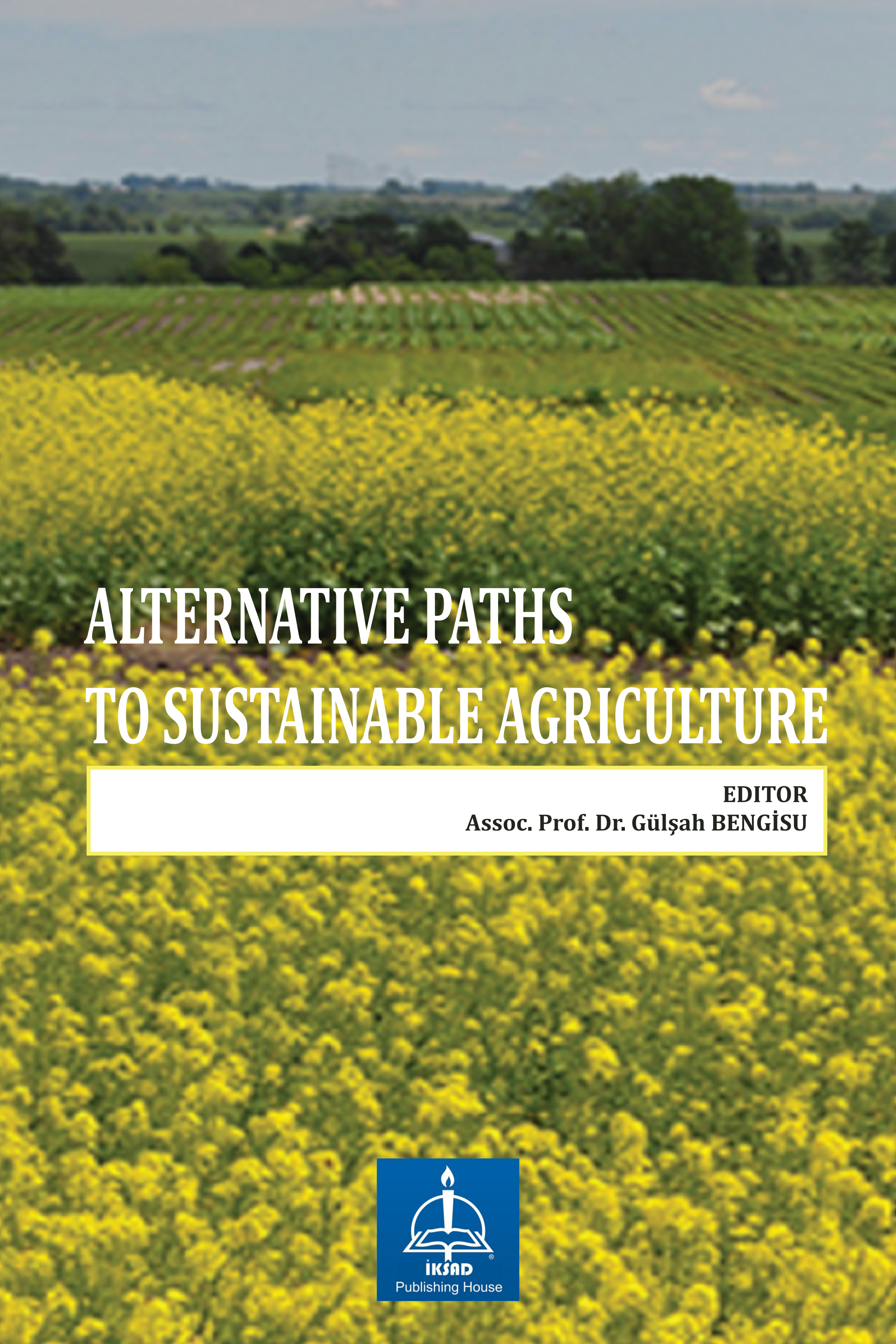

ALTERNATIVE PATHS TO SUSTAINABLE AGRICULTURE

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(The Licence Number of Publicator: 2014/31220)
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E mail: iksadyayinevi@gmail.com
www.iksadyayinevi.com

ISBN: 978-625-8405-81-1
Cover Design: İbrahim KAYA
March / 2022
Ankara / Turkey
Size = 16x24 cm

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PREFACE

Agricultural ecosystems have a variety of properties and strategies towards agricultural intensification differ. For a sustainable intensification, agricultural yields increase without negative environmental results and without additional land after application of a process. Some of alternative pathway for sustainable intensification of agriculture are breeding insect resistant crops to increase crop health, utilising agro-ecological approaches to pest management, mixing plant species in cropping and livestock farming systems, benefiting from functions of secondary metabolites, reducing contamination of food and fodder and using physiological and behavioral response dynamics to pheromones, which all are valuable solutions. Solution fitting to smallholder farmers, diversifed types of livestock, integrated pest management techniques and precision agriculture (to fit future smart applications) are more eligible. Here in this chapter, reader may find some of these approaches from different sub-categories.

Assoc. Prof. Dr. Gülşah BENGİSU

CHAPTER 1

THE PLANT OF THE OLD AND NEW WORLD's SORGHUM and ITS USE IN ANIMAL NUTRITION

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1. INTRODUCTION

The history of the *S. bicolor* plant dates back to ancient times. Sorghum, which is an animal feed and human food, is among the five important grains of the world. Sorghum was cultivated in Africa 3000 years ago, it is still a widely consumed food source in Africa, Asia and Latin America (Dial, 2012; CGIAR, 2016). Today, sorghum; It is spread all over the world and is grown on an area of approximately 45 million hectares (Anonymous, 2016).

Sorghum in general; While almost all of them are fed to farm animal in the America and European countries, it is the main cereal feed consumed by humans in a large part of Asia and Africa (Fageria et al., 1997). Then again, sorghum is cheaper than maize, whose grains are used extensively as a unprocessed material in the nutriment manufacture and as energy feed in poultry nutrition. With this; Being more tolerant of drought and heat stress, diseases and pests than corn plants is seen as an advantageous situation in sorghum cultivation (Fageria et al., 1997; Amzallag and Seligmann, 2000; Getachew et al., 2016). Consequently, the use of sorghum in forage crop agriculture, especially in silage production is increasing day by day (Açıkgöz et al., 2003). Worldwide, sorghum ranks fifth among cereals in terms of cultivation area and production amount, after barley, maize, rice and wheat (Fageria et al., 1997; Ayana and Bekele, 2000). Sorghum, which has the greatest development potential, is among the important cereals.

For centuries, sorghum has been the main food source in Africa and Asia. Sorghum, which has made itself accepted in America, has also become an indispensable product of the old continent, which is hungry for efficient and durable products. On the other hand, it requires very little water thanks to its CO_2 absorption mechanism, which provides a higher photosynthetic efficiency even in arid case and its dense and deep root system, which allows it to absorb and use the water and nutrients in the soil more effectively. In addition, since it can use the fertilizer in the soil effectively, it does not need fertilizer input, but it does not need plant health spraying because it is not exposed to diseases and pests much.

Sorghum; Argentina, Nigeria, India, America and Mexicoare the most significant manufacturecountries. In each of these countries, an average of 7-8 million tons of sorghum is produced annually. The amount of sorghum produced worldwide is between 55 and 60 million tons. Nigeria, India, Argentina and Ethiopia follow the USA and Mexico in world sorghum production. In 2013/14 season, Nigeria produced 6.5 million tons, India 5.2 million tons, Argentina 4.2 million tons and Ethiopia 4 million tons of sorghum production. (FAO, 2017).

Especially in last years, the use of sorghum seeds in the diet of celiac patients has started to gain importance, since they do not contain gluten. Although tannin-free varieties of the plant, which has been cultivated for about 3000 years, have been developed in recent years, it is predicted that varieties containing tannin can be used in food supplements for obesity control and healthy life in the coming period.

The white-colored varieties of the plant are mostly used as food, and in general. It is seen that the outer shells containing tannins and other secondary substances are separated by different methods and used for food purposes (Adeola, 2006). Sorghum is a feed raw material that has the potential to meet the increasing global food demand; Its resistance to heat and drought are its important features. For this reason, researches on sorghum are carried out.

The genetic diversity among sorghum subspecies is very high. Therefore, sorghum has become more durable to pests and pathogens. In addition, sorghum is an effective feed raw material in using water efficiently; it is a very effective feed in converting solar energy into chemical energy (Ogbaga Chukwuma et al., 2014). Due to all these superior qualities, sorghum has become a promising candidate feed raw material to meet this increasing demand as a result of the increase in global food demand. For this reason, many firm around the world are conducting research on sorghum. Sorghum also plays an active role as a biofuel. The stalk of sweet sorghum has a more sugar content that can be converted into ethanol. Therefore, sorghum biomass can be scalded and turned into syngas, bio-oil and coal.

2. Usage Areas of Sorghum

2.1. Use as Food

Since sorghum has very high energy, protein, vitamin and mineral values, it is very important for poor regions in the world. Sorghum can be grown in the semi-arid tropical regions of Asia and Africa, which are the poorest parts of the world, without the need to apply any fertilizer or other inputs in areas where other crops do not grow well. This is why sorghum has been one of the most important staple foods for poor rural people for centuries (Zohary and Hopf 2000).

According to the 2006 report of the United Nations National Sorghum Producers Association; Almost half of the world sorghum production is used as human food. According to FAO (2017) data, 95% of the total food supply in Africa and Asia is sorghum.In Africa, the Middle East, Asia and Central America, porridge, boiled, leavened-unleavened bread (tortilla), bakery products, cakes, couscous, noodles, snacks, sorghum flour, porridge, vinegar, molasses and local alcoholic beverages are made. However, sorghum seeds can be popped like corn seeds. But popping sorghum seeds are smaller than corn seeds. (Picture 1)

Picture 1. Popcorn on the left and popped sorghum seeds on the right.

It is made with sorghum injera flatbread in Ethiopia, and dosa in Sudan with a sorghum-grain mixture. In South American cuisine, sorghum syrup is used as a sweet condiment. In Arabic cuisine, unground sorghum is often cooked to make couscous, soups, porridge and cakes.In China, different food products (approximately 40 different products) are made from sorghum, which is among the first cultivated plants (Picture 2).

Picture 2. Boiled Chinese sorghum

Sorghum, which is genetically more similar to corn plant than wheat, rice and barley, is considered a safe food for celiac patients because it does not contain gluten (Ciacci et al., 2007). Since 2000, sorghum has been increasingly used in homemade and commercial breads, and particularly in cereals for a gluten-free diet.

2.2. Use as a Folk Medicine and for Medical Purposes

Although alcohol is produced from its seeds in China, the seed pods are cooked with brown sugar and a little water and applied to the chest of measles patients. The natives of Çuraçao (Venezuela) grind millet seeds with the seeds of *Crescentia* species in lung diseases; In Venezuela, they roasted the seeds and turned them into powder and used them in the treatment of diarrhea. In Brazil, seed decoction was used for bronchitis, cough, and other chest ailments, and its ash was used to treat goiter. In Brazil, Aruban Indians applied hot seed oil packets to the backs of patients suffering from pulmonary congestion. According to Grieve's Herbal (1931), the decoction prepared by boiling 50 g of seeds in one liter of water until half a liter is used in the treatment of kidney and urinary tract disorders (Duke, 1983).

2.3. Use in Making Alcoholic Beverages

Since the gluten content of sorghum is lower than other grains, it has been used in gluten-free beer production in recent years. While the African versions aren't "gluten-free," truly gluten-free beers are made that use substitutes like sorghum or buckwheat because malt extract is also used. In South Africa, sorghum is used to brew beer, including the local version of Guinness. Sorghum, which is widely used as a local brewer's yeast in Africa, is very important as a brewer's yeast, developed in Mexico and containing 100% amylopectin.

African sorghum beer is a beverage that tastes similar to milk and has a high protein content. However, African sorghum beer has a fruity sour taste and brownish-pink color. Alcohol content is also between 1% and 8%. Because this beer is unfiltered, its view is overcast and fermented and may also contain cereals particles. African sorghum beer made from sorghum also has lactic acid fermentation along with alcoholic fermentation (Haggblade and Holzapfel 1989). The sorghum grain used in brewing is a source of lactic acid bacteria due to its natural microflora. Therefore, in brewing, a tuft of crude sorghum or malted sorghum is mixed with must to initiate lactic acid fermentation. There are a lot of strains of lactic acid bacteria in African sorghum beer, but Lactobacillus spp. responsible (Van der Walt 1956).In addition, the world-famous "Maotai" and "Fen" liqueurs produced in China are also produced from sorghum grains (Ecoport, 2009).

2.4. Use in Animal Feeding

The stems and leaves of sorghum are used in silage making, straw and animal feeding in the form of green chopping. Sorghum grains are used in feed rations of poultry, meat and dairy cattle and pigs. (Kuzu and Bengisu, 2019).

Grain sorghum composition is similar to maize, but is particularly rich in starch; constitutes more than 70% of the dry matter. Therefore, grain sorghum is a good feed material for poultry, pigs and ruminant animals as an energy source. Although the crude protein content of sorghum grain varies under growing conditions, it is between 9 and 13% DM. When we compare it with the corn grain, it is seen that it is higher than the corn grain. Sorghum grain, like corn grain, has a low lysine content, so amino acid supplementation is necessary when used in animal nutrition. However, the oil content in sorghum grain is also slightly lower than in maize and does not contain xanthophylls. At the same time, 70% of the phosphorus in the sorghum grain is bound to phytate (Sauvant et all., 2004).

2.4.1. Use in the Feeding of Ruminants

Sorghum is generally preferred in the diet of ruminants, and sorghum is especially tasty and nutritious for cattle (Piccioni, 1965). There are kafir proteins in sorghum. These kafir proteins also make starch digestion difficult. Therefore, sorghum starch is less broken down in the rumen than wheat or barley starch. However, The low rumen starch degradability seems to be beneficial because the slow fermentation rate is less acidogenic in the rumen. In addition, low rumen degradability also results in excess starch being lost in the faeces, escaping from the rumen and reaching the intestine (Sauvant, 1997). For this reason, sorghum grain contains less energy than maize due to the shrinking of the total energy supply. (Laurent, 1988).

High-yielding cows need high levels of energy. For this reason, various methods have been applied to increase starch degradability (Offner et al., 2003). Studies have shown that the best way to increase energy level is steam exfoliation (Oliveira et al., 1993). Steam-sliced sorghum has 20% more net energy than dry sorghum. Furthermore, steam-sliced sorghum is much more beneficial as It not only improves milk yield, milk protein yield, urea cycle, microbial protein flow to the small intestine, but also plays a role in improving the consumption of amino acids (Santos et al., 1998; Theurer et al., 1999). In the researches; It has been observed that calves with sorghum grains have a high daily lıve weıght ıncrease intake; dairy cows with sorghum grain added to their feed should be given less milk protein in summer (Moss et al., 2000).

Silage is a type of roughage made to meet the nutritional needs of ruminant animals. Sorghum silage, which is one of the silages made using different plants, stands out with its high productivity and drought resistance when compared to corn silage.It shows low digestibility compared to corn silage.In a study conducted in sheep (Alves et al., 2012), the effect of adding sorghum silage with or without tannin on performance was investigated instead of corn silage. The researchers determined that there was no difference between the feeds given to the sheep in terms of feed efficiency, the carcass parameters were not affected by the silage type, and the tannin sorghum silage was effective.Behling et al., (2017) stated that sweet sorghum silages had higher in vitro dry matter digestibility. They reported that it is recommended for the feeding of ruminant animals, however, these varieties have greater potential if used in the second crop.

As an alternative to barley grain, it has been determined that the addition of grain sorghum to the rations of dairy cows does not cause any negative effects on the health of the cows (Lefter et al., 2019).Sorghum is a cyanogenic plant. When its level in feed exceeds 20 mg per 100 g (200 ppm, 200 mg/kg), liver enzymes are damaged and HCN begins to accumulate in the animal body. This can lead to the death of animals (Sinha et al., 2019).Dias et al.,(2020) stated that crude glycerol can be recommended instead of sorghum grain in the rations given to beef cattle.The use of sorghum silage instead of corn silage in the rations of lactating buffaloes increased the average milk yield, decreased the %linoleic acid level, and serum criteria were not affected (Tudisco et al., 2020).Lauriault et al., (2021) reported that sorghum feeds produced potentially toxic levels of hydrocyanic acid, with an additional mean body weight gain of 94.9 kg in pearl millet fed animals ($p < 0.001$).Sabertanha et al., (2021) showed that silages obtained from first and second form sorghum in sheep did not make a statistical difference on feed consumption of sheep.

2.4.2. Use in Feeding Pigs

The low tannin sorghum grain used in the feeding of pigs has the same energy level as the corn grain. However, the amino acid digestibility of low-tannin sorghum is slightly lower than that of maize (Sauvant et al., 2004). Studies have shown that high tannin sorghums have lower energy and protein digestibility than low tannin sorghums, especially in growing pigs (Cousins et al., 1981).As a result of the researches; it has been observed that sorghum with low tannin content, when properly substituted with soybean meal, vitamins and minerals, can be added to the ration of up to 60% in the feed of weaning pigs with a body weight of 9 to 25 kg and up to 75% in the feed of growing pigs (Jacquin, 1991).To increase the digestibility of the sorghum grain, it is necessary to reduce the particle size. Therefore, the sorghum grain is ground with a roller or hammer. When used in this way for feeding pigs, hammer milled sorghum (650 μm) was found to be better digestible than roll milled sorghum (1 mm) (Walker, 1999).Puntigam et al., (2021), in their study investigating the effects of fermenting whole grain sorghum with different DM levels, reported that pigs in the rearing period were most effective when using fermented whole grain sorghum with a DM level of 701 g/kg.

2.4.3. Use in Poultry Feeding

Sorghum is extremely important in broiler and layer nutrition in the many territory where it is found. Sorghum grain is very important in the nutrition of poultry and can be used as the main grain source. 70% grain sorghum can be used in the feeding of chickens (Jacquin, 1991). Compared to corn, low tannin sorghum emerges as a feed raw material with more metabolizable energy. (Sauvant et al., 2004) and can largely replace maize grain (Subramanian et al., 2000). use of sorghum shows slightly lower performance (Batonon et al., 2015). Although poultry prefer tannic varieties, they can be fed with high tannin sorghum provided that they are rearranged after 10 days of high humidity storage. Sorghum, which has a high moisture content, has a high protein content and metabolic energy value. However, low tannin sorghum has low digestibility (Daghir, 2008). Adding oil, methionine or grinding grain sorghum can also be beneficial to improve digestibility.

An increase in phytate content causes a low P content, which causes a decrease in growth performance and locomotive disorders. To prevent this, P supplementation or phytase should be added. Likewise, a low level of xanthophyll (10 times smaller than yellow corn) causes discoloration, and pigment supplementation is required to prevent this (Walker, 1999). The newly developed sorghums with higher protein digestibility, lower starch content and higher lysine content decreased chicken performance (Elkin, 2002).

