some agricultural factors such as cultivar plant diversity, seed rate, row spacing, seed placement, and fertilizer management can be applied to support crop competitiveness (Lemerle et al., 2001).

VII.1.2. Cultivating time

Early sowing provides a competitive advantage for cultivated plants. This advantage is slow germination and growth of weeds that cannot benefit from sunlight due to the germination and shading of the crop before weeds (Cici et al., 2008). When wheat was cultivated early, there was a 68-80% reduction in the population of canary herb (*Phalaris minor*) (Kumar et al., 2013). When cultivating barley seeds 4-6 weeks before normal cultivating dates, it caused to reduce weed seed production and biomass (Lenssen, 2008). Changes in cultivating times significantly affect the weed population (Norsworthy et al., 2012).

VII.1.3. Fertilization

Careful timing of fertilization is important to ensure the development of the crop plants at an optimum level and limit the use of nutritional elements by weed species (Norsworthy et al., 2012). It has been determined that with the application of N-fertilizer in the root extension phase of winter wheat, *Veronica hederifolia* reduces the biomass and supports the production of biomass for crop according to the N-fertilizer application during the wheat cultivating period (Liebman and Davis, 2000).

VII.1.4. Crop rotation

Crop rotation is considered an important technique for controlling weeds (Cardina et al., 2002). Rotation of plants with different life cycles prevents weed density and therefore seed production. Allelopathic effects of cultivated plants on weeds are extremely important in crop rotation (Derksen et al., 2002). Populations of broad-leaved and narrow-leaved weeds density such as *Chenopodium album*, *Amaranthus retroflexus*, and *Setaria faberi* were reduced in the corn-oat rotation system by 88%, 29%, and 80%, respectively (Cardina et al., 2002).

VII.1.5. Plant covers

Live cover plants that can be applied in orchards compete with other weeds in terms of nutrients in the soil, suppressing more than one weed species. It also minimizes above-ground residues, soil erosion, and nutrient losses. Covering plants prevent biotic and allelopathy effects and other weeds that can germinate (Teasdale et al., 2007). Cover crops contain a wide range of plants grown for various ecological reasons outside the soil (Sarrantonio and Gallvet, 2003). Rye cover crops are capable of holding more nutrients than fertilizer applications and preventing the emergence and growth of many weeds. Rye cover prevented the growth of 45% of *Ambrosia artemisiifolia*, 85% of *Setaria viridis*, 100% of *Amaranthus retroflexus*, *Chenopodium album* and *Portulaca oleracea*, but had no effect on *Setaria glauca* (Shilling et al., 1986).

VII.1.6. Crop residue

Crop residue retaining is used as an effective method to reduce the density of weeds. Some weed populations are highly susceptible to mulch, while other weed species may emerge and outflow from soil moisture in a small amount of mulch. It may be enough to leave large amounts of residue in the field to minimize weed density (Chauhan et al., 2012). When the percentage of crop residue (*Secale grain* or *Vicia villosa*) is increased, a significant reduction in weed density has been observed (Teasdale et al., 2007).

VII.2. Mechanical control

VII.2.1. Hand tools

Hand hoe is an effective method to prevent the spread of annual weeds. However, it is less effective against perennial weeds due to vegetative reproductive organs (rhizome, stolon and tuber). It is widely used to control weeds that are problematic in horticultural crops (Zimdhal, 2007).

VII.2.2. Soil cultivation

Tilling the soil is known to be effective in lowering weed populations. It is important to plow the soil. Especially when the tillage is done 45 days before cultivating, many weed species are released until cultivating time, and the weed reserve in the soil is significantly reduced since the soil is cultivated again during cultivating (Shrestha, 2006). Tillage can temporarily drag some weed seeds to deeper layers, while encouraging others to germinate, reducing weed seeds reserves in the soil (SantínMontanyá et al., 2016).

VII.2.3. Thermal method

Thermal methods, effective in weed control; covers flame, hot water, steam and solarization methods. These methods do not have any side effects in agriculture and water (Ascard et al, 2007).