The nutrient digestibility of sorghum depends on the variety, age, animal species, tannin concentration in the grain, low starch presence, and resistance to digestive enzymes. In general, sorghum is a very suitable feed crude material to replace corn in livestock and poultry feeds (Etuk et al., 2012).Mabelebele et al., (2018), in their study examining the effects of whole sorghum additive and feed form on the performance and nutrient digestibility of broiler chickens, found that there was a significant increase in feed consumption, live weight and carcass yield in chickens fed with pellet feed. Researchers reported that all sorghum additives did not affect feed consumption and live weight gain in broilers during the rearing period.Selle et al., (2018), in their study investigating the effects of using sorghum grain in chicken meat production in Australia, explained that sorghum is used in the nutrition of both poultry and other animals.Saleh et al., (2019), in their study investigating the effects of using low tannin sorghum instead of corn in broiler compound feeds, determined that using low tannin sorghum (50%) improved performance, improved antioxidant status, and induced plasma oils.

2.4.4. Usage of Rabbits in Feeding

Sorghum is widely used as a sole grain in commercial rabbit feeds or experimental control diets in Mexico. Sorghum grain is used by farmers in different countries such as Uganda, Ghana and Rwanda to feed their backyard rabbits. Typically up to 20% to 40% of the compound feed is added, but up to 50% is added to the feed without any problems on growing rabbits. In some studies, it has been stated that up to 75% of compound feeds are included (Gongnet et al., 1993).Malted sorghum grains were used instead of raw sorghum or maize grain to feed growing rabbits, but malting did not confer any technical or economic advantages (Aderemi et al., 2010). High moisture sorghum grain silage with low or high tannin content can be used in the feeding of developing rabbits. However, the digestible energy of low tannin sorghum is slightly higher (17.9 vs. 17.2 MJ/kg DM) (Furlan et al., 2004).Mohammed et al., (2017), in their study investigating the effects of different sorghum cultivars on the performance of rabbits in the rearing period, reported that two sorghum cultivars, Chakalare and Jigare, could be substituted for corn without any adverse effects on the rearing rabbits.Researching the effects of using some feed ingredients in rabbit feeds, Atchadé et al., (2020) emphasized the necessity of white and yellow corn and white and red sorghum for a balanced diet of rabbits.

2.4.5. Use in Fish Feeding

Like other grains, sorghum is frequently used in a water feed formulation and can be included in fish diets up to 50%, although less palatable than maize (Hasan et al., 2007). Because the feed made using sorghum grain is darker and denser, the pellets cannot bind as well as corn.Researching the effects of sorghum and phytase additives instead of corn in fish feeds, Rodrigues et al., (2020), reported that sorghum additive could be an alternative; stated that phytase additive increased fish performance.

2.5. Use as Biofuel

Two-color Sorghum, one of the sorghum varieties, is an important world grain used in the production of food (sorghum syrup or sorghum molasses), feed, alcoholic beverages, as well as biofuels. Studies have shown that sorghum sap-based ethanol has four times the energy efficiency of corn-based ethanol, but on par with sugarcane (FAO, 1995).Grain Sorghum was first used as animal feed in Australia, South America and the United States. In recent years, it has been used especially to produce biofuels by juicing sweet sorghum stalks and then fermenting them in ethanol. For this reason, Texas A&M University in the United States is conducting research on developing new sorghum varieties to produce ethanol.Due to the need for renewable fuel sources, saccharin is widely used in sorghum ethanol production. In a study on this subject, the effect on the digestive behavior and performance of fattening lambs fed with saccharin sorghum and corn silages was investigated (Vargas Junior et al., 2020). The researchers found the dry matter of sorghum silage, saccharine sorghum silage and corn silage 33.9; 35.06%, respectively; 34.60; crude protein levels of 13.15%; 12.82; 13.77; organic matter content is also 937.3; They found 946.7;947.3 g/kg DM.

2.6. Other Area of Usage

Sorghum is also available in new and expanding markets; It is used in the construction of building materials, fences, flower arrangements, pet food, brooms. Sorghum's versatility gives it the flexibility to go beyond traditional markets and increase the profitability of producers. Sorghum straw (root fibers) can also be used to make biodegradable packaging and as an excellent wall covering for home building. However, since it does not accumulate static electricity, it is also used in packaging materials of sensitive electronic equipment. In addition, the recovered stems of the sorghum plant are used to make a decorative milling material marketed as Kirei board (Holzwart, 2010).Starch and protein are obtained from the endosperm part of the sorghum plant, and fixed oil is obtained from the embryo part. The part of the seed, which is called bran, excluding the endosperm and embryo part, is rich in secondary substances and has come to the fore in the production of food supplements and food dyes in recent years. (Awika and Rooney, 2004).

3. Sorghum Chemıcal Composıtıon And Energy Value

About 70% of sorghum is starch, so sorghum is an energy-rich feed raw material. Sorghum starch consists of 2 parts. The first of these is amylopectin, which is a branched chain polymer of glucose, containing 70% to 80%; the second consists of 20 to 30% amylose, a straight chain polymer. Unprocessed sorghum starch has low digestibility. For this reason, different methods are applied to increase the digestibility of sorghum starch; Among these, processing with methods such as flaking, pressure cooking, puffing, steam cooking or micronization of starch has an important place. Also, sorghum starch does not include gluten. This makes it an important grain for those sensitive to gluten (Fenster, 2012).

The main components of sorghum are starches and proteins, respectively. The important amino acid content of sorghum protein varies according to soil, variety and growing conditions (Leder, 2004). However, some studies show that the prolamin fraction of sorghum is quite insufficient in terms of arginine, lysine, tryptophan and histidine amino acids; showed that they have high levels of glutamic acid, proline and leucine amino acids. The digestibility of sorghum protein also varied between 30% and 70% between different sorghum varieties. Also, Sorghum is a good feed ingredient as a source of B-complex vitamins. Some sorghum varieties contain β-carotene, which can be turned into to vitamin A by the human body.

The absence of tannin in sorghum varieties developed in recent years has increased their use as animal feed. As can be seen in Table 1, the starch and oil contents of sorghum, which are the main energy sources, are the same as the corn plant, but the protein content is slightly higher. Sorghum also has a low fiber content. However, the profile of sorghum's amino acids is slightly different from that of corn (less lysine and sulfur-containing amino acids, more threonine, and twice as much tryptophan).

Table 1. Thiamine, riboflavin and niacin concentrations of sorghum and maize

Compound (g/kg) MS	Sorghum	Maize
Starch*	747	747
Protein*	109	90
Oil*	42	42
Wall*	98	105
Total sugar**	13	19

Calcium**	0.4	0.5
Phosphorus**	3.2	3.0
Lysine**	2.5	2.8
Threonine**	3.6	3.5
Met+Cys**	3.8	4.3
Tryptophan	1.2	0.6

*Source: qualit@lim my sorghum; Arvalis Research – Institute for Plant Research – France Agrimer; **INRA table.

Sorghum is a feed raw material that is perfectly compatible with animal feed compound feeds. In this, sorghum's energy value, nutrient composition, richness in protein and low in mycotoxins play an active role. It has a very high energy value especially for poultry.

Etuk et al., (2012) stated that the nutrient content of sorghum differs according to countries. Dry matter of sorghum is 88.94-93.31%; 8.9-14.89% of crude protein level; 2.50-3.70% of crude oil; reported that the organic matter level was 93.06%.

In a study investigating the effects of different sorghum varieties on their ensiling properties and nutrient content, the nutrient content of sorghum silages was investigated. In the study, crude protein ratios of sorghum silages were found to be between 6.7-10.70%; NDF contents of 47.82-61.06%, ADF contents of 30.51-44.04%, lactic acid content of 19.00-44.38 g/kg/DM, butyric acid content varied between 2.14-4.48 g/kg DM (Kaplan, 2013).In a study investigating the nutrient content and digestible dry matter yields of some sorghum cultivars (Akdeniz et al., 2003), it was determined that the nutrient content of grain sorghum cultivars differed between cultivars. The dry matter of grain sorghum cultivars was 26.64-35.36%; crude protein varies between 4.59 and

5.85%; The digestible dry matter yield was found to be 251-484 kg/da.Öten and Çınar (2018), who stated that the nutrient contents of grain sorghum and sorghum silage varieties differ from each other, reported that the crude protein contents of different sorghum varieties vary between 10.51-14.12%.

CONCLUSION

Sorghum, which has many uses, is grown in very large areas, especially in poor regions of the world. Sorghum is highly preferred because it is drought resistant, not selective in terms of growing conditions and does not need high input.Sorghum, which is used in both human nutrition and animal nutrition, has become an important human food, especially in recent years, because its grain does not contain gluten. It is also an important energy plant. These features of sorghum show that it will be the indispensable plant of the future.

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CHAPTER 2

DETERMINATION OF PRODUCER BEHAVIORS RELATED TO FORAGE CROP CULTIVATION IN BOZOVA-SANLIURFA-TURKEY

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Introduction

This study was carried out to determine the farmers' approaches to the forage crops production in the villages of Akmagara, Arpali, Catak, Golbasi, Eskin, Incirli and Kizlar in the Bozova subprovince of Şanlıurfa province (Turkey). Survey questions were prepared for this purpose, a survey was conducted with 50 producers from randomly selected seven villages and then the results were evaluated. The roughage needed in animal production in the Southeastern Anatolia Region is generally supplied from three main sources by farmers: 1) natural meadow-pastures, 2) forage crops, 3) crop residues. Livestock production in the region is largely depend on pastures, and concentrate feeds mixed with crop residues (cereal straws and stubbles). Animal product yields are low in the region. Grazing periods in the rangelands extend up to 240-270 days, and this unconscious and intense grazing decrease the quality forage plant species in the pastures. The damages caused by foraging and walking herds temporarily coming to the region from other regions is also at a damaging level. The pastures of Southeastern Anatolia Region are representing the weakest vegetation pastures in Turkey due to hot climate, stony soils and bedrocks covering large areas. There is 0,8 ha of pasture area for 1 cattle in the region. However, considering the yield and composition of the rangelands in the region, this figure should be 4 ha. Alfalfa (*Medicago sativa* L.) is the most cultivated perennial forage species worldwide (Benabderrahim et al., 2020). High-quality perennial leguminous crop Alfalfa (*Medicago sativa* L.) has a long history of cultivation (Rovkina et al., 2018). It attracts great interest especially due to its role in milk production schemes (dos Santos et al., 2020). *Vicia sativa* subsp. s*ativa* (common vetch) is a self-pollinating annual legumes with short growth period, good nutritional value (Liu et al., 2014). Integrating protein rich forages into livestock feding systems is required for sustainable farming. Generally, winter period is the most difficult period for the production of forage protein to replace purchased feeds (Marley et al., 2016). Vetch is an important forage due to its multiple usages as hay, grain, silage, and green manure (Chung et al., 2013). Some forage crops (alfalfa, sainfoin, vetch, bitter vetch, silage maize) acreage, production amount and yield values for Turkey, Sanliurfa and Bozova in 2019 are given in Table 1.

Table 1. Alfalfa, sainfoin, vetch, bitter vetch, silage maize cultivation area, production amount and yield values of Turkey, Şanlıurfa and Bozova in 2019 (TUIK, 2022)

Forage Crop	**Turkey**	**Sanliurfa Province**	**Bozova Subprovince (Şanlıurfa)**
Bitter vetch, Green herbage (ha)	2.561	15	-
Alfalfa, Green herbage (ha)	641.212	4.803	35
Sainfoin, Green herbage (ha)	175.276	-	-
Maize, Silage (ha)	500.750	22.892	800
Bitter vetch, Green herbage (ton)	14.855	12	-
Alfalfa, Green herbage (ton)	17.949.264	71.534	788
Sainfoin, Green herbage (ton)	1.781.789	-	-
Maize, Silage (ton)	25.499.870	1.085.459	38.500
Bitter vetch, Green herbage (t/ha)	5,8	0,8	
Alfalfa, Green herbage (t/ha)	28,1	14,8	22,5
Sainfoin, Green herbage (t/ha)	10,3	-	-
Maize, Silage (t/ha)	50,9	47,4	48,1

To improve the yield and quality of livestock production in the region and to alleviate the pressure on the pastures and increase their yield and quality, it is needed to increase forage crops cultivation frequency in field crop rotations.

1. Materials and Method

A survey was conducted in 2021 with 50 farmer selected from the Bozova subprovince of Sanliurfa (Turkey). Main purpose of the survey was to determine the perspectives of farmers on forage crops cultivation and their thoughts on governmental agricultural policies related to forage crops. Likert type questions were used. This is an attitude scale developed by Likert. The generally used scale is triple and in this study, triple scale was used. Here, there is a spectrum ranging from "agree" to "disagree". Factor sentences were univocal and definite.

2. Results and discussion

- 40% of farmers were growing their own livestock, instead 60% were buying & selling livestock. Farmers growing their own livestock stated that alfalfa increase milk and meat yields significant.
- The resistance of forage crops against diseases according to the farmers was as strong (60%), moderate (26%) and weak (14%). Farmers reported that some forage crop species and varieties are sensitive to diseases. Planting time also affects the resistance of forage crops to diseases.

– 76% of the farmers reported that they locate in a suitable region for forage crop cultivation, whereas, 24% were at opposite opinion. Extension activities are needed in region to improve farmers' cultivation capacity under biotic and abiotic stress conditions.
– For the drought resistance of forage crops, 6% of the farmers gave the answer as resistant, 34% as medium resistant and 60% as weak. Some forage crops, such as alfalfa, have higher water requirement. Especially in summer, the most important factor affecting the growth of alfalfa is water. Since the summers are dry and hot in the Southeastern Anatolia Region, the importance of water is high.
– Farmers said that their fertilizer requirement was at high amount (8% of farmers), medium amount (56% of farmers) or low amount (36% of farmers). While the fertilizer requirement of legume species alfalfa is very low, requirement of maize is quite high.
– "Do you get your money's worth?" question is replied by 46% of the farmers with “yes”, 14% with “no”, 40% “partially” answers. It was determined that the farmers who say "I can't get paid for my labor" have deficiencies and/or mistakes in their farming methods, equipment usage, and seed variety.
– Sprinkler system (46% of the farmers), mini spring irrigation (38% of the farmers) and drip irrigation (16% of the farmers) were the prefered irrigation systems. Farmers select irrigation method according to the forage plant species.

- Farmers stated the costs as high (22% of the farmers), medium (38% of the farmers) or low (40% of the farmers). Species of the cropped forages were the main effector on the costs. Alfalfa was the lowest costing forage crop species according to farmers due to high yields with multiple harvest-irrigation (average 5 harvest per year) applications during 7-8 years.
- Farmers were growng alfalfa (54% of the farmers), vetch (24% of the farmers) or maize for silage (22% of the farmers). Although cultivation of alfalfa is arduous, the farmers reported that they were satisfied with the alfalfa due to less fertilizer requirement, resistance to diseases, and marketing advantage of this crop.
- “Are you satisfied of cropping forage species?” question was replied by farmers as “yes” (50% of farmers), “no” (14% of farmers) or “some” (36% of farmers). Inadequacy of governmental supports; low productivity; and frequently increased fertilizer, medicine and fuel prices were the complaints.
- Most of the farmers (72%) informed that they were engaging in animal husbandry. Other farmers (28%) were not engaging in animal husbandry due to time, personnel or pasture inadequency.
- Governmental support recieving farmers ratio was %74 of all subject farmers. Rest of them (%26) were not recieving any governmental support.
- 84% of the farmers were married and 16% were single.
- 54% of the farmers were primary school graduates, 34% were secondary school graduates, and 12% were high school graduates.

- 66% of the farmers informed that they have a regular income, whereas 34% informed that they do not have a regular income.
- 54% of the farmers were satisfied, 26% were partially satisfied, and 20% were not satisfied with forage crop production. Irregular yields and prices in some years, partial engagement in livestock bussiness or owning very small enterprices were the reasons for dissatisfaction.

3. Conclusions

Improving the level of agronomic techniques in forage crop cultivation may positively affect the yields. The low governmental subsidies were an important factor for the growers to give up production. Frequent hikes in input prices were a problem. With the use of new models and more modern agricultural machinery, productivity increases and production processes become easier. It was observed that young people were fleeing from agriculture, and incentives targeting young people should be implemented. Seminars should be organized for forage crop growers to meet their technical knowledge requirements.

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CHAPTER 3

IN VITRO STUDIES ON LESS STUDIED SPECIES OF *ASPARAGACEAE:* A REVIEW

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INTRODUCTION

Asparagus and Agave are the most studied genus of Asparagaceae family. The genus Asparagus and Agave comprises approximately 200 and 166 species, respectively. Apart from these two, Asparagaceae family contain 112 more genus.

Total 114 genera of Asparagaceae were scanned to determine in vitro tissue culture studies published in English in the post-2010 period on less studied species of Asparagaceae. Studies on 28 different Asparagaceae species are summerised here below.

Plants species of family *Asparagaceae* contain many compounds like phenolics, steroids, tannins, triterpenes, alkaloids, glycosides, saponosides, 5-hydroxymethyl-2-furaldehyde, diosgenin, serine, lysine, aspartic acid, threonine and many others. They are also sources of food, fodder, oils, drinks, cosmetics, fibres, drugs etc. Due to increasing awareness about the valuable products obtained from them, they are depleting at an alarming rate, leading to their unscientific harvesting, overexploitation and increasing anthropogenic pressures like deforestation, excessive grazing, expanding urbanization, habitat loss, encroachment and bioprospecting for new sources (Qadir et al., 2017).

Total 114 genera of *Asparagaceae* were scanned for in vitro tissue culture studies in English published in the post-2010 period on less studied species and summerised.

1. *Beaucarnea purpusii* Rose

This endemic and endangered plant's in vitro regeneration from longitudinal sections of seedlings were studies by del Carmen Vadillo-Pro et al., (2016). Effects of 3 cytokinins: N6-benzyladenine (BA), kinetin, and thidiazuron, 1-phenyl-3-(1,2,3-thiadiazol-5-yl)urea (TDZ), in semisolid media and 3 different concentrations, and the effects of BA and TDZ pulses at higher concentrations in liquid culture medium, were investigated. Adventitious shoot formation by direct organogenesis was observed from all treatments.

2. *Danae racemosa* L. Moench

This ornamental plant's in vitro propagation was studied by Shen et al., (2013). An in vitro propagation protocol was developed using seeds as material for culture initiation. Shoot multiplication occurred on MS medium +/- BAP with 100% multiplication percentage. However, shoot number was significantly increased from an average of 2.8 to more than six with the addition of 5 or 25 μM BAP.

3. *Barnardia japonica* (Thunb.) Schult. et Schult. fil.

The plant was studied for micropropagation by in vitro direct regeneration in the study of Pianova et al., (2021). Highest number of new plants (average 61 new shoots) was formed when explants are cultivated on high concentration of kinetin (10 mg/L) medium with minimum α-naphthylacetic acid (0.1 mg/L).

4. *Tupistra albiflora* K. Larsen

Palee, (2020) evaluated a protocol for micropropagation of this species for multiple shoot and root induction. It was found that the MS medium containing 3 mg/L BA induced 100% shoot formation with the highest number of 3.2 shoots per explant. For root induction, in vitro shoots were cultured on MS agar medium supplemented with 0, 1, 2, 3 and 4 mg/L NAA for 8 weeks.

5. *Lachenalia viridiflora* W. F. Barker

Micropropagation via organogenesis of this native endangered plant of South Africa, was studied by Maslanka et al., (2022). Bulbing was significantly more efficient on media with 3% sucrose. This process was tightly related to explant type.

Fig. 1. Morphological variation in *Lachenalia* (Kleynhans et al., 2012).

6. *Liriope platyphylla*

A rapid protocol for efficient shoot organogenesis and plant regeneration from meristem cultures of this species was developed by Park et al., (2011). Combined application of zeatin and auxins was found vital for shoot organogenesis of the species.

In vitro rapid propagation of this species was developed via their study by Wang et al., (2010). The optimum explant type inducing buds were upper rhizome and middle rhizome. Optimum medium for rhizome culture was MS + 2.0 mg 6-benzyladenine/litre + 0.5 mg NAA/L.

7. *Hosta* spp.

Choi et al., (2019 aimed in their study to establish an in vitro propagation system by shoot tip culture of six *Hosta* species native to Korea: 1) *Hosta clausa* Nakai, 2) *Hosta capitata* (Koidz.) Nakai, 3) *Hosta minor* (Baker) Nakai, 4) *Hosta jonesii* M.G.Chung, 5) *Hosta yingeri* S.B.Jones, 6) *Hosta venusta* F.Maek., for mass proliferation and new variety development. Highest number of differentiated shoots were obtained by medium supplemented with 0.5 mg/L TDZ in *H. yingeri* (9.8 pieces); 0.5 mg/L BA in *H. minor* (11.1 pieces); 2.0 mg/L TDZ for *H. capitata* (5.4 pieces); 1.0 mg/L BA and 0.1 mg/L TDZ in *H. venusta* (8.1 pieces); 1.0 mg/L TDZ for *H. clausa* and *H. jonesii* (3.3 pieces and 5.8 pieces, respectively).

8. *Ornithogalum spp.*

Objective of the study of Joung et al., (2020) was to investigate the optimum plant growth regulators concentration for explants cultured in vitro to produce inflorescences direct from in vitro propagules in a year. Optimum concentration based on flowering date and rate, and scape length and width were considered 1.35–2.7 μM NAA and 4.4–6.6 μM BA.

Huan et al., (2014) studied the polyploid development ınduction of *Ornithogalum thyrsoides* by pendimethalin and colchicine in vitro. Tetraploid *Ornithogalum thyrsoides* was induced by both mutagens.

Tun et al., (2013) used plant activator benzothiadiazole to promote *Ornithogalum dubium* and *Ornithogalum thyrsoides* in vitro differentiation and regeneration. Benzothiadiazole enhanced the morphogenesis rates in *Ornithogalum* cultures by triggering a plant regulator-like activity.

9. *Dasylirion cedrosanum*

This plant's in vitro multiplication and rooting was conducted on vermicompost extract basal medium in a study of Ramirez-Gottfried et al., (2021). They determined that, vermicompost extract based medium at 10 mL L-1 concentration may be used to replace MS medium completely in the rooting stage of *D. cedrosanum*.

10. *Drimiopsis kirkii*

This ornamental bulbaceous plant was used for plant regeneration through indirect somatic embryogenesis pathway via callus developed from leaf explant in the study of Haque & Ghosh, (2014). Optimum friable calli were induced on MS basal medium supplemented with 3.0 mg/l of 2,4-dichlorophenoxyacetic acid and 1.0 mg/l of NAA.

11. *Ledebouria ovatifolia*

In vitro propagation and ultrastructural studies of somatic embryogenesis on this species was studied by (Baskaran et al., 2016). Highest numbers of somatic embryos from friable, embryogenic callus were obtained by liquid medium with 15 g L^{-1} sucrose, 10 µM glutamine, 0.1 µM picloram, and 0.2 µM thidiazuron.

12. *Bellevalia tauri*

Nasircilar et al., (2017) aimed to increase the number of bulblets by in vitro produced primary bulblets as an explant source. The best result was obtained by MS medium containing 1 mg l-1 NAA and 0.25 mg l-1 BAP. Total 2.83 bulblets per explant were produced by this medium.

13. *Hyacinthella micrantha* (Boiss.) Chouard

Bulut et al., (2019) targeted to improve a standard in vitro multiplication protocol using basal scales for bulblet production of this species. The highest ratio of bulb scales forming shoot/bulblets per explant (87%) and bulblets per explants (5.60) were induced on a Orchimax media supplemented with 8 mg/L Zeatin.

14. *Eucomis zambesiaca* baker

Factors affecting in vitro bulblet induction of this species was analysed by Cheesman et al., (2010). Optimum treatment for bulblet induction was found 4.90 µM IBA, with an average bulb diameter of 4.4 mm and a mean bulblet mass of 79.1 mg.

15. *Merwilla plumbea* (Lindl.) Speta

Physiological and biochemical responses of this plant under in vitro culture with different cytokinin applications was studied by Moyo et al., (2017). The study provided significant insights on the residual effect of exogenous cytokinins on the regulation of auxin homeostasis and phenolic acid and flavonoid metabolism in one year old *Merwilla plumbea* plants growing under ex-vitro conditions.

16. *Scilla autumnalis*

In vitro propagation of this plant was studied by Banciu et al., (2010). Results indicated that this plant species can be multiplicated, rooted and acclimatized on MS supplemented with NAA, IBA, IAA, kinetin and BAP with a good efficiency.

17. *Scilla hyacinthina*

A suitable plant regeneration protocol was developed from leaf and bulb explants of this species by Kamaleswari et al., (2016). Maximum number of shoots was obtained by medium containing 1.5 mg/l TDZ. Rooting of shoots was achieved on half-strength MS medium supplemented with 1.5 mg/1 IAA.

18. *Scilla scilloides*

To establish in vitro rapid propagation system for this species, effects of different explants and plant growth regulators on in vitro plant regeneration of this species were investigated through tissue culture methods using seedlings obtained from sterile germination as material.

The results showed that hypocotyls was the best explants. Best medium for adventitious buds was 1/2MS+TDZ 0.3 mg/L+6-BA 3.0 mg/L.

19. *Ruscus aculeatus* L.

In vitro plant regeneration and multiplication of this species was studied by Banciu & Aiftimie-Paunescu, (2012). Results showed that this plant species can be multiplicated, rooted and acclimatized on MS supplemented with NAA, IBA, kinetin and BAP with a good efficiency.

20. *Ruscus hypoglossum* L.

Callus cultures of this species were induced on TDZ containing medium by Ivanova et al., (2013) and indirect shoot regeneration rate was evaluated on different medium compositions. TDZ ensured higher regeneration rates, caused shoot, and cladode alterations in regenerates persisting throughout the cultivation. Callus induction was optimal at 30 g.l–1 sucrose and reduced with increase of sucrose concentration. Increase of the sucrose (15–60 g.l–1) influenced shoot proliferation positively.

Fig. 2. Flowers of *Hyacinthus orientalis* (Bintaş et al., 2021).

21. *Hyacinthus orientalis* L.

The influence of explants type and growth regulators on in vitro callus induction and bulblet formation of this species was studied by Gheisari & Miri, (2017). Combination of 1 mg L-1 BAP and 1 mg L-1 Kin from scale and 2 mg L-1 BAP and 1 mg L-1 Kin in both explants were the best for callus fresh weight for “Pink Pearl” and “Blue Jacket” varieties, respectively.

22. *Polygonatum verticillatum* (L.) All.

An optimum micropropagation method of this species was developed by using stem disc explants in the study of Bisht et al., (2012). Multiple shoots were initiated from stem disc explants on MS medium added different concentrations (0.25–10.0 mgl−1) and combinations of cytokinins (TDZ, BAP and Kn) along with (0.5–1.0 mgl−1) auxins (NAA/IAA/IBA). 1.0 mgl−1 BAP with 0.5 mgl−1 NAA was the most effective to produce maximum shoot number.

23. *Dracaena sanderiana* Sander ex Mast

An in vitro protocol was developed for plant regeneration from nodal explants of *this species*. Highest frequency of shoot regeneration (85%) and number of shoots per explant were obtained on medium supplemented with 7.84 μM N6-benzylaminopurine. Rooting was high on MS solid compared to liquid medium when added with 7.38 μM indole-3-butyric acid.

24. *Yucca elephantipes* Regel.

The influence of BA (0.4, 2.2, 4.4, 11.1, 22.2 μM) and TDZ (0.5, 2.3, 4.5, 11.4, 22.7 μM) on shoot multiplication of this species on MS medium was studied by Kozak, (2010). Highest shoot formation was obtained from nodes on MS medium supplemented with 4.5 μM TDZ or 11.1 and 22.2 μM BA (6.5, 6.0, 5.8, respectively). The growth regulator-free medium and the media with a low level of BA were the most effective in inducing roots.

25. *Polianthes tuberosa*

A plant regeneration method was developed for *this* species by Naz et al., (2012). Optimal concentration of BAP for inducing shoot formation was 3.0 mg/L. Rooting frequency was highest in MS medium with 1 mg/L NAA.

Singh et al., (2020) established a study on in vitro methods like shoot tip culture and callus mediated regeneration of tubers obtained from nematode infection fields to produce totally nematode free plantlets. Tubers of different varieties produced multiple shoot bud on MS media including 4 mg L−1 BAP and 0.1 mg L−1 NAA. Maximum callus induction was obtained on MS containing 1 mg L−1 2,4-D, 1 mg L−1 NAA and 0.5 mg L−1 BAP and 1 mg L−1 2,4-D and 2.25 mg L−1 BAP.

26. *Chlorophytum borivilianum* Sant. et Fernand

The effect of plant growth regulators, gelling agents and sucrose on shoot multiplication, shoot growth and rooting of this plant was determined. BA was found better cytokinin over kinetin for shoot multiplication. Sucrose concentrations from 116–290 mM in the basal medium promoted shoot multiplication. Phytagel as a gelling agent was found more effective for shoot proliferation and growth compared to agar (Kumar et al., 2010).

27. *Chlorophytum nepalense* (Lindl) Baker

Sautrik & Jha (2011) detailed a big scale micropropagation protocol for this Himalayan endemic medicinal herb. Multiple shoots were obtained from shoot crown explants on Gamborg's B5 medium supplied with different concentrations and types of cytokinins in combination +/- IBA and NAA. B5 basal medium supplemented with BA and IBA produced maximum number of shoots after eight weeks of culture.

28. *Sansevieria trifasciata* var. Laurentii (Prain)

An efficient protocol was developed by Kaur & Mudgal, (2021) for rapid propagation of this plant under in vitro conditions. Leaf segments sized 1 cm were surface sterilized and inoculated on Murashige and Skoog media supplemented with 3% sucrose, 0.8% agar, and diversified concentrations of IBA (1 to 10 mg/L). Multiple shoots were produced at higher IBA concentrations.

29. CONCLUSİONS

Regeneration, propagation, micropropagation, organogenesis, indirect somatic embryogenesis, shoot tip culture, adventitious shoot formation, shoot multiplication, root induction, bulbing, meristem cultures, polyploid development, embryogenic callus formation, rhizome formation protocols, rapid protocols, different plant growth regülatör mixtures/concentrations, morphogenesis rates, different growth mediums were studied in mostly in endangered native species of Asparagaceae family.

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CHAPTER 4

SUSTAINABLE AGRICULTURE: AN OVERVIEW OF CONCEPTS AND HIGHLIGHTS

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INTRODUCTION

Human has used the natural resources of the world for its vital needs from the first day of its existence until today. The resources that were used for food, shelter and protection in the past have started to be used as if they were unlimited in activities such as agriculture, industry and energy, which are increasing and changing day by day. Especially in the last century, the problem of using natural resources has emerged with the increase of the world population increasingly and amount of production activities after the industrial revolution. Sustainable agriculture is of great importance to provide the needs of human over the world and to leave a better livable world to future generations.

Nutritional material, which is necessary for human life, can be obtained as a result of agricultural activities in the past and today. Soil is one of the most important resources used in the production of these nutrients. Soil is an important but limited resource for human life, which can occur in a very long time, but can deteriorate as a result of misuse, and after deteriorating it takes a very long time to restore or recover. Almost 13 billion ha of world are consisted from land, 37% of this (5 billion ha) land is agricultural areas. When we look at the distribution of this agricultural area according to the way of use; Field crops are grown about 1.5 billion ha, perennial plants are on 1.5 billion ha, and the rest 2 billion ha are covered by pastures and meadows (TÖİR, 2014; Akci et al., 2016).

With the rapid increase in population, developments in technology and diversification of economic activities, natural land cover has been used by people continuously. This situation can cause the fast consuming of natural resources and negatively affect the environment to an irreversible extent. Due to the decreasing natural resources and their misuse, it has become impossible to benefit from the lands. Therefore, the idea of realizing sustainable use has gained importance in order to protect potential lands. Land utilization studies are carried out in almost every single country and maps are prepared using appropriate methods. Producing land cover/use maps that show a lot of information together provides important advantages in terms of protection, use and development of land assets. (Ateşoğlu, 2016; Tunçdilek, 1985).

In sustainable agricultural practices, which are thought to meet the needs of future generations; the importance of biological nitrogen fixation, crop rotation, biological control and appropriate cultivation techniques that will cause the least damage to natural resources is very important. Sustainable agriculture in general terms; to minimize non-agricultural inputs by using biological inputs and to increase productivity by preventing the deterioration of natural resources accordingly (Açıksöz, 2001).

The history of industrialization is characterized by the intense depletion of fossil fuels, especially coal, natural gas and oil. The intense consumption of the natural resources in addition to unrestrained growing economies of the country have given rise to environmental problems (Gökmenoğlu and Taşpınar 2018). The fast fossil fuel consumption caused to increase in the concentration of atmosphere greenhouse gas. The notable increase of other greenhouse gases, particularly CO_2 in the atmosphere, has become a great danger about environment and so human health (Javid and Sharif 2016, Yurtkuran and Terzi 2018).

During the last fifty years, agriculture has undergone tremendous changes. Food supply and safety and the sustainability of these concepts have gained great importance due to government policies that support surplus usage of pesticides, newly developed technologies and mechanization, expertise and maximal production. Despite of a lot of advantages of the mentioned changes, these applications will be resulted by serious damages to the world agricultural environment. Soil losses, pollution of surface waters, decrease in small scaled farms, increase in production costs, and separation in social and economic statues in provincial economies are among these costs. Global warming, loss of forests, soil erosion from water besides wind correspondingly using inappropriate agricultural techniques, and the outspread responses of personage actions on the environment that lead to overuse of rare resources, especially water resources; Sustainable agriculture and food security are under serious threat (Chernyak, 2001).

With the access to more detailed information about the earth, depending on technological developments, the dimensions of the pressure created by humans on natural resources have clearly shown themselves. Using of land and changes in land cover are more and more recognized as a fundamental universal resource (Maina et al., 2020; Karakoç, 2011).

While environmental problems are increasing constantly in the world and in Turkey, the vital limits of natural assets are rapidly shrinking. While increasing the productivity in agriculture, protecting the soil and natural agricultural lands, raising the living standard of the farmer, and most importantly ensuring food security by providing satisfactory and high quality nutrients for the rapidly growing population of the world are the main factors of sustainability in agriculture. Sustainable-good agriculture-smart agriculture practices that increase soil quality and evaluate organic wastes have become important for environmentally friendly production (Baran et al., 2021).

Sustainable agricultural practices aim to increase health, life quality and productivity, it is also aimed to reduce the damages that may occur in the natural environment both of long and short period, to rise the contribution to the country economy with improve the income to be obtained from agriculture and to increase the welfare of human working on the agricultural sector along with so all the people over the world.

CONCEPTS OF SUSTAINABILITY

Sustainability is derived from the Latin word "sustinere", which means to preserve its existence, including continuity or support for a long time (Rigby and Cáceres, 2001) and in the simplest sense, it is the ability of something to perpetuate its existence, that is, to continue (Meadowcroft, 1997). The concept of sustainability has a qualifying feature and qualifies the concept with which it is used together. For example, when the concept of sustainability is considered together with the concepts of improvement, it characterizes the concept of progress beside emphasizes that development should have certain characteristics. Therefore, when the meaning of the concept of sustainability differs, it adds different qualifications to the concepts that it is used together. These qualifications are; sometimes it is the continuity of the desired situations and conditions, sometimes strict and serious limitations in the use of non-renewable resources or the economical and repeated use of renewable resources. In addition, it sometimes takes the form of protecting the assets required by social, economic and environmental systems, at least at the required level (Bozlağan, 2002). It is known that both agricultural income and electricity and coal consumption used in agricultural activities acquire a positive and serious effects to the CO_2 emissions (Ngarava et al., 2019).

The concept of development is used to describe a dynamic process that develops positively over time. In the economic sense, development is the high standard of living of all people living in a country and being equal to each other. If there is a growth in the country, the increase in the welfare level of the people is related to development. Development takes place when there is continuous and stable economic growth and with positive changes in the social, cultural and economic lives of people (Su, 2018).

The concept of rural development was defined for the first time by the United Nations organization and accepted as rural development. Looking at this definition from a general point of view, it is seen whether the quality of society is rural or not. rural development; it is the process of combining the efforts of narrow societies to develop its culture, economy and social statues with the attempt to the state in this regard, integrating these communities throughout the nation and ensuring that they contribute fully to national development efforts (Haydari, 2019). People living in a country; a structure that ensures maximum welfare in matters such as economic, social, politics, justice, education and security will be possible with development (Batı, 2013).

It is clear that the adequate and correct use of land use by view to its agricultural sustainability potential will canalize to devising schedules relevant with arrangement in the future. Land use has environmental dimensions as well as economic, social and cultural dimensions. The fact that these dimensions are formed from the interaction of complex systems; this has necessitated the consideration of time-dependent changes on the land cover from many perspectives (Alevkayalı and Tağıl, 2020). It has been tried to obtain results by applying the researches made with different methods and techniques on the earth about land use to different areas. Many methods have been matured to assistance and better understanding the management of land, and the number of studies about usage of lands and changes in land cover has increased significantly over the past two decades (Kolb et al., 2018).

Sustainable development has been the subject of many international conferences, meetings, congresses and meetings since its adoption as a concept. Many decisions have been made and goals have been set. These targets have been tried to be achieved within the determined dates and practices, policies and strategies have been developed to achieve them. The foundations and principles of sustainable development were also established in these meetings and congresses, which were discussed especially in the center of environmental problems. Although conceptually very broad and open to different definitions, these foundations have led to the adoption of the sustainable development approach as a new field of study, as the foundations on which societies globally converge. During these studies, many new ideas and approaches related to the concept were put forward (Dinçer, 2019).

In the Report of Our Common Future printed 1987, the headmost mark to be emphasized and discussed is sustainable evaluation and the holdings owned by humankind. In this way, the concept of 'Sustainable Development' took its place on the world agenda with this report (Aydın Eryılmaz et al., 2018).

Development is the process of improving the quality of people's abilities by increasing their quality of life, freedom and dignity. The increase in the number of educated people will positively affect the development. The coexistence of all positive changes and developments in a society means that there is development (Javanshirli, 2018).

Sustainable agriculture is a system which meets human nutrition and fiber needs satisfactorily for a long time, development of resources depending to the quality of environment besides economic mean in agriculture, support non-renewable resources in addition to vitality in economy in farm work, quality increasing in farmer life and also for society, integrate crop and animal production practices (Bayram, 2004).

According to an overall assessment; sustainable agriculture includes many science and so need to interdisciplinary projects. Furthermore, sustainability is a concept that does not depend only on a region or living thing, but has a universal character.