VII.2.3.1. Flaming method

The heat produced by the propane flame can reach temperatures up to 990ºC and dry the plant leaves and damage the plant cells (Diver, 2002). For this method to be lethal, leaf tissue must be exposed to temperatures between 55-70 ºC for a period of 65 to 130 microseconds (Knezevic, 2017). In general, some narrow leaf weeds are more resistant to flame than broadleaf weeds because of their stolon and rhizome root structure (Ulloa et al., 2010). When using 60-80 kg/ha propane in this method, some narrow leaf weeds such as *Setaria viridis*, *Pennisetum glaucum*, and *Echinochloa crus-galli* can be controlled over 80%, while broadleaf weeds such as *Amaranthus retroflexus*, *Abutilon theophrasti*, *Ipomoea hedefracea*, and *Chenopodium album* can be controlled 90% (Ulloa et al., 2010; Knezevic, 2017). If it is applied in areas with a high amount of crop residues, it should be done carefully, as this can cause a fire. The flame method is a technique used to control weeds in corn and soybean fields. The success of weed control with this method can vary depending on both timing and temperature (Ascard et al., 2007). In a Danish study, the Flame method has been found to keep the weed density at the lowest level in the feed beet *Beta vulgaris* fields (Rasmussen, 2003). The flaming method is not suitable for all crop types, so farmers should first be informed about which crops are sufficiently heat resistant and at which stage weed burning is appropriate (Naylor and Lutman, 2002).

VII.2.3.2. Hot water method

Hot water application may be an alternative method for weed control in small areas, but it may not be practical in large-scale control operations since the equipment requires a large amount of water and energy. Another disadvantage of hot water application can be harmful to beneficial soil microorganisms and insects. It can control some pathogens and nematodes as well as weeds in small areas (Ascard et al., 2007). Whilst white mustard (*Sinapis alba*) is in the two-leaf stage, using a hot water spray at 110 ºC, 90% control can be achieved with 1.3 km / h speed of equipment and 0.5 km / h movement speed in the six-leaf stage (Hansson and Mattsson, 2003).

VII.2.3.3. Steaming method

A steam generator can kill weeds in the soil, usually at 60-80 °C and in 20-30 minutes (Melander et al., 2013). A study conducted in strawberry fields revealed that steaming the soil at 70 °C for 20 minutes provides good weed control (Samtani et al., 2011). Weed steaming significantly reduced the germination of *Alopecurus myosuroides* and *Fallopia convolvulus*, but was not very effective on *Matricaria chamomilla*. The success of this method may vary depending on weed species, vapor temperature, exposure time, and plant size. In perennial weed species, the exposure to steam should be repeated as they can reproduce (Ascard et al., 2007).

VII.2.3.4. Solarization method

Soil solarization method is based on the principle of raising the soil temperature by laying the transparent white-colored polyethylene on the soil surface, fully absorbing sunlight in the hot summer months. High soil temperature can kill bacteria, fungi, weeds and weed seeds (Stapleton and Devay, 1986). Soil solarization has been successfully used to control weed species with minimal cover in semi-arid regions (Johnson et al., 2007). In a study of the effects of soil solarization on *Orobanche ramosa* and *Orobanche cernua* in tomato fields, it has been found that both black and transparent plastic mulches reduce the Orobanche seed bank by 89% and 98%, respectively. *Cyperus esculentus* was controlled when it was solarized for at least 90 days in the summer of the previous year (Johnson et al., 2007).