SUSTAINABLE AGRICULTURE

Sustainable agriculture has been defined in various ways. According to this; it is the direction of agricultural activity in a way that will protect productivity and the environment in the long term, ensure economic development, and increase the quality of rural life (Tan and Köksal, 2004). According to another source; the idea of "self-feeding cities of the 21st century" has emerged as a result of environmental pollution, the decrease or complete loss of natural resources in recent years, and as a result, people in many countries are faced with the problem of hunger. In this context, the concepts of "urban agriculture" and "ecological agriculture" have gained importance in developing and developing countries in order to reach sustainable cities. With these concepts, it is aimed to support the concept of urban agriculture, to ensure the transfer of resources to future generations, and to create living spaces compatible with nature (Açıksöz, 2001).

In the book named as: "Green Development" underlined the need to protect the environment on the basis of development. The author examined together the development strategy and attitudes towards environmental protection, especially in developing countries. He thinks that if different policies are implemented, especially in developing countries with arid areas, it will be more rational to fight against increasingly severe environmental problems (Adams, 2009).

Sustainable agriculture is not simply a list of methods or the production of crops with reduced use of agrochemicals. Sustainable agriculture is applied intensively to each individual land, conserving resources by considering the long and short term economy (Olson, 1992).

A large part of agricultural production in the world is realized with the use of intensive inputs. However, the damage caused by the intensive use of inputs to the environment is increasing, making it necessary to implement emergency action plans in this regard. The producers, who want to buy more products from the unit area due to population pressure and free market conditions, have also implemented many practices that will harm the environment. While the amount of chemical fertilizers and pesticides used in developed countries increases, producers who do not use sufficient inputs in developing countries destroy the ecological balance by destroying non-agricultural lands. While 10-20% of the cultivated land in the world is affected by various types of degradation, 70% of the pastures have been destroyed. This destruction of land has reduced food production in cultivated areas by 13% and grassland production by 4% in the last 50 years (Tema, 2004).

Ensuring sustainable agriculture is the development of agricultural structure by using environmentally friendly agricultural technologies at the appropriate level, as well as protecting existing natural resources for long years. The lack of attention to sustainability, which is one of the biggest problems today, prevents the issue of how to make maximum use of the land without disturbing the natural balance and polluting it. However, if a sustainable agricultural policy can be achieved, it will be possible to take corrective measures for the future (Nacar, 2021).

Agricultural production is an energy cycle system. If the soil cannot meet the nutrients needed by the plant, fertilization techniques emerge. When the soil cannot provide the necessary moisture for the development of the plant, irrigation is activated. With the emergence of water problem in the world, new irrigation methods and fertilization methods have been started to be used. In addition, it shows that it is possible to produce without harming human health without harming the environment in other applications operating in agricultural production. Along with these, other practices in agricultural production are now systematically regulated, implemented and monitored in a way that protects natural resources and living life and protects food safety (Karaçal and Tüfenkçi, 2010).

The supply of most of the foodstuffs and raw materials required for the continuation of human life is met owing to agriculture relative sectors and it is not acting to the agricultural sector. The agricultural sector has an important place in Turkey's social and economic development from past to present. However, in the transition period from the agricultural revolution to the industrial revolution, it is presented that the weight of agriculture sector in the economy has decreased over time. Factors such as natural conditions, seasonal characteristics, low price elasticity of demand and supply, limited market control, education and income level affect agricultural production. Based on these features, the agricultural sector is a sector that should always be taken care of, it should be protected and supported by the policies applied (Şaşmaz and Özel, 2019). Each subject included in the concept of sustainability is important in terms of ensuring continuity, especially due to its importance in terms of the continuity of living things and natural resources; agricultural sustainability stands out as an essential issue.

SUSTAINABLE AGRICULTURE AND RESEARCH HIGHLIGHTS

Agroecology; it is a branch of science that emerged from different disciplines based on agriculture, ecology, anthropology and rural sociology. Agricultural ecology has been defined as a better environment friend and social emotional way to agriculture which focus to sustainability of ecology through production systems as well as production (Kara, 2001). It has been determined; agriculture is an essential determinant of pollution of environment in addition to energy consumption contributes significantly to CO_2 emissions for short term and also for long term (Ghosh, 2018).

One of the issues that can be applied in sustainable agriculture is; mixed planting systems. In the study examining the effects of biofertilizers, organic fertilizers and chemical fertilizers relaying on yield statues and some other properties of Alexandria clover and annual grass mixture, they reported that the application of these three fertilizers as a mixture combination increases the yield of clover and grass mixture, and increases the digestible crude protein and crude fiber values (Thalooth et al., 2015).

Sarkodie and Owusu (2017) "The relationship between carbon dioxide, crop and food production index in Ghana: By estimating the long-run elasticity and variance decomposition" determined relations in Ghana amongst CO_2 emissions and animal and plant production indices for the period 1960-2013 years. Evidence from the study obtains that for long term, a ratio of 1% increase in the crop production index increases the CO_2 emissions by 0.52%, and a 1% increasing of the animal production index increases by 0.81%.

Eutrophication can be defined as the deterioration of water quality and aquatic living environment with the emergence and increase of high aquatic plants as depending on increase in the ratio of phosphorus and nitrogen compounds in water. As a result of eutrophication, 0.6 kg of phosphorus and 3.1 kg of nitrogen per person are thrown into the sewers (waste waters) and seas and rivers, which are important by pathogenic microorganisms. Concentration of 0.1 mg of phosphorus per 1 liter in the water source; It is accepted as a water quality measure for eutrophication (Yarbaşı et al,, 2007).

A previously made study report implied that; it shows that the use of chemical fertilizers and agricultural exports have a positive effect on CO_2, but agricultural value added, agricultural imports and agricultural lands carry to negative effects to CO_2 emissions (Ronaghi ve ark. 2018).

In a study, innovative approaches were made for the solution of problems by considering human behavior and environmental problems together. In addition, subjects such as natural resources economy and sustainable development were also mentioned (Tietenberg, 2004).

Rafig et al. (2016) “Agriculture, trade openness, and emission: an empirical analysis and policy options” investigated the effect of agriculture, renewable and consumption of non-renewable featured energy on CO_2 emissions, based on the years 1980-2010. According to results of the research, it is implied; renewable energy and agriculture reduce CO_2 emissions, alongside non-renewable featured energy consumption increases.

In a two-year study examining the effects of applications such as poultry feather meal, chicken manure, pelleted chicken manure and mixture of chicken manure and poultry feather meal on meeting the nitrogen need of the plant by optimizing the phosphorus requirement, it was found that in the first year of the experiment, the cultivation of cover crops increased the grain yield by 52% and poultry feather flour increased the corn yield by 18-23 kg/da. It was also reported that the chicken litter application provides a very important economic gain compared to all other applications (Spargo et al., 2016).

It shows that burning stubble, use of chemical fertilizers, number of animals and agricultural machinery have a positive effect on CO_2 emissions (Ullah et al. 2018). In another study; It has been stated that renewable energy consumption, foreign trade and agricultural added value have a negative effect on CO_2 emissions, while non-renewable energy consumption causes to positive effect (Koshta et al., 2020).

Another study on the subject included information on the economics of conservation of environmental resources. He examined issues such as strategies for environmental protection at a global level, the interaction of the market and governments to protect the environment, and environmental protection in developing countries (Tisdell, 2005). According to a study on the subject, economic caution, development in finance and natural resources cause to rise in carbon emissions. On the contrary, agricultural added value reduces carbon emissions (Wang et al., 2020).

Environmental problems are among the most important problems of recent times. Technologies that have emerged since industrialization cause serious damage to the ecological balance. In a study conducted in this context, solution suggestions were made about the negative factors that may occur or may occur in the Burdur Lake Basin, which is one of the largest lake basins in Turkey (Kaya et al., 20l5).

The results of a study show that arable land, number of tractors, fertilizer use and agricultural exports have significant and positive effect on carbon footprint by means of statistics (Balogh, 2019).

In a two-year study in Brazil of corn grown after vetch planted as a cover crop, pig compost and chicken manure as a source of organic fertilizer in forage millet (millet) cultivation and chemical NPK-containing fertilizers were compared with each other and at the end of two years, pig compost was better than chemical fertilizer. They reported that the best results were obtained from chicken manure applications, therefore, chicken manure can be used successfully in millet cultivation (Basso et al., 2017).

Today, the problem in effective usage of natural resources and renewable energy has reached a different dimension with the increase in population and accordingly the increase in needs. Many countries in the world produce more than they need in order to increase the income to be obtained from production without considering nature. Especially for agricultural relative sectors, the damages may also give rise to plantings made without thinking to increase the income show their effects after many years.

SUSTAINABLE AGRICULTURE OVER THE WORLD

The most important pressure on the destruction of the environment is the population. The United Nations Population Division predicts that total world population will be around 8.9 billion by 2050, an increase of 41% (UN, 2008).

Sustainable use of agricultural lands working group, according to the current situation assessments prepared in the agriculture specialization report and in the context of the Turkey Tenth Development Plan (2014-2018), it is clear that the possibility of expanding the agricultural lands in the world is very limited and on the other hand, erosion, misuse, climate change have caused to drought and desertification etc. problems. A significant amount of agricultural land is pushed out of agriculture every year due to reasons; considering the ever-increasing need for agricultural raw materials and nutrients, it is stated that these developments regarding agricultural lands threaten the future of human beings. Misuse of agricultural lands in the agriculture specialization report; Rapid population growth, unplanned urbanization and developing industrialization are associated with problems in the implementation of current policies and related laws (Gökce et al., 2019).

When examination of the adventure of mechanization in agriculture, it is seen that the first complex tool that started to be used in agriculture was the plow. This was followed by the reaper, introduced in 1840, and the combine-harvester in 1882. However, the generalization of mechanization in agriculture was with the tractor, which was introduced in 1905 (Dinler, 2000). It can be said that mechanization in agriculture in Turkey started after 1950 to a large extent (Başarır et al., 2006).

In Turkey, on the other hand, sustainable agriculture is generally considered with sustainable development. In Turkey's VI. and VII of the

Five-Year Development Plans, it has been adopted as the basic principle and policy to ensure the administration of natural resources by apply a way that will authorize to sustainable economic development and to leave a social, physical and natural environment that is decent for future generations (Pezikoglu, 2005). Sustainable Agriculture Federation operates in order to encourage environmentally friendly agriculture, to educate producers on sustainable agriculture, to raise awareness and to ensure that they use methods that do not harm the environment while producing and produce that will not harm consumers. The Federation continues its training and consultancy activities in line with its objectives. In addition, the Sustainable Rural and Urban Development Association in Ankara, the Sustainable Agriculture Farmer Aid Association in Ankara, the Sustainable Agriculture Development Association in Bolu, the Sustainable and Ecological Agriculture Association in Ankara and the Sustainable Living Association in Istanbul for the understanding and implementation of sustainable agriculture, they are doing useful works (Federation of Sustainable Agriculture Associations - Sürdürülebilir Tarım Dernekleri Federasyonu, Anonymous, 2021).

Turkey is among the countries that are exposed to high levels of erosion in the world due to its topography, climate, wrong agricultural methods, excessive pasture and forest destruction, and the fact that the soils are mostly susceptible to erosion. Erosion in Turkey is 12 times higher than in Europe. Especially in Turkey, the risk of water erosion is much higher than in EU countries. 99% of our eroded soils are affected by water erosion and the remaining 1% by wind erosion. The rate of areas with water erosion risk in Turkey is 73%. Among the EU countries, after Turkey, the countries with the highest risk of water erosion are; Portugal (69%), Spain (47%), Slovakia (46.8%), Italy (30%), Hungary (24.5%) and Greece (20%) (OECD, 2008).

As in developed and developing countries, it is seen that the economic share of the producers has decreased proportionally due to the structural development of social and economic development situation in Turkey. Since 2004, the share of agricultural producers in exports has been 48%. Its share in national income has decreased to 9% and its share in employment has decreased to 15%. However, it would be a wrong judgment to judge that the importance of agricultural producers in the country's economy has decreased by looking at the economic indicators. It would be a more accurate judgment to consider the economy as a complete whole and as a supporting element among the sectors in the development process. Undoubtedly, the socio-economic and technological country problems of agriculture have an important value in the decrease country economy by decreasing of importance in agricultural production. The foremost of technological problems is the inefficient use of agricultural technologies by our farmers. It is thought that high efficiency will be achieved by using too many chemical fertilizers in agricultural production. Due to the different types, amounts and application periods of the fertilizers used, and due to the lack of knowledge of our producers on this subject, the environment and living creatures that are dependent on the environment are negatively affected. Lack or excess of nutrients in our soils, heavy metal accumulation or deficiency, salinization, destabilization of the working principles of microorganisms, excess nitrate with eutrophication in water, secretion of sulfur and nitrogen-containing gases into the atmosphere, etc., due to improper fertilization poses difficulties. 10% of Turkey's total agricultural production is met by Konya. Konya. With its 2.6 million hectares of agricultural area, it constitutes a very important ratio of 11.2% of the total agricultural area of the country. 2,659,890 hectares of the total surface area of the province is suitable for agriculture. Annual precipitation amount is 326 mm. It covers 3.4% of Turkey in terms of surface area. About 1.653.000 ha of Konya's agricultural land is cultivated, and 1.008.306 ha is left fallow to be planted the next year. Although its wetland is 1.899.000 ha, its irrigated land is 374.259 ha. Additionally, 176.949 hectares of wetlands are irrigated by state water works, and l97.311 hectares are irrigated by the producers' own irrigation tools. The total amount of water in the Konya Plain is 5.84 billion cubic meters/year, of which 3.82 billion cubic meters/year is usable water. Agricultural irrigation water deficit is around 8.2 billion cubic meters for every year. About 3.82 billion cubic meters per year of water available for the purpose of use; approximately 0.92 billion cubic meters per year in groundwater, almost 2.3 billion cubic meters per year of surface water, besides approximately 0.6 billion cubic meters per year from the agriculturally usable water of the Göksu River (Tuik, 20l8).

Although the share of the agricultural population in the total population in Turkey is gradually decreasing as a result of economic development and rapid urbanization, it still constitutes a large total. The most important reason for this is that although the migration from rural areas to urban areas continues, the structural and sectorial development that will provide sufficient employment for the immigrant labor has not been achieved. This situation causes an increase in slums and unemployment in cities (Kıral and Akder, 2000). As of 2006, the share of agricultural employment in total employment was 27.3 percent in Turkey, while this rate was 2.5 percent in the USA, based on the average values of 2001-2003. According to the income level of the World Bank, these rates in country groups are as follows: 35.8 percent in the group of middle-income countries, 40.3 percent in the group of lower-middle income countries and 14.2 percent in the group of upper-middle income countries. This rate, which is 3.9 percent in the group of high-income countries, is 4.8 percent in EU countries that have accepted the monetary union (WB, 2007).

It is seen that agricultural production is carried out with different rotation systems according to the regions in Turkey. It has been observed that more productive products are grown by leaving the lands fallow. In addition, it has been concluded that while the roughage required for animal production is produced, the productivity coefficient and sustainability of our lands will also be ensured. Research shows that; Green manure to be applied in different regions with the appropriate time and plant variety shows that it is not impossible to get high quality and high yields as well as sustainability in land productivity (Karakurt, 2009).

Land use changes in the USA between 1982 and 1997 were examined in line with global climate change, international trade, wildlife and other policy relative issues (Plantinga and Soeun, 2002). The United States of America country is the third largest country in the world, following to

Russia and Canada, by a total area with 9.8 million km². The USA is a country governed by the presidential system and consists of 51 different administrative divisions, including 50 states and the capital with special status. The country, which has a great biological and ecological diversity, is one of the countries in the world that opened to agriculture last, and it is the second largest country in the world in agricultural production, although the share of agriculture in the national economy is 0.9%. The USA has a desert, tropical, semi-tropical, temperate and arctic climate and is known as a country where many different products are grown. 65% of agricultural production in the USA consists of vegetable, 30% animal and 5% fish and forest products. There are 157 million hectares of arable land in the country, which has 403 million ha in agricultural area, along with pasture and meadow areas. The most suitable regions for agriculture are temperate climate and semi-tropical regions. There are approximately 2.2 million agricultural holdings in the country, with an average size of 177 hectares. Producers hold 50% of the total land in the country and large landowners hold 5% of the total land. Only 27% of the agricultural products produced in the country are for nutritional purposes and the rest is produced for energy, industry and feed purposes. It is estimated that there are approximately 50 million hectares of land in the country that can be opened for agriculture or irrigation will increase the yield (Birişik, 2019). In the book, in which basic issues related to environmental economics are discussed, valuable information has been provided on environmental policies implemented in the USA and international environmental problems, apart from environmental analyzes and environmental policy analyzes (Field and Field, 2002).

The Integrated Arable Crop Production Alliance (IACPA) in the UK carries out programs in the field of integrated product management (IACPA, 2007). One resource includes environmental issues and policies. The subject has been dealt with mostly on the basis of countries with industrialized economies, and the perspectives of organizations like the International Monetary Fund, the World Bank, the World Trade Organization and the United Nations have been examined (Ison et al., 2002). Perhaps one of the most important techniques of sustainable agriculture is organic agriculture. Organic agriculture is developing quickly all over the world. It is widely used in North America and European countries (Bayram, 2017).

In the study carried out in South Africa, the interest, experience and knowledge of people in biodiversity were evaluated in terms of income groups, and this evaluation was carried out using a contingent valuation method (Turpie, 2003).

With a population of 1.4 billion and an area of 9.3 million km^2, China states that it has the status of a country with the fifth largest land assets. The world's most populous country has the status of the world's largest agricultural producer country with a very old agricultural history, rich biodiversity and 21% of the world's primary agricultural production. The share of agricultural production in the country's economy is around 8%. China is one of the oldest civilizations in the world and produces silk, rice, tea, peach, orange, etc. It is a large agricultural economy where many agricultural products can be seen in every climate, including desert. There are 105 million hectares of arable land in the country, which has 500 million hectares of agricultural land, including pasture and meadow areas. This country, which has a different climate, is suitable for agricultural production, except for central China. As a result of intensive agriculture and rapid urbanization in China, 10 million hectares of agricultural land have been lost in the last 20 years (Birişik, 2019). In a study conducted in China; It shows that chemical fertilizer consumption, number of animals, paddy area, grain production, stubble burning and agricultural GDP have a statistically significant and positive effect on CO_2 emissions in the long term (Hongdou et al., 2018).

The place in the Common Agricultural Policy of the policies implemented for the protection of the environment in EU countries and their compatibility with it have been examined. In the study, the applied policies were evaluated on the basis of sub-sectors (wine, cereals, dairy products, livestock breeding, etc.) and the amount of support transferred to these sectors and the effects of these supports on the environment were evaluated (Baldoc et al. 2002).

CONCLUSIONS

The principles that make up the concepts of agroecology and sustainability are the use of renewable resources, minimization of toxic waste, conservation of resources, management of ecological relations, adaptation to the local environment, assessing the physical and potential limits of the farm; ensuring selection of plants and animals suitable for the ecological environment, diversification, empowerment of people, management of the whole system, maximizing long-term benefits, value of health (Agroecology, 2007).

Especially modern agricultural practices and changes in agricultural technology over time increase these negative effects. With the mechanization in agriculture, the rapid conversion of non-agricultural areas to agricultural areas, the spread of high-yielding species and the adoption of monoculture, the homogenization of high-value export products and the excessive use of pesticides in the fight against pests and the uncertainties in land ownership rights lead to a decrease in biodiversity. Agricultural expansion in the form of cultivating non-agricultural areas has led to the destruction of natural habitats, including tropical forests, pastures and wetlands. Likewise, genetic erosion has created negative effects on the animal stock. Farmers' focus on species that are in high demand in the market for more productive species and established diets have led to the extinction or the brink of extinction of many traditional species. The decrease in biodiversity reduces the flexibility of ecological elements in the face of negative changes and pressures in the environment and makes it difficult to adapt to new conditions, causing climatic vulnerabilities, economic losses, risking productivity and food security, and leading to social costs (Thrupp, 2000).

It is seen that resources are used thoughtlessly for the purpose of respond to the demands for globalizing world and all people are affected by this situation. The most recent example of this is the global warming problem, which has different effects on the whole world. In the past centuries, people have used all the resources of the world without thinking that they can harm the environment and future generations. Accordingly, it is very essential to protect the existing natural resources in Turkey and in the world and to use them to meet the needs of future generations.

The most important basic factor that provides the vital cycles of all living things in nature; agricultural production. For the continuation of agricultural production; it is essential that everyone understands the concept of sustainability and pays attention to the basic principles. The concept of sustainability is one of the most talked about concepts in health, agriculture, food production, economy, education and many other fields. Within the concept of sustainability in order to increase and develop agricultural production capacity; involving a planned struggle, compatible with climate change, soil management, food security and sustainability of all these basic elements are vital and require a holistic struggle and rational practices because each of them is directly or indirectly connected to each other. The most important pillar of agriculture is soil, water, species in nature and the biological diversity of these species, which are limited natural resources, and biosecurity is essential to ensure sustainability in this regard. Today, intensive agricultural practices based on intensive tillage, rapidly increasing use of chemical fertilizers and pesticides; it leads to deterioration in soil quality, pollution of waters and reduction of biodiversity. Because of all the basic elements mentioned; the basic element that is indispensable in terms of agricultural production; is sustainable agriculture. Although there is a great deal of methods to improvement the sustainability in agriculture, the main target is; is to offer a probable solution for enabling agricultural schemes to satisfy a expanding population in changing environment conditions. As a result of inefficient and unconscious use of natural resources; the existence, adequacy of the available resources can be destroyed irreversibly. Especially human; In addition to considering future generations, the concept of sustainable agriculture, which deals with practices that will increase the quality of agricultural lands for development, economic development and a livable environment, should be adopted by everyone, both through education and practices.

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CHAPTER 5

IMPACT OF THETRUST, PERCEIVED RISK, ENVIRONMENTAL END ENERGY BENEFIT ON THE ACCEPTANCE OF NUCLEAR POWER PLANTS

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1.INTRODUCTION

Turkey is unable to meet its domestic energy requirements from internal sources, and so relies heavily on foreign purchases. In recent years, Turkey has been planning nuclear power plants as an alternatives, seeking to reduce its dependence on foreign energy (Akcay, 2009). The Chernobyl (Russia) and Fukushima (Japan) nuclear accidents have resulted in a higher perception of the risks and a lower perception of the reliability of nuclear power plants among the public, and debates related to nuclear power plants are continuing all over the world. Accurate information and positive public perceptions of nuclear power and nuclear power plants play a crucial role in the acceptance of this energy source by a country, and it thus becomes important to investigate the factors of trust, benefit and risk that are thought to influence public acceptance of NPPs, as well as the causal relations between these factors.

This study examines the factors that affect public Acceptance of nuclear power plants in Turkey using the NPPAM and structural equation modeling approach. For this purpose, a research model was designed following a literature review, and various hypotheses were developed to test the relationships within the model. The factors included in the model are “Trust”, “Perceived Environmental Benefit”, “Perceived Energy Benefit”, “Perceived Risk” and “Acceptance”. In the proposed NPPAM, Trust was defined as an endogenous variable, Acceptance as an exogenous variable, and the others as mediating endogenous latent variables. Structural relations within the proposed NPPAM were analyzed using the SEM, and the fit of the proposed model was assessed based on various fit criteria.

2. METHOD AND MATERIAL

2.1. Hypothesis design: Trust, Benefit and Risk factors impact on the acceptance of nuclear power plants

This study focuses on the effects of Trust, Energy Benefits, Environmental Benefits and Perceived Risk on the public Acceptance of power plants. Many factors have been identified in related literature that affect public acceptance of NPPs. Liu et al. (2008) proposed a model related to the acceptance of NPPs that includes the factors Perceived Benefit, Risk, and Trust, and the determinants affecting acceptance and relationships are also among these factors. The present study thus includes causal models and hypotheses that have been put forward in previous studies.

"Public Acceptance" is a concept that is frequently used to understand public attitudes toward energy, the environment and climate change. In a general sense, it is thought that the perceived benefits and risks of nuclear power have a direct influence on the level of public acceptance. Previous studies report that people perceive nuclear energy technologies not only as a means of lowering energy costs, but also as a source of alternative energy and a means of reducing the carbon emissions associated with the use of conventional energy sources (Bird et al., 2014; Visschers et al. 2011; Visscher and Siegrist, 2013; Guoa and Ren, 2017).

Trust is key factor affecting public acceptance. People who know little about technology and are not knowledgeable about the probability of technology-related disasters must rely on factors of trust concerning the construction and operation of NPPs when evaluating the risks and benefits of nuclear energy (Greenberg, 2009; Siegrist et al., 2000; Whitfield et al., 2009). Siegrist (1999) argues that public acceptance of a new technology or dangerous facilities is determined from perceived benefits and risks. Trust in scientists, companies and public agencies is considered to have an important effect on these perceived benefits and risks. Previous studies have reported that trust has a negative relationship with perceived risks and a positive relationship with perceived benefits (Visschers and Siegrist, 2013).

H_1: As Trust in NPPs increases, so do the perceived Energy Benefits of NPPs.

H_2: As Trust in NPPs increases, so do the perceived Environmental Benefits of NPPs.

H_3: As Trust in NPPs increases, perceived Risks decrease.

H_{4a}: As Trust in NPPs increases, so does the Acceptance of NPPs

According to Culley et al. (2010), the construction and operation of nuclear power plants can be seen as an industry that generates more jobs and tax revenues, and that accelerates economic development. In addition, there are studies in literature reporting a positive correlation between the perceived benefits of nuclear energy and public acceptance (Bird et al., 2014; Frewer et al., 1998).

H_{5a}: As the perceived Energy Benefits of NPPs increase, so does the Acceptance of NPPs.

Contu and Elshareif (2021) investigated the willingness of three countries (UK, Italy and United Arab Emirates -UAE) to accept hypothetical nuclear power projects with an online survey of 4000 people. In this context, it is aimed to estimate the perceived benefit and risk impact of accepting nuclear energy projects in three countries. A perceived high risk is considered to be a factor that can reduce the public acceptance of nuclear power. Environmental benefits and risks are considered to be critical factors affecting the level of acceptance in literature. It is further reported in literature that perceived environmental benefits play a more significant role in the public acceptance of nuclear power than perceived risks (Chung and Kim, 2009; Visschers and

Siegrist, 2013; Wang and Li, 2016). Many empirical studies have shown that the perceived risk of nuclear power plants is negatively correlated with the acceptance of nuclear energy technologies (Visschers et al., 2011). Nuclear accidents in the past have resulted in an increase in the perceived risk, and at the same time decreased public acceptance of nuclear energy (Bird et al., 2014; Visscher and Siegrist, 2013).

H_{5b}: As the Perceived Risks of NPPs increase, the Acceptance of NPPs decreases.

Roh and Kim (2017) investigated the public's attitudes towards nuclear energy after the Fukushima nuclear accident. The analysis instigated the perceptions of risk and benefit have been aggravated since the accident and that the effect is stronger on risk perception.

Furthermore, it is reported that Environmental Benefits and Risks have a direct effect on Acceptance and that Trust has an indirect effect that is mediated by Environmental Benefits and Risks on Acceptance. Previous studies have shown that Environmental Benefits and Risks have a significant effect on Trust (Siegrist 1999, 2000; Wang and Li, 2016). Roh and Kim (2016) found that Korean public was aware of the benefits of nuclear energy but were reluctant regarding the safety of nuclear energy. Previous literature includes studies in which the perceived environmental benefits related to nuclear power are important, and may affect the level of acceptance positively (Tanaka, 2004; Whitfield, et al., 2009). In addition, trust is considered to have a positive effect on energy benefits

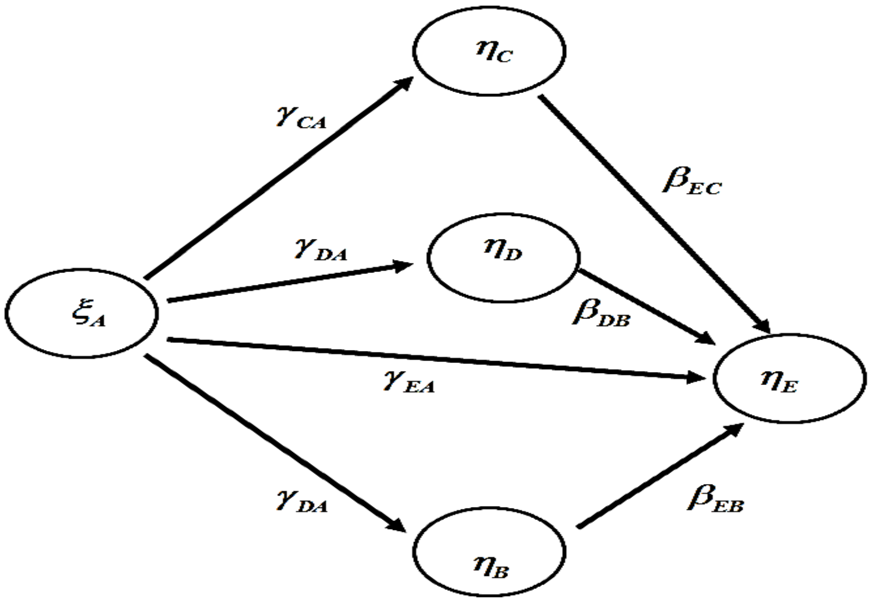
H_{4b}: As the perceived Environmental Benefits of NPPs increase, so does the Acceptance of NPPs.

Previous studies have in particular explored in detail the relationship between trust and risk perception (Bronfman et al., 2008; Perko et al., 2014; Zeng, et al., 2017). In literature on risk perception, trust is generally considered to be a critical factor affecting perceived risks and it has been found that trust in organizations that operate radioactive waste pools, in particular, had a strong effect on perceived risk (Greenberg et al., 2007; Poortinga and Pidgeon, 2005; Rosa and Clark, 1999).

As is the case in the present study, previous studies have also focused on the effects of the factors of "Trust", "Benefits" and "Risks" in the public acceptance of nuclear power plants. A review of literature reveals a lack of studies on the public acceptance of the NPPs planned for construction in Turkey, and in this regard, the present study will provide valuable information about Trust, Risks, Benefits and public Acceptance concerning the NPPs planned to be constructed in Turkey.

2.2. *Design of the research model*

The development of the proposed NPPAM in the study was informed by Visschers et al. (2011) and Wang and Li (2016). Different to Wang and Li's (2016) model, the model in the present study predicts Trust to have a direct effect on Acceptance, and includes this relationship in the model. The Nuclear Power Plant Acceptance Model (NPPAM) proposed in the study is given in Figure 1.



ξ_A: Trust, η_B : Perceived Environmental Benefits, η_C : Energy Benefit η_D : Perceived Risks , η_E : Acceptance

Figure 1. Nuclear Power Plant Acceptance Model (NPPAM)

The latent variables and parameters in the NPPAM given in Figure 1 are defined as follows.

γ_{CA}: The direct effect of Trust on Perceived Energy Benefits

γ_{DA}: The direct effect of Trust on Perceived Risks

γ_{EA}: The direct effect of Trust on Acceptance

β_{EC}: The direct effect of Perceived Energy Benefits on Acceptance

β_{EB}: The direct effect of Perceived Environmental Benefits on Acceptance

β_{DB}: The direct effect of Perceived Risks on Acceptance

The NPPAM assumes that Trust, as the exogenous latent variable in the model, affects perceived Environmental and Energy Benefits and Perceived Risks. Furthermore, it is assumed that all of the latent variables in question have a causal relationship with the acceptance of NPPs.

The NPPAM proposed in the study consists of one exogenous latent variable (A: Trust n=1) and four endogenous latent variables (B: Environmental Benefits, C: Energy Benefits, D: Risks, and E: Acceptance; m=4). The formulae on which the structural models in the SEM are based can be expressed as in Equation 1.

$$\eta = B\eta + \Gamma\xi + \zeta \tag{1}$$

In Equation 1, η denotes the endogenous latent variable; η denotes the vector of the latent variable with $mx1$ dimensions; B denotes the mxm matrix of the coefficients between the endogenous latent variables where the main diagonal is zero; Γ denotes the matrix of coefficients between the exogenous and endogenous latent variables with mxn dimensions; ξ denotes the vector of the exogenous latent variable with $nx1$ dimensions; and ζ denotes the vector of the latent error terms with $mx1$ dimensions.

The matrix representation of the structural model and the structural equations are given in detail in Equations 2-7.

$$\begin{bmatrix} \eta_B \\ \eta_C \\ \eta_D \\ \eta_E \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ \beta_{EB} & \beta_{EC} & \beta_{ED} & 0 \end{bmatrix} \begin{bmatrix} \eta_B \\ \eta_C \\ \eta_D \\ \eta_E \end{bmatrix} + \begin{bmatrix} \gamma_{BA} \\ \gamma_{CA} \\ \gamma_{DA} \\ \gamma_{EA} \end{bmatrix} \begin{bmatrix} \xi_A \end{bmatrix} + \begin{bmatrix} \zeta_B \\ \zeta_C \\ \zeta_D \\ \zeta_E \end{bmatrix} \tag{2}$$

$$\begin{aligned} \eta_B &= \gamma_{BA}\xi_A + \zeta_B \\ \eta_C &= \gamma_{CA}\xi_A + \zeta_C \\ \eta_D &= \gamma_{DA}\xi_A + \zeta_D \\ \eta_E &= \beta_{EB}\eta_B + \beta_{EC}\eta_C + \beta_{ED}\eta_D + \gamma_{EA}\xi_A + \zeta_E \end{aligned} \tag{3}$$

The general measurement model of the endogenous latent variables in the SEM are written as in Equation 4.

$$\mathrm{y} = \Lambda_y\, \eta + \varepsilon \tag{4}$$

In Equation 4, p denotes the number of total observed variables of the endogenous latent variables; y denotes the vector of endogenous latent variables with px1 dimensions; Λy denotes the relationship between endogenous latent variables and the observed variables of those endogenous latent variables; η denotes the vector of the endogenous latent variables with mx1 dimensions; and ε denotes the error vector of the observed variables with px1 dimensions. The matrix representation of the measurement model of the endogenous latent variables in the SEM can be expressed in detail as in Equation 5.

$$\begin{bmatrix} B4 \\ B5 \\ C1 \\ C2 \\ D6 \\ D7 \\ D8 \\ E15 \\ E16 \\ E17 \end{bmatrix} = \begin{bmatrix} \lambda^y_{B4} & 0 & 0 & 0 \\ \lambda^y_{B5} & 0 & 0 & 0 \\ 0 & \lambda^y_{C1} & 0 & 0 \\ 0 & \lambda^y_{C2} & 0 & 0 \\ 0 & 0 & \lambda^y_{D6} & 0 \\ 0 & 0 & \lambda^y_{D7} & 0 \\ 0 & 0 & \lambda^y_{D8} & 0 \\ 0 & 0 & 0 & \lambda^y_{E15} \\ 0 & 0 & 0 & \lambda^y_{E16} \\ 0 & 0 & 0 & \lambda^y_{E17} \end{bmatrix} \begin{bmatrix} \eta_B \\ \eta_C \\ \eta_D \\ \eta_E \end{bmatrix} + \begin{bmatrix} \varepsilon_{B4} \\ \varepsilon_{B5} \\ \varepsilon_{C1} \\ \varepsilon_{C2} \\ \varepsilon_{D6} \\ \varepsilon_{D7} \\ \varepsilon_{D8} \\ \varepsilon_{E15} \\ \varepsilon_{E16} \\ \varepsilon_{E18} \end{bmatrix} \tag{5}$$

The general measurement model of the exogenous latent variables in the SEM is written as in Equation 6.

$$\mathbf{x} = \Lambda_x \xi + \delta \tag{6}$$

In Equation 6, q denotes the number of total observed variables of the exogenous latent variables; x denotes the vector of exogenous latent variables with qx1 dimensions; Λx denotes the relationship between exogenous latent variables and the observed variables of those exogenous latent variables; ξ denotes the vector of the exogenous latent variables with nx1 dimensions; and denotes the error vector of the observed variables with qx1 dimensions.

The matrix representation for the measurement model of the exogenous latent variables in the SEM can be expressed in detail as in Equation 7.

$$\begin{bmatrix} \boldsymbol{A}11 \\ \boldsymbol{A}12 \\ \boldsymbol{A}13 \\ \boldsymbol{A}14 \end{bmatrix} = \begin{bmatrix} \lambda^x_{A11} \\ \lambda^x_{A12} \\ \lambda^x_{A13} \\ \lambda^x_{A14} \end{bmatrix} \begin{bmatrix} \xi_A \end{bmatrix} + \begin{bmatrix} \delta_{A11} \\ \delta_{A12} \\ \delta_{A13} \\ \delta_{A14} \end{bmatrix} \tag{7}$$

2.3. Questionnaire and sample

The development of the measurement instrument used in the present study was informed by studies conducted by Wang and Li (2016), Kim et al. (2014), Zsóka et al., (2012), Corner et al. (2011), Carr and Devgun (2011) and Visschers et al. (2011). The data collection instrument contains 18 statements measuring the factors of Energy Benefit, Environmental Benefit, Risk, Trust and Acceptance. A 5-point Likert-type scale was used (5 = completely agree, 1 = completely disagree), and the items in the instrument aimed at measuring the five factors of A: Trust, B: Perceived Environmental Benefits, C: Energy Benefit, D: Perceived Risks and E: Acceptance.

The questionnaire was conducted face to face with the people living in 14 metropolises in Turkey. The questionnaires were distributed in proportion to the population of the provinces. The questionnaires Istanbul f=190, Ankara f=115, Izmir f=90, Bursa f=75, Kocaeli f=60, Eskişehir f=45, other 8 provinces f=175 were applied to people. Of the total respondents, 49 % (f=378) were female, 51 % (f=390) were male, 67 % (f=515) were married and 33 % (f=253) were single. The educational level of the participants were elementary school 15 % (f = 115), high school 20 % (f = 152) and college graduates 65 % (f= 501). Of the total, 16 % (f=126) of the participants never watched environmental documentaries on TV, 10 % (f=78) watched them every day, 14 % (f=110) watched them once every two or three days, 25 % (f=189) watched them once a week and 35 % (f=265) watched them once every two weeks.