VII.3. Biological control

The biological control for weeds using natural enemies started at the beginning of the 20th century and developed rapidly. The first study on this subject was the use of natural enemies against the *Lantana camara*, a cactus species in the Hawaii Islands, and *Opuntia* species in Australia. Biological weed control is a system that involves the use of various biological organisms and biological-based approaches to significantly reduce weed density (Sodaeizadeh and Hosseini, 2012). Many living organisms, such as fish, birds, herbivores, insects, fungi, bacteria, viruses, parasitic plants, which can reduce the population of weeds, can be used as biological factors. In Hawaii, cactus (*Lantana camara*) spread with birds in that area and was found intensely everywhere 40 years after birds entered. Larvae from insect species (*Crocidosema lanata*) were used and *L. camara* was taken under control in a short time (Güncan, 2013). Geese feeding on weeds that have just emerged from strawberry fields are considered important birds, Geese are especially effective in the morning and evening (Singh et al., 2018). Pathogens such as *Alternaria macrospora* were used in the granular formulation to control seedlings of *Anoda crista* herb before it appeared. *Septoria cirsii* fungus species against *Cirsium arvense*, *Bactra verutana* insect species against *Cyperus rotundus*, *Sclerotina* spp. fungus species against *Orobanche cernua*, *Microlarinus larevnii*, *M. lypriformis* insect species against *Echinochloa* spp. species *Emmolocera* spp. insect species found effective (Sharma, 2006). Essential oils extracted from eucalyptus have been found to be effective on *Melilotus officinalis* and *Amaranthus retroflexus* and have a low effect on *C. arvensis* (Üstüner et al., 2018). In another bioherbicide study, *Cuminum cyminum*, *Mentha longifolia* and *Allium sativum* in the effect study of essential oils on *Rumex crispus* and *C. arvensis*, *A. sativum*'s effect was 100%, seed germination of *R. crispus*, It has been reported that it inhibits root and shoot growth, *C. cyminum* and *M. longifolia* sourdough is 100%, while the three essential oils have a significant effect (100%) on the parameters examined against *C. arvensis* (Üstüner et al., 2018a). Some plants are very competitive in nature and can prevent some weeds. These plants can secrete some inhibitory compounds during an event called allelopathy. Thus, these plants act as bio-herbicides. Biological control of weeds in modern agriculture is provided by various bioherbicides used in many countries of the world (Singh et al., 2018). Isothiocyanates, which are secondary metabolites, occur under the enzyme effect in cabbage plants. The use of isothiocyanates was effective in the fight against some important weeds in tomato production (Bangarwa et al., 2012).

VII.4. Integrated control

One method for controlling of weeds may ineffective., it is preferred to apply more than one method together for effective control. Integrated pest management is promoted by FAO as a preferred strategy for pest control worldwide (Singh et al., 2018). Integrated weed management has three main objectives. Weed density should be reduced to tolerable levels, the amount of damage caused by a particular weed density to an associated crop should be reduced, and the composition of weed communities should be made less harmful (Liebman, 2001).

VIII. Results and Discussion

The ease of use of herbicides in agricultural production provides important advantages such as the rapid acquisition of results and the control of some weed species that are difficult to control by other methods. Despite these advantages of herbicides, widespread and improper use is known to cause serious consequences for the structure, environmental pollution, and the entire biological system, often threatening human health. Unless the rapid increase in herbicide consumption is reduced, serious losses are expected to occur in the short and long term. For these reasons, it has become important to investigate alternative and friendly, more reliable methods with the environment and humans of combating weeds. Of course, the use of herbicides may not disappear completely, but keeping the chemical method first in the fight against weeds in agricultural production can lead to enormous environmental damage. It is possible to expand solarization and plastic polyethylene methods. Some of the biological control methods can last for a long time and hence the effect is delayed and considering that the applicability as a region is not very common, farmers do not seek such alternative methods of struggle. The fact that herbicide use gives results in a short time attracts farmers. It is likely to become widespread due to the fact that essential oils obtained by making use of the allelopathic properties of plants are an effective and short-term method with the practical use in the agricultural sector. It is very important to increase and support scientific researches for bioherbicide production. Herbicide use can be reduced by using more than one alternative method in the integrated weed management program. Therefore, farmers should be convinced and their awareness about the negative effects of herbicides should be increased. For these reasons, separate studies should be conducted on integrated weed management for weeds related to each crop. In addition, integrated weed management must be formulated and presented so that it can be used by farmers.

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