3.RESULTS

3.1. Descriptive analysis

The results of the analysis showed that 69 percent of the participants found nuclear power plants as a useful alternative energy source. Furthermore, 56 percent of the respondents had positive opinions about the environmental benefits of NPPs, whereas about 44 percent reported negative opinions. In addition, 50.27 percent of the respondents reported positive views and 49.73 percent reported negative views about the Trust factor, with statements referencing the "proper selection of project site," "the quality and reliability of construction," and "the employment of expert staff". The results show that 53 percent of the respondents agree with nuclear power plants, while 47 percent express a negative opinion. It was understood from the answers given that 84 percent of the participants saw nuclear power plants as risky, and 16 percent did not. A notable finding is that although a high percentage (84%) of respondents acknowledge the risks associated with NPP, 53 percent report Acceptance. Given the high cost of energy in the country, the fact that energy bills make up a significant portion of people's spending may explain why nuclear power plants are viewed as an energy source despite being perceived as risky.

3.2. Validity of the NPPAM

In the study, Weighted Least Squares was preferred as the parameter estimation method, since the data did not show normal distribution. The Chi-square value $\chi 2=191.72$ (df= 70, $p<0.01$) and The $\chi 2$ /df =2.74 <3 was calculated. Other values were as follows: RMSEA=0.048, SRMR = 0.069 <0.10, NFI= 0.91>0.90, NNFI= 0.92>0.90, IFI = 0.92>0.90, CFI= 0.93>0.90, GFI= 0.95>0.90, CAIC (Consistent model= 459.25<saturated model CAIC = 802. 60). Looking at these results, it is clear that the model's fit falls within the acceptable range.

The convergent validity of the measurement tool was understood by meeting three conditions; (1) standard factor loading greater than 0.50

and statistically significant, (2) Compound Reliability (CR) and Cronbach's Alpha (CA) values greater than 0.70, (3) . The Explained Average Variance (AVE) value is greater than 0.50 (Hair et al., 1998; Fornell and Larcker, 1981).

The AVE values for the NPPAM were found to vary between 0.64 and 0.82, CA values between 0.74 and 0.92, and CR values between 0.80 and 0.93. When the model's convergent validity was checked, it was observed that the standard factor loadings ranged from 0.57 to 0.93, as shown in Figure 2. These results indicate that the constructs have convergent validity. In order to establish the discriminant validity of the model, the square root of the AVE value of each construct is compared with the correlations between the related construct and other constructs. If the square root of the AVE value is higher than the correlations between constructs, then the discriminant validity criterion is met (Fornell and Larcker, 1981). As Table 1 shows, the AVE square root values are higher than the correlations between constructs, indicating that the discriminant validity criterion is.

Table 1. Discriminant validity

	A	B	C	D	E
A	**0.84**				
B	0.60	**0.86**			
C	0.55	0.86	**0.90**		
D	-0.40	0.65	-0.24	**0.80**	
E	0.78	- 0.26	0.72	-0.44	**0.91**
AVE	0.71	0.74	0.81	0.64	0.82

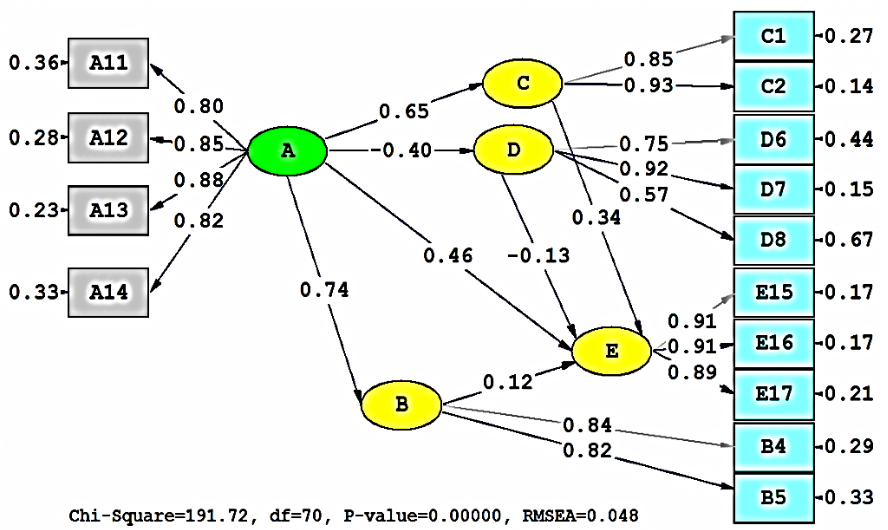
3.3. Path diagram and parameter estimates of the NPPAM

The path coefficient between Trust and Environmental Benefit was calculated as $\gamma_{BA}=0.74$. This finding shows that a one-unit increase in the participants' trust levels in the construction and operation of the power plant will cause a 0.74-unit increase in their Environmental Benefit perceptions.

The path value between Trust in Power Plants and Energy Benefit perception was determined as $\gamma_{CA} = 0.65$. This result means that a one unit increase in Trust will cause a 0.65 unit increase in Perceived Energy Benefits. It has been revealed that a one-unit increase in the level of Trust in Power Plants will lead to a 0.40-unit decrease in Perceived Risks.

The path coefficient between the Energy Benefit perceptions of the power plants and Acceptance was calculated as $\beta_{EC} = 0.34$. This result indicates that a one-unit increase in Perceived Energy Benefits will result in a 0.34-unit increase in participants' acceptance of nuclear power plants.

The coefficient of the relationship between Risks and Acceptance is $\beta_{ED} = -0.13$. The negative sign in this coefficient indicates that a one-unit increase in perceived Risks results in a 0.13-unit decrease in Acceptance. The coefficient between Environmental Benefits and Acceptance is $\beta_{EB} = 0.12$, and the coefficient between Trust and Acceptance is $\gamma_{EA} = 0.65$. This indicates that a one-unit increase in the public's Trust results represents a 0.65-unit increase in the Acceptance of NPPs.



A: Trust, B: Perceived Environmental Benefits, C: Energy Benefit, D: Perceived Risks, E: Acceptance

Figure 2. Path diagram of the model (NPPAM)

$$\eta_B = 0.74\xi_A + 0.45 \qquad ; R^2 = 0.55$$
$$\eta_C = 0.65\xi_A + 0.58 \qquad ; R^2 = 0.42$$
$$\eta_D = -0.40\xi_A + 0.84 \qquad ; R^2 = 0.16$$
$$\eta_E = 0.12\eta_B + 0.34\eta_C - 0.13\eta_D + 0.65\xi_A + 0.25 \qquad ; R^2 = 0.75 \tag{8}$$

All of the coefficients in Table 2 were found to be statistically significant, and so hypotheses H_1, H_2, H_3, $H_{4\mathbf{a}}$, $H_{4\mathbf{b}}$, H_{5a} and H_{5b} can be said to be supported by the data.

Table 2. Hypothesis test results

Hypotheses	Flow direction	Standardized parameter estimates	Results of hypotheses
H1	$A \rightarrow C$	0.65^{**}	supported
H_2	$A \rightarrow B$	0.74^{**}	supported
H_3	$A \rightarrow D$	-0.40^{**}	supported
H_{4a}	$A \rightarrow E$	0.46^{**}	supported
H_{4b}	$B \rightarrow E$	0.12^{*}	supported
H_{5a}	$C \rightarrow E$	0.34^{**}	supported
H_{5b}	$D \rightarrow E$	-0.13^{**}	supported

$^{**}p<0.01$; $^{*}p<0.05$

4.CONCLUSION

In this study, nuclear power plants were investigated with a proposed SEM accepted by the public. The results of the research show that all the factors considered in the study affect the acceptance of nuclear power plants. Our findings show that the acceptance of nuclear power plants is largely influenced by people's perception of their benefits from a desire for safe energy, and perceived risks have an impact in the case where they are accepted. It also shows that, while nuclear power plants are considered, the environmental advantages of people's nuclear energy are less important than the advantages of the desire for a safe energy. Previous studies have reported that when people are asked to make a choice between climate change or nuclear power plants, they reluctantly choose nuclear power plants for deceleration of climate change (Pidgeon et al., 2008). Similar to the findings of this study, Visschers et al. (2011) and Wang and Li (2016) found that risks have a negative impact on

Acceptance. In these two studies, the coefficient of the relationship between Trust and Risks was found to be -0.53 and -0.44, respectively, whereas in the present study, this figure is -0.40.

These findings show that the level of trust is positively related to perceived energy supply and environmental benefits and negatively related to perceived risk. The literature shows that trust plays a key role in the acceptance of nuclear power plants. The results of this study also revealed that public confidence is the most important determinant of the acceptance level of nuclear plants. Visscher et al. (2011) and Wang and Li (2016), while determining the coefficient between Energy Dec and Acceptance as 0.76 and 0.52, respectively, in this study it was calculated as 0.34. Previous studies have shown that public acceptance of NPPs is influenced to a much lesser extent by perceived energy supply benefits and perceived risks or benefits related to climate change mitigation. There have been many studies that suggest that perceived benefits are much more important than perceived risks when it comes to recognizing a danger (Siegrist, 1999, 2000). As a result, it has been evaluated that people care more about the benefits than the risks when forming an opinion about the acceptance of nuclear power plants.

The model proposed in this study suggests that there may be a direct relationship between Trust and Acceptance, which are not included in the models of Visschers et al. (2011) and Wang and Li (2016). As a result of the SEM analysis, a direct relationship between Trust and Acceptance was found to be 0.43 ($p<0.01$) which revealed that the Energy Benefit variable has a mediator role between Trust and Acceptance (A→C→E: 0.22). In the previous work of Visschers et al.

(2011) and Wang and Li (2016), this coefficient was reported as 0.16 and 0.23 respectively. The total relationship which includes direct and indirect effects of between Trust and Acceptance was calculated as 0.79. The obtained path coefficient confirmed that the existences of the direct relationship between Trust and Acceptance in the model which proposed in our study. Besides that the results of this study revealed that the most important variable accepting to NPP was Trust. In addition, the results also show that in societies towards a high risk of NPP Trust is the most significant factor in terms of Accept to NPP.

As the NPPAM results show, Trust is one of the most important factors influencing acceptance, which points to the importance of the components that make up the Trust factor, namely "proper selection of project site," "the quality and reliability of construction" and "employment of expert staff" for the acceptance of NPPs. Analyses show that the level of acceptance of NPPs among people prioritizing energy was 69 percent, while Liu et al. (2008) found that the level of acceptance of NPPs among Chinese people was 71.43 percent.

The arithmetic means and standard deviations for the model factors A, B, C, D and E were as follows: A: 2.97 (sd: 1.12); B: 3.10 (sd: 1.14); C: 3.52 (sd: 1.19); D: 4.22 (sd: 0.78); E: 3.02 (sd: 1.27). Among these factors, Risk has the highest mean value, whereas Trust has the lowest.

The *F* test conducted to see if the means of the factors included in the model differed by gender revealed significant differences in all factors. For factor A, the arithmetic mean was 2.89 for the female participants and 3.05 for the male participants, and $F(766,1) = 4.14$ ($p=0.042$); for factor B, the arithmetic mean was 3.35 for the female participants, 3.68 for the male participants and $F(766,1) = 14.17$ ($p<0.01$); for factor C, the arithmetic mean was 2.94 for the female participants, 3.26 for the male participants and $F(766,1) = 14.73$ ($p<0.01$); for factor D, the arithmetic mean was 4.28 for the female participants and 4.15 for the male participants, and $F(766,1) = 4.80$ ($p=0.029$); and for factor E, the arithmetic mean was 2.88 for the female participants and 3.15 for the male participants, and $F(766,1)= 8.97$ ($p=0.003$).

The greatest differences between the male and female participants were in factors B: Perceived Environmental Benefits and C: Perceived Energy Benefits. These results indicate that in terms of Energy Benefits, Environmental Benefits, Trust and Acceptance, women are less supportive of nuclear power plants, and consider NPPs to come with higher risks when compared to men.

When comparing the means of the factors included in the model for educational attainment, significant differences were found in the factors of Trust and Risk. Pairwise comparisons showed that significant differences existed between elementary school graduates on the one hand (Mean: 2.65) and middle school (Mean: 3.38) and high school (Mean: 3.15) graduates on the other in the factor of Trust; and between elementary school graduates (Mean: 3.90) and college graduates (Mean: 4.26) in the factor of Risk. These findings indicate that people with higher levels of education perceive higher levels of risk. Whitfield et al. (2009) found that a low level of education is associated with a higher perception of risk for nuclear energy. , Mourogov (2000) stated that the management level of power plants should be improved in order to increase the level of public trust. Contu and Elshareif (in the press 2022), on the other hand, stated that when announcing developments in nuclear energy, the environmental, public and private benefits associated with such projects should be clearly emphasized. It is considered that there should be a high level of public confidence in the implementation of the nuclear energy program in government agencies and the contractor/executive companies. In particular, it is necessary to inform the public accurately, openly and transparently so that the authorities can increase public participation.

5.DISCUSSION

The future of nuclear power depends on two important factors. One relates to the technical aspect of nuclear power; and the other regards its institutional and social acceptance. Although significant scientific and technological developments have been achieved in the area of NPP safety and waste management, the acceptance of NPPs by the public has not improved to any significant degree due to the nuclear accidents experienced that have occurred in the past. Accordingly, the future of nuclear power is, to a large extent, associated with public acceptance (Palabiyik et al., 2010).

Public opposition to nuclear power is based on various factors, including the high risk perception in the areas of health and safety in general, the lack of information on the technology to be used, the numerous potential environmental risks, other risks that may occur as a result of the poor operation of NPPs, the loss of value of real estate in the vicinity of NPPs, and the additional taxes to be imposed on the public. While different types of opposition to similar investments can be observed, the main arguments of the opponents of nuclear power include: that the investment to be made is unnecessary, that there is a lack of confidence in the government or operating organization, that the conditions for the safe operation of the plant are unsatisfactory, that there are serious potential threats to health and safety, and in particular, that there exists a significant chance of irrecoverable threats to health (Schively, 2007; Palabiyik et al., 2010).

In 2008, the percentage of nuclear power supporters was 44 percent, while the percentage of opponents was 45 percent. Support of nuclear power varies significantly from one country to another in Europe, although a significant proportion of the population of countries that have operational NPPs tend to support nuclear power, unlike the people in countries that have no NPPs. On average, around six out of 10 people support nuclear power in the Czech Republic (64%), Lithuania (64%), Hungary (63%), Bulgaria (63%), Sweden (62%), Finland (61%) and Slovakia (60%), while contrasting figures in this regard can be noted in Romania and Spain, both of which have NPPs, where the percentage of supporters of nuclear power is lower than the average of the 27 EU countries, to accounting for 24 percent in Spain and 35 percent in Romania. Countries that do not have any NPPs have the lowest percentage of nuclear power supporters, where eight out of 10 people in Cyprus (7%), Austria (14%), Malta (15%) and Greece (18%) are against nuclear power (Eurobarometer, 2007; Palabiyik et al., 2010). Liu et al. (2008) noted that the level of acceptance of NPPs among Chinese people was 71.43 percent. In the present study, the level of acceptance of NPPs was calculated to be 53 percent.

In studies conducted at regular intervals regarding the acceptance of the public to nuclear power, an association has been identified between the public's affirmative view and climate change and the security of energy supply. The major motive of political decision-makers in regards to nuclear power is the diversification of energy sources. Although the level of public acceptance is not considered an effective barrier to the implementation of nuclear power programs, the fact that participation and transparency are ensured in making such decisions in countries like the United Kingdom, Finland and Japan results in more affirmative attitude of the public towards nuclear power (FORATOM, 2017).

It is crucial that the public be informed so that people can form a general view on the subject, that supporting and opposing views be discussed among different participants in the same forums, and that people's attitudes and opinions on the subject be understood. Policy makers need to formulate policies that minimize the risks specific to the planned projects at each stage of NPP investments, to keep the public informed, and to include the public in the decision-making process.

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CHAPTER 6

VISIBLE NEAR INFRARED REFLECTANCE SPECTROSCOPY (VNIRS) TECHNIQUE FOR DETECTION OF PLANT DISEASES

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INTRODUCTION

Plant diseases cause yield losses of up to 10% worldwide (Zhang et al. 2012). The early diagnosis of the disease and the detection of the spatial distribution of the disease is thus important (Zhang et al. 2012; Bilgili et al. 2018). Determining the spatial distribution of the disease accurately prevents the areas affected by the disease from being bypassed and unnecessary chemical use (Zhang et al. 2012). Contrary to traditional techniques used in the diagnosis of diseases, spectroradiometric methods can enable early diagnosis of diseases in field conditions, it provides timely intervention to diseases and can help reduce economic losses (Herrmann et al. 2018; Giraldo-Betancourt et al. 2020). Also spectroradiometric techniques are not destructive (Giraldo-Betancourt et al. 2020). Non-image spectroradiometric techniques such as Visible Near Infrared Reflectance Spectroscopy (VNIRS) make important contributions to the diagnosis, determination and monitoring of diseases in precision agriculture applications (Mahlein et al. 2013). VNIRS technique is based on the principle of measuring the radiation coming from the surface of the material as a function of wavelengths to obtain a reflection spectrum called fingerprint (spectral library) for each material. Spectral data collected from plants by spectroradiometer can provide information about the nutritional, water and health status of plants, biotic and abiotic stress conditions in plants (Giraldo-Betancourt et al. 2020).

The studies on VNIRS have been found to be important in the development of inexpensive sensors for the easy and rapid diagnosis of plant diseases (Mahlein et al. 2013). Spectral data collected from plants using spectroradiometry can help with the following;

i) Diagnose spectral changes in plants under biotic stress conditions such as plant diseases

ii) Reveal significant spectral bands in the spectral diagnosis of specific plant diseases, which is especially important for the development of inexpensive sensors

iii) Generate spectral disease indices for plant-specific diseases

iv) Create models between disease intensities and reflections obtained at different wavelengths and spectral features or indices extracted from these reflections in order to determine the effect of disease severity on the spectral reflection of the plant

v) Test the discriminating power of spectral data between healthy and diseased plants

vi) Compare different statistical methods and machine learning algorithms in classifications and models used for disease diagnosis with spectra

2. Collection of Spectral data

For the diagnosis of plant diseases, spectral measurements are obtained with different spectrometers capable of measuring at visible and infrared wavelengths (Figure 1, Table 1). Spectral measurements can also be made by mounting spectroradiometers on tractor-like equipments (Herrmann et al. 2018). Studies on the diagnosis of plant diseases by spectroradiometric studies have been generally carried out under controlled laboratory conditions by inoculating different disease species into plants (Giraldo-Betancourt et al. 2020). Very few studies have been carried out in field conditions either by inoculating diseases into plants or on diseased plants already in the field (Heim et al. 2018).

Whether it is leaf diseases or plant root diseases, the reflections collected due to the diagnosis of these diseases by spectroradiometer are obtained directly from the leaves of the plant. Reflections collected directly from the leaf of the plant are generally made with the help of leaf clips. In addition, the reflection of all parts of the plant can be obtained from a certain height from the plant canopy. Spectral data were collected at different stages of the disease and the potential of the technique are tested for each stage separately to determine the earliest diagnosis period for the disease.

Figure 1. Collection of plant reflections by spectroradiometer from plants in laboratory and field; Leaf clip attached to ASD FieldSpec 3 (upper left); Leaf clip (upper right) (Bilgili et al., unpublished data).

3. Spectral Preprocessing & Spectral Vegetation Indices

After obtaining the raw spectral data, it is subjected to some spectral preprocessing (Figure 2). The most widely used spectral pretreatments are first derivatives (Heim et al. 2018), spectral averaging over certain wavelength ranges (Abdulridha et al. 2016) and wavelet transformation (Karadağ et al. 2020). Multiple correlations between spectral bands can be eliminated by preprocessing the spectra (Heim et al. 2018). It also speeds up operations and in some cases improves classification accuracy. Instead of using wavelengths across the entire spectrum, the raw spectra are averaged over the 10 and 40 nm intervals (Abdulridha et al. 2016). In this way, multi-correlation and noise in the wavebands are tried to be eliminated.

In addition to spectral preprocessing, plant and disease indices are extracted using spectral data at different wavelengths and associated with the physiological characteristics of healthy and diseased plants with these indices or used as input for classification (Giraldo-Betancourt et al. 2020). While some of the indices created are general-purpose plant indices, some are direct disease indices. Indices are obtained by proportioning the bands of different wavelengths and used directly in the diagnosis of diseases.

Giraldo-Betancourt et al. (2020) have used five different spectral indices (Normalized Difference Vegetation Index (NDVI), Chlorophyll Red-Edge (ChRE), Modified Chlorophyll Absorption Ratio Index (MCARI), Blue/Green Index (BGI), Simple Ration (SR) and Zarco and

Miller (ZM)) from the spectral data collected at different periods from goosbery plant they infected in the greenhouse environment. Using disease-specific spectral disease indices has improved distinguishing three different diseases in sugar beet using spectral data (Mahlein et al. 2013). Researchers have reported that spectral disease indices produced more successful results in differentiating diseased and healthy plants compared to general spectral vegetation indices.

4. Evaluation of spectral data

The differences in the spectral behavior of diseased and healthy plants can be determined by plotting the spectral values obtained at different wavelengths (Figure 2). The changes in the spectral reflection of the plant due to the disease can be observed in the spectral band ranges where these changes occur.

Plants under stress due to biotic factors show significant changes in their reflections in both the visible (350-700 nm) and infrared spectral regions (700-2500 nm). These generally expressed spectral regions are grouped into more specific sub-regions; 490-530 nm (blue edge), 510 - 530 nm (green edge), 690 – 740 nm (red edge), short wave infrared (900-1700 nm) (Zhang et al. 2012).

In general, the most changes in the spectral reflection of the plant are observed in the visible region (350-700 nm) due to biotic stresses. There are spectral differences in the infrared region as well as the visible region. The visible region have been found more important than the infrared region for powdery mildew disease in wheat (Zhang et al.

2012). Information at wavelengths shorter than 700 nm have been found to be more important for powdery mildew and other three diseases on grape.

A sample spectra of healthy and diseased plants obtained at visible and infrared wavelengths is given in Figure 2. Compared to healthy plants, in general, the reflection of diseased plants in the visible region increases, and their reflection in the infrared region decreases (Sterling and Melgarejo, 2020).

As a result of the decrease in chlorophyll production due to the plant's stress during the disease, the adsorption of the light reaching the visible region decreases, therefore the light reflection increases.

Table. 1. Summary of methodology, statistical methods, important bands in the diagnosis of various plant diseases with VNIRS technique

RESEARCH	CROP	PLANT PART	DISEASES	MEASUREMENT TYPE	ENVIRONMENT	EQUIPMENT	TYPE OF SPECTRA/INDICES	STATISTICAL METHODS	SIGNIFICANT WAVEBANDS
Zhang et al. 2012	Wheat	Leaf	Powdery mildew	Leaf	Laboratory	ASD FieldSpec	First derivative Continum removed spectra & Spectral vegetation indices	Correlation analysis, Independent t test, MLR & PLSR	470 nm, 670 nm (Cholorophyll adsorption), 550 nm 8green peak), 730 nm (red edge)
Mahlein et al. 2013	Sugar beet	Leaf	Cercospora leaf spot Sugar beet rust Powdery mildew	Leaf & Canopy	Laboratory & Field	Pistol grip foreoptic attached to ASD FieldSpecPro FR	Disease specific Spectral disease indices	k nearest neighbor	500 nm, 690 nm, 730 nm 500 nm, 570 nm, 700 nm 450 nm, 720 nm
Abdulridha et al. 2016	Avacado	Root	Laurel wilt Phytophthora root rot	Leaf	Laboratory	SVC HR-1024 spectroradiometer	Raw spectra averaged over 10 and 40 nm	Stepwise discriminant Multilayer perceptron NN Radial basis function	717-757 nm red edge range
Heim et al. 2018	Lemon myrtle trees	Leaf	Fungal	Leaf	Field	Spectral evolution PSR-3500 with Leaf clip	Raw spectra, First derivative	Random forest classifier	555 nm, 605 nm, 695 nm, 715 nm, 725 nm, 735 nm, 755 nm
Herrmann et al. 2018	Soybean	Root	Sudden Death Syndrome	Leaf & Canopy	Field	Piccolo Doppio dual field of view two spectrometer system mounted on a tractor & ASD Fieldspec 3 Leaf clip	Spectral indice (Normalized difference spectral index (NDSI)	Partial Least Square Regression (PLSR) Partial Least Square discriminant analysis (PLSDA)	Chlorophyll adsorption bands (670, 690 nm), Red edge (745-750 nm), NIR bands (750-900 nm), Water adsorption bands (1390, 1400 nm)
Giraldo-Betancourt et al. 2020	Cape gooseberry	Root	Fusarium vascular wilt	Leaf	Greenhouse	FieldSpec 4 Leaf clip	Spectral indices (NDVI, ChRE, BGI, SR, ZM)	Pearson's correlation analysis	551 nm, 670 nm
Sterling and Melgarejo, 2020	Rubber tree	Leaf	South American Leaf Blight (SALB)	Leaf	Laboratory	Apogee PS-100 Spectroradiometer	Spectral vegetation indices	Pearson's correlation analysis General Linear Model (GLM)	674 nm, 600-700 nm
Marin-Oriz et al. (2020)	Tomato	Root	Vascular wilt disease	Leaf	Laboratory	Ocean optics HR2000	Raw spectra	Pearson's correlation analysis Linear Discriminant Analysis	448-523 nm, 624-696 nm, 740-960 nm, 973-976 nm, 992-995 nm
Pithan et al. 2021	Grape	Leaf	Downy mildew Powdery mildew Black- foot Petri disease	Leaf	Greenhouse	FieldSpec 3 attached with Leaf clip	Spectrum ratio	Discriminant analysis	443 nm, 496 nm, 516 nm, 573 nm, 695 nm, 1420 nm, 1900 nm, 2435 nm

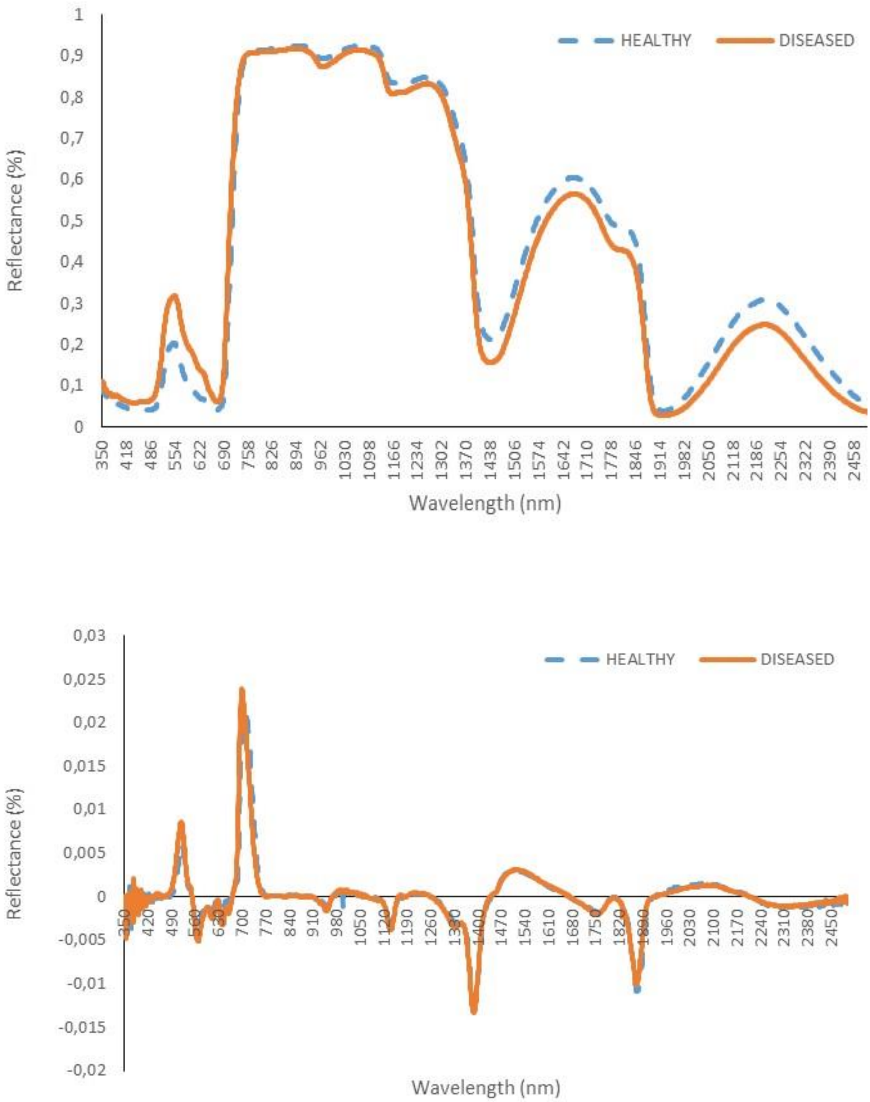

Figure 2. Raw (upper) and first derivative (bottom) spectra of healthy vs diseased crops (Bilgili et al., unpublished data)

Light adsorption decreases due to decreasing chlorophyll in the region called chlorophyll adsorption region (around 470, 670 nm). Sterling and Melgarejo (2020) have verified the high reflections that occur in the visible wavelength. They have showed that high spectral reflections in disease-sensitive clones are associated with reductions in photosynthetic pigments by measuring chlorophyll content indices.

In the infrared spectral region, in contrast to the visible region, there is a decrease in light reflection due to plant disease. The decrease in reflection in the infrared spectral region has been associated with the deterioration of the cell structure and water molecules due to plant disease and the entry of the pathogen into the plant.

5. Significant bands and band selection techniques

There are certain spectral bands at different wavelengths specific to each disease (Table 1). In terms of the effective use of spectroradiometry, detection of important bands that can be useful in the diagnosis of diseases is important (Mahlein et al. 2013). It also increases processing speed and is important for the development of inexpensive sensors for diagnosing plant diseases. Utilizing all spectral bands in disease diagnosis increases the processing load of the statistical method used (Zhang et al. 2012).

In general, bands in the visible region (400-700 nm) have been associated with the chlorophyll structure of the plant, bands in the red-edge region (685-715 nm) with chlorophyll structure and general plant stress, bands in the infrared region (1300 – 2500 nm) with cell integrity, as well as water content (Heim et al. 2018; Hermann et al. 2018; Giraldo-Betancourt et al. 2020).

Various methods have been used in the selection of important bands in the diagnosis of diseases, which included Principal Component Analysis (PCA), the relief algorithm (Mahlein et al. 2013), reflectance sensitivity analysis (Spectrum ratio between mean reflectances of diseased and healthy plants) (Sterling and Melgarejo, 2020; Pithan et al. 2021). Sterling and Melgarejo (2020) have calculated reflectance sensitivity for each wavelength dividing mean reflectance from the leaves of diseased plants by mean reflectance from the leaves of healthy plants in order to find significant wavebands showing more changes as response to disease severity. Similar approach has been used by Pithan et al. (2021).

6. Statistical techniques & Machine Learning Algorithms

With the help of various statistical methods and machine learning techniques, the relationships between spectral data and disease severity can be modeled, and distinguish between healthy and diseased plants can be made (Table 1). Pearson correlation analysis has been used to examine the relationships between the plant physiological parameters measured from healthy and diseased plants and the different indices calculated from the spectral data of these plants (Giraldo-Betancourt et al. 2020). Similarly, relationships between disease severity and spectral vegetation indices or different spectral indices obtained from disease sensitive wavelengths have been investigated using Pearson's correlation analysis (Zhang et al. 2012; Giraldo-Betancourt et al. 2020 ; Sterling and Melgarejo, 2020). The relationships between pathogen growth and spectral reflection in the plant root have been revealed by correlation analysis (Marin-Ortiz et al. 2020).

6.1. Modeling

There have been studies that model the severity of the disease using spectral data. Zhang et al (2012) have modeled the severity of mildew disease in wheat with MLR and PLSR techniques. Hermann et al (2018) have developed a linear model (PLSR) to predict root disease inoculation status (pathogen abundance) using spectral data.

A General Linear Model has been constructed to relate disease severity and various spectral vegetation indices obtained using the wavelengths sensitive to disease investigated (Sterling and Melgarejo, 2020).

6.2. Classification

In general, classifications have been performed to make distinctions between healthy plants and diseased plants based on spectral data (Figure 3). The use of spectral data has been also tested to distinguish between healthy, diseased and chemically treated plants (Heim et al. 2018), distinguishing healthy plants from plants under both biotic (diseased with pathogen) and abiotic stress (water stress or salinity) (Abdulridha et al. 2016; Marin – Ortiz et al. 2020).

Using various machine learning algorithms, high and very high success rates have been achieved in classification. Classification accuracies vary depending on the type of disease, the machine learning technique used, inputs used in the classification model, the environmental conditions in which the spectral data and type of spectral measurement (leaf vs canopy) are obtained as well as disease severity and period (early or late stages of the disease infection).

Heim et al. (2018) have achieved an overall success rate of 79% for diseased healthy and fungicide treated lemon myrtle trees in field conditions using random forest classifier method. The same researchers have achieved 95% success in classification by taking the first derivative of the spectra. In the study where canopy and leaf measurements have been made in the early diagnosis of sudden death syndrome in soybean plant in field conditions, leaf measurements were more successful both in cross-validation (79 % vs 87%) and also in independent validation (82 % vs 92 %) than canopy measurements in classifying healthy and diseased plants (Herrmann et al. 2018). Parallel to the increase in the severity of the disease (from 1 – 2 % to 30 %), the classification error in differentiating healthy and diseased sugar beet plants with spectral data also has decreased (from 52.1 % to 5.8 %) (Mahlein et al. 2013). Similarly, Zhang et al. (2012) have obtained the highest spectral discrimination power from heavily damaged leaves among three different levels of damaged plant leaves in wheat powdery mildew disease (normal, slightly damaged and heavily damaged). Pithan et al. (2021) have achieved an overall success level of 94.3% in the classification of four different diseases in the grapevine plant. The researchers have obtained a more successful result by using eight different spectra rather than the whole spectrum. A similar result has been reported by Zhang et al. (2012), researchers have shown graphically that the accuracy of classification decreases with the addition of more spectral variables to the classification. Marin-Ortiz et al. (2020) have achieved 100% classification success with the combined use of plant reflections and linear discriminant analysis technique between plants infected with *Fusarium* root disease, subjected to water stress and control plants. In the study in which Laurel wilt and *Phytophthora* root diseases of avocado plants have been classified by three different classification techniques (Stepwise discriminant, Multilayer perceptron NN, Radial basis function) using spectral reflections, the more successful results at early stages of disease (Per cent accuracies > 90 %) have been obtained from MP compare to other two (Per cent accuracies between 60- 73 %) (Abdulridha et al. 2016).

Different approaches can be used to test the accuracy of the models established for the classification of healthy and diseased plants. In cases where the data set is limited, n out cross-validation is generally preferred (Zhang et al. 2012), while independent validation test sets are used in studies with sufficient data. For independent test datasets, the whole dataset is divided into two parts, one set for calibration and the other set for validation (Herrmann et al. 2018). Herrmann et al. (2018) have split the data set into parts using 70 % of data as calibration and the rest of the data as validation data set in the study in which they have diagnosed the sudden death syndrome in soybean with spectral data in order to test the classification accuracy of healthy and diseased plants.

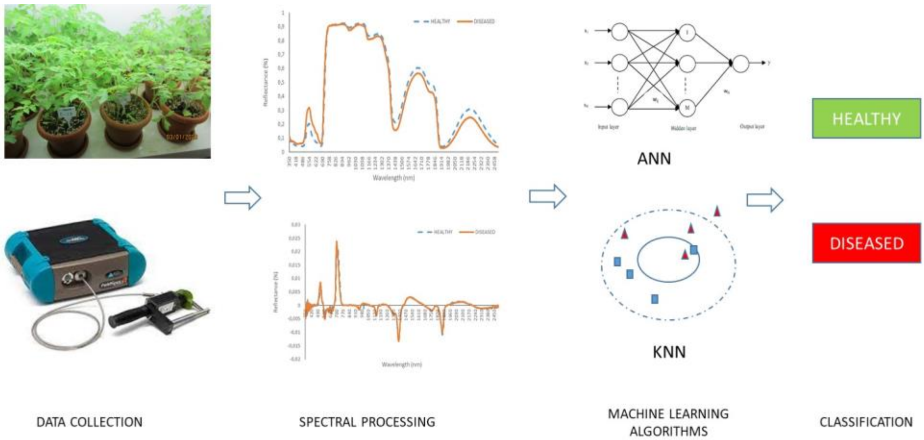

Figure 3. Stages in classification of healthy and diseased plants using spectral data; acquisition of spectral data, preprocessing of spectral data, classification using different machine learning techniques.

CONCLUSION

Using spectral data collected by spectroradiometric methods plant diseases can be diagnised successfully. Regardless of the plant and disease type, classification technique used, studying environment, spectral range used, or spectral pretreatment, previous studies have reported very high success rates. In the successful results obtained, the data obtained by direct contact with the plant by using high resolution spectroradiometers under controlled conditions play important role. Therefore, the high success rates achieved may seem quite optimistic. Successful results obtained under controlled conditions should be tested in field conditions and the validity of the technique should be demonstrated. It is very important to test the spectral bands which are reported to be useful in the diagnosis of specific plant diseases in real field conditions by integrating them into drone-like equipments.

VNIRS technique may have advantages such as speed, non-destructiveness, easy and accurate results. But the technique may have some disadvantages; for example, in order to obtain accurate results in some plant diseases, the severity of the disease may need to cover the plant at a certain rate or the problems such as drought or nitrogen deficiency, can produce similar spectral results with diseases in field conditions. Such problems may limit the use of the method.

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CHAPTER 7

THE ROLE OF PHEROMONES IN BIOTECHNICAL CONTROL WITH PESTS

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INTRODUCTION

In addition to meeting the nutritional needs of living things and creating the livelihood of the population living in rural areas, the agricultural sector also provides employment opportunities in the urban area by providing raw materials to the processing industry. The way to increase the yield and quality of agricultural products is through the use of modern agricultural techniques and inputs. As a complementary component of modern agriculture, pesticides from plant protection products are one of these inputs (Tiryaki et al, 2010). Since sustainable agricultural production, protection of human health, environment and biological diversity gains more and more importance nowadays, pesticides have been questioned in particular (Bulut and Göçmen, 2000).

Intensive pesticide use causes the development of drug resistance mechanisms of diseases, pests and weeds, while causing beneficial organisms in nature to be adversely affected, and pesticide residues that will occur in the product pose a problem for human health. In addition, the tendency to become a customer for healthy products by setting limits for the amount of drug residues that may be in the product they will buy, especially in developed countries, is a factor that reduces competitiveness in exports. The main objective of the integrated struggle studies, which were initiated in 1970 in order to protect human and environmental health and to carry out sustainable agriculture, is to train the producers to reach the level where they can implement integrated combat programs (Karaturhan, 2005). At the beginning of the alternative control methods, biological and biotechnical control methods, which are the most important components of integrated control, come first. With the biological control method, harmful organisms that cause economic losses in plant production are combated by using beneficial organisms found in nature.

Biotechnical control, on the other hand, means controlling the biological and physiological behaviors in their normal course with some techniques instead of killing harmful organisms directly (Birişik et al., 2013). Studies for classical biological control started with the importation of parasitoids and predators control *Icerya purchasi* Maskell (Hemiptera: Monophlebidae) in 1910 for the first time in our country. Later, beneficial insects were imported control apple cotton weevil, mulberry crustacean, sunn pest, citrus mealybug, carob moth, red scab, brown snail, aphids, bay whitefly and citrus whitefly. Many insects usually secrete pheromones to communicate with each other. Thus, synthetic pheromones are produced based on the sex pheromones of insects. Biotechnical methods are a modern method of struggle in which the drug is not used or used less. The general purpose of these methods is to protect the environment and human health. In Entomology, biotechnical methods can be described as "using the physical, chemical and biological characteristics that affect the development of harmful species, keeping the population under pressure and their behavior", as well as "attracting and trapping systems, pheromones, hormones, repellent and all kinds of factors that prevent growth (autocidal control). methods) can be defined as research, development and application.

These chemical substances are called semiochemicals or “Behavior modifying chemicals” that affect or change behavior. Biotechnical methods were first used for some forest pests in 1964. Since it has no negative effects on humans and the environment, applications have gradually increased and it has become an important study in the field of Plant Protection (Serez and Zümreoğlu, 2001). Studies on biotechnical control in Turkey do not date back to ancient times. As a result of the R&D studies initiated control insects that cause damage to different types of fruits, vineyards and vegetables in the 1980s, the effectiveness of the biotechnical control method was revealed and this control method was included in the technical instructions. Especially in parallel with the development of organic agriculture, these products have been imported and used widely (Birişik et al., 2013).

1. Biotechnical Control

The technique of preventing mating is thought to be the creation of a dense odor cloud as a result of the pheromone scent secreted by female insects being distributed to an area together with the emitters and thus preventing male insects from finding female butterflies (Anonymous, 2010).

The methods applied by using some natural and artificial substances that are effective on the physiological, biological and behavioral characteristics of the pest, by disrupting its normal characteristics such as mating, shelter and feeding are called 'Biotechnical Methods' (Altındişli, 2004). To achieve this aim, some synthetic and natural compounds or methods such as pheromone, pheromone-trap systems, traps, spawn inhibitors, attractants, sterilisers, repellants, feeding inhibitors, insect growth regulators, insect growth inhibitors and sterile insect release are used (Altındişli and Özsemerci, 2009).

The biggest advantage of biotechnical methods is that they adapt easily to environmental conditions and are species specific. If these methods are applied especially control pests of economic and main importance, they contribute to the re-establishment of the natural balance, which was previously disturbed by the use of chemical pesticides in that area, as they reset or minimize the use of pesticides. As a result of re-establishing the natural balance, pests can be easily controlled by natural enemies, and the need for chemical control gradually decreases. In biotechnical methods, some compounds are needed to combat pests. These compounds can be found naturally in living things or they can be produced synthetically. The biotechnical method, which has the widest area of use to combat harmful insects, is sexual (sexual) pheromone-trap systems.

1.1. Pheromones

Pheromones are used for two different purposes in insect control programs. The first of these is population density determination, and the second is extermination by trap. Both use pheromone traps, in which preparations containing pheromone substances are usually mounted. Today, pheromone traps are widely used besides other trap types in all kinds of control programs including biological control and in population survey studies. For example, good results are obtained from traps with pheromone and light apparatus for catching night-flying butterflies. Likewise, the density of the pest can be determined by utilizing pheromone traps in population surveys carried out to decide whether there is a need for control.

Pheromones were previously equated with hormones. Although they are secreted in small amounts like hormones and fulfill a certain vital function, their secretion outside the body distinguishes them from hormones. Pheromones are often species-specific. There are also those that perform very different functions and in different combinations. Pheromones, which have a very high spreading ability, can be effective even from an enormous distance of 7-8 km.

Factors such as distance, temperature, wind and humidity can also reduce and increase the effect of pheromones (Anonymous, 2007). Looking at the historical development of sexual pheromones and traps and emitters, it was revealed by research 120 years ago that female butterflies have the ability to attract male butterflies and attract them to their location. Before the artificial production of pheromones 100 years ago, traps in which female butterflies were placed directly as lures were used.

The chemical diagnosis of the sexual attractant of the silkworm in the 1950s was the most important development in the history of biotechnical control, and after Schneider proved by means of an electroantenogram that the antennae of male butterflies are the organs that detect the attractant secreted by the female. After the discovery of this type of attractant secreted by females in the same species to attract males, it was named pheromone.

The sexual attractant of female silkworms was the first pheromone to be diagnosed as bombykol in 1959. After the discovery of this pheromone, the studies of scientists focused on the orientation of harmful insects to smell and the sense of smell (Schenider, 1999). Pheromones are derived from the Greek words “Pherin” (to carry) and “Hormon” (to encourage, to warn). Pheromones are also defined as endo and exohormonal chemical compounds that are secreted by some individuals of the species and cause a hormonal reaction in other individuals of the species (Serez and Zümreoğlu, 2001). Although pheromones differ from hormones by being secreted out of the body, they are similar to hormones in that they are secreted in small amounts and synthesized for a specific function. Pheromones regulate sexual and social behavior in many species, and as there are pheromones specific to each species, different pheromones are secreted for different functions within the species. Although it is different in each pheromone, the spreading abilities of pheromones, which can show their effects even from distances such as 7-8 km, are positively or negatively affected by environmental factors such as humidity, wind and temperature. Communication is achieved by using pheromones in socially living species such as ants, termites and bees (Keeling et al., 2003; Kaib et al., 2004; Sade, 2007). Pheromones have played an important role in informing the male animals of the breeding time of a female animal, calling them to her side, regulating the social life of the ants, preventing the reproduction of all female bees except the queen bee and making them work as workers. Since pheromones are highly effective, odorless and volatile substances, other living things are unintentionally affected after they are secreted. In insect species such as bees and ants, pheromones play a very important role in the regulation of social life and reproduction as a means of communication.

An insect contains 9–10 mg of pheromone or less. Today, over 1,000 pheromone types have been identified. They have been found mainly in insects, but also in crustacean arthropods, spiders, fish, frogs, reptiles and mammals, but not in birds. In general, after being secreted from a living thing, pheromones can provide many interactions, such as communication, and cause behavioral changes in other organisms of the same species. When dealing with pests, knowing at what times, where, and at what stage of life the pest appeared, gives very important information about the behavior and population of this pest. In the light of this information obtained, effective, easy and cheap solutions can be reached in the control.

The use of chemicals in the control pests loses its effectiveness day by day due to reasons such as the pest's discovery of this chemical and creating immunity to this chemical, and the chemical left behind in the products obtained. At this point, the use of pheromones in the control of pests is very advantageous as it does not harm the environment and provides high success.

1.2. Classification of Pheromones

Pheromones for meeting insects; It is divided into sex pheromones and aggregation pheromones. The sex pheromone is used by solitary insects to find a mate for mating. The assembly, that is, the general meeting pheromone, indicates that a suitable place for incubation has been found. The purpose of gathering is to occupy the host tree cooperatively and meanwhile the spouses can find each other (Oğurlu, 2000).

1.2.1. Gender Pheromones

In sexual reproduction, which occurs in insects and is necessary for the continuation of generations, male and female individuals must meet. The meeting takes place in many species thanks to the secreted pheromones (Oğurlu, 2000). The most commonly used control harmful insects are the sexual pheromones. Males are attracted by the scent that female insects emit from their bodies as a mating call. Each type of insect has its own specific smell. These odors are used in trap systems either naturally obtained from the body of the insect or by synthesis and production.

Species-specific pheromone substances obtained artificially in laboratories are impregnated in capsules or diffusers in a certain amount. A non-drying adhesive-coated table is placed in the trap, which is prepared in the most attractive color and shape, and a pheromone capsule is attached to it. This prepared trap system is hung on a branch of the plant or on a pole nailed to the ground with wire or rope. These traps are placed at suitable spacing and height in the garden or field, in the direction of the prevailing wind if it is important for the species being struggled. Perceiving the pheromone, the male individual heads here and falls on the sticky table and is caught in the trap. The most important feature expected from a pheromone trap is that it spreads the pheromone at a rate close to the most effective amount and continuously throughout the life of the trap (Anonymous, 2008).

1.2.2. Assemblage Pheromones

It is produced by any individual belonging to a species, but it acts on both female and male individuals and gives a warning of the same quality. They are commonly seen in bark beetles (Scolytidae). For this reason, they are also called “General Meeting Pheromones” (Serez and Zümreoğlu, 2001). In bark beetle species, individuals who find a suitable place for vital activities such as feeding and laying eggs secrete pheromones to call other members of the group there.

2. Uses of Pheromones for Controlling Purposes

2.1. Mass Trapping Technique

In this method, which works according to the principle of suppressing the male insect population, it is aimed to prevent the mating and thus the formation of new offspring by catching the majority of the male individuals of the harmful insect species or by keeping their numbers under pressure. The application should be made in the early period when the pest population has not yet started to form. It is not an effective method control every insect species, and successful results have been obtained control cherry fly (*Rhagoletis cerasi*), olive fly

(*Bactrocera oleae*) and partially apple borer (*Cydia pomonella*) in the world. Sex attractant pheromones are used in the control insects in two ways, indirect and direct. It is used indirectly to monitor pest populations and decide when to control. In agricultural warfare, that is, mass capture, pheromones are used directly control pests in two ways. The first one is to catch the pests in mass and reduce their populations by placing traps with pheromone at certain intervals and at certain densities in the culture areas. The first studies on the application of mass capture method in Turkey started in 1991 with *Cydia pomonella* (L.) within the scope of the National Biotechnology Project (Zümreoğlu, 1990). Great success has been achieved as a result of the mass capture of *Dendoctonus micans* (Kug.) (Coleoptera: Scolytidae) (Giant bark beetle) in forest areas in and around Artvin by the Ministry of Agriculture and Forestry.

Figure 1. *Dendoctonus micans* caught by the mass capture method

2.2. Mating Disruption Technique

This technique, which makes use of sex pheromones, is intended to change the behavior of the male insect by placing too many pheromones in the relevant region. The male individual, which is exposed to intense pheromone release, is confused in which direction to go and cannot find the female. In this way, mating is prevented and since no new offspring is formed, a decrease in the pest population is observed.

2.3. Monitoring and Identification (Monitoring) Technique

The aim of this technique, which is called monitoring and determination, is to determine the time of emergence of the adults, their harmful behavior, the time when it is appropriate to use traps, and the time when the spraying period is appropriate.

Figure 2. Use of pheromones in pest control

3.Advantages of Using Pheromones in Pest Control

- Highly adaptable to environmental conditions,
- No undesirable side effects on human health and the environment,
- To be reliable in terms of ecological conditions,
- Easy to apply,
- It is a very safe procedure compared to drug use,
- They can be integrated especially with chemical and biological methods,
- Consist of completely non-toxic substances,
- They do not harm other living things in nature, as they are attractive and attractive odors specific to the species,
- Allows for a selective struggle,
- The goal is not to harm any living thing other than the living thing.

4.Disadvantages of Using Pheromones in Pest Control

- Not being equally applicable to all kinds of pests,

- Especially high initial investments,

- The effects are relatively low if the population density is high.

CONCLUSION

Insect tracking and control with the most commonly used pheromone traps in the Biotechnical Control method, which is one of the methods of controlling insects, is increasingly used by farmers to become an alternative to Chemical Control due to its environmentally friendly and long-lasting effect. In addition to monitoring the populations of pests for monitor purposes, pheromone traps strengthen the hand of both technical personnel and producers in combating mass trapping. In particular, for pests whose chemical control is difficult or the desired results cannot be achieved in insecticide applications, biotechnical control method seems to be promising in pest control in the coming years.

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CHAPTER 8

AFLATOXINS AND AFLATOXIN FORMATION & MANAGEMENT IN RED PEPPERS

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INTRODUCTION

Microorganisms can take place in the flora of agricultural products and various foodstuffs or they can be transmitted to these products in different ways afterwards. Fungi, namely molds, constitute an important group among these organisms. Molds play an important role in the production of many organic substances such as vitamins, enzymes, antibiotics, alcohol, organic acids in the industry. However, they can also cause undesirable changes and spoilage in foods and agricultural products under suitable conditions for their development. In addition, they can cause diseases in humans and animals by producing various toxic metabolites in the products they develop. These toxic metabolites created by molds are called "mycotoxins" and the disease forms they create in humans and animals are called "mycotoxicosis" (Taydaş and Aşkın, 1995).

About 10% of the world's crops are destroyed each year due to fungal infections (Zhang et al., 2012). Losses from mycotoxins are only part of it. Aflatoxins in agricultural products are the most toxic mycotoxins and are one of the most important microbiological problems of recent years. Aflatoxins are metabolites of *Aspergillus flavus* and *Aspergillus parasiticus* species known as *Aspergillus flavus* group.

Mycotoxins are secondary metabolites of some sub-fungi that develop and reproduce in agricultural products depending on ecological conditions in all stages from field to consumption. These toxins are formed by some fungi such as *Aspergillus*, *Penicillium* and *Fusarium* under certain humidity and temperature conditions (Kumar et al., 2008). The most common mycotoxins can be listed as aflatoxin (AF), ochratoxin, trichothecenes, zeranol, patulin, cyclopiazonic acid and fumonisin (Kumar et al., 2008; O'Riordan and Wilkinson, 2008).

In this study, it is aimed to evaluate the presence of aflatoxins, which come to the forefront with their carcinogenic, teratogenic, hepatotoxic and mutagenic effects, in foods and especially in red peppers, how they are formed, the contamination situation from farm to table, and the management of aflatoxin.

2. What is Aflatoxin?

Aflatoxin, which has significantly affected our lives in recent years, is one of the many chemicals produced by some of the molds we encounter everywhere in our daily life. Among these chemicals, some of them are poisonous because they cause disease in humans and animals, and aflatoxin is one of them. In fact, the word aflatoxin is derived from the name of the mold that makes it (*Aspergillus flavus*) and the word "toxin" meaning poison.

Contamination of food products, which have an important place in human nutrition, with aflatoxin is a common situation in various parts of the world. Therefore, these contaminations both pose a risk to public health by affecting food safety and also cause significant economic losses in the agricultural industry (O'Riordan and Wilkinson, 2008).

This substance affects many organs in humans, especially the liver, and gradually leads to liver cancer. This effect has been definitively proven in recent years by genetic studies. In addition, studies conducted in many countries have shown that there is a close relationship between the number of people suffering from liver cancer and the food they consume with aflatoxin.

Aflatoxin, which is known to be the most toxic among mycotoxins, is produced by *A.flavus* and *A. parasiticus* molds, namely fungi. It is stated that *A. nomius*, which has similar properties to *A. flavus*, also produces aflatoxin. (Betina, 1989; Kurtzman et al., 1987).

3. How Is Aflatoxin Formed?

Aspergillus flavus, *A. parasiticus*, *A. nomius* and *A. pseudotamarii* species are fungi that can produce aflatoxin. Among the products in which aflatoxins occur, oilseeds, nuts, legumes, cereals, meal, feed, foods of animal origin, spices, etc. many more products can be counted. It has been revealed in many literature that various red pepper species belonging to the Capsicum genus are among the risky products in terms of aflatoxin formation (Nesheim, 1976; Bullerman, 1986; Taydaş, 1993; Yıldırım, 1996; Aydın et al., 2007).

The first condition for the formation of aflatoxin in a food is the contamination of the spores of the fungus that produces this toxin to the food; The second, more important condition is that the food itself and the environment it is in must have conditions that will allow the spores of this fungus to germinate and multiply. Although the fungus or its spores often do not have any negative effects on human health, some of the substances they produce are harmful and many of these substances do not disappear with high temperature. There is a possibility that aflatoxin or another similar toxic substance will occur in every food item where fungi can grow.

Aflatoxins can occur during harvesting, drying, storage, processing of the product in the form of food and feed, as well as while the product is developing in the field or garden. Aflatoxin formation is impacted by many factors such as product humidity, drying rate, relative humidity of the environment, temperature, density of fungi or spores in the environment, toxin formation power of growing species, competition between microorganisms, resistance of the crop and the cultivated variety, activity of insects or other pests, plant stress, air temperature and the composition of atmospheric gases (Çoksöyler, 1999).

Relative humidity and temperature are important parameters in the development of aflatoxins. The optimum conditions for the development of aflatoxin are 24–35 °C and relative humidity above 70% (Arrus et al., 2005; Odoemelam and Osu, 2009). In addition, aflatoxin production in foods and mycelial growth of the fungus are controlled by temperature and water activity (aw) (Table 1). Other factors are temperature application, modified atmosphere packaging and use of preservatives (Molina and Giannuzzi, 2002). Therefore, it is a common contaminant in seeds such as peppers, grains, corn, cotton, peanuts and hazelnuts that are dried in the air or sun (Bonjar, 2004;

Giorni et al., 2008). It is known that there are high amounts of aflatoxins, especially in seeds.

Table 1. Optimum conditions for the formation of aflatoxin and *Aspergillus* (Odoemelam and Osu, 2009).

***Aspergillus* (opt.)**		**Aflatoxin (formation)**	
Temperature	32-33 ºC	Temperature	12-40 ºC
pH	3,5-8	pH	5-6
Water activity (aw)	0,94-0,98	Water activity (aw)	≥0,83

The temperature and water activity (aw) values required for mold growth are not the same as those required for toxin formation and vary according to the species. For example, *A. parasiticus* grows at 0.82 aw and produces toxins at 0.83 aw. Aw values for the growth of *A. flavus* and production of mycotoxins, on the other hand, are 0.73 and 0.85, respectively. In this case, the moisture content is also 8-12% and 17-19% (Giorni et al., 2008).

The minimum temperature values required for mold and toxin formation also differ. The lowest temperature range for the development of *A. parasiticus* is 6-8 ^{O}C, while optimum growth is provided at 25-35 ^{O}C. While the best growth range for *A. flavus* is 19–35°C, it produces toxins between 12–42°C (Bhat et al., 2010).

Aflatoxin contamination can occur quickly. In a study, it was stated that the presence of aflatoxin in plants inoculated with *A. flavus* was 0.3-2 ppb two days later, 950-2.800 ppb four days later and 3.600-4.500 ppb seven days later. (Coppock and Christian, 2007).

4. Aflatoxin Formation in Red Peppers

Red pepper powder is a spice obtained by drying and grinding a vegetable belonging to the *Capcicum annuum* species, which belongs to the ‘Solanaceae’ family, and used to add flavor and bitterness to the dishes (Madhyastha and Bhat, 1984).

Red pepper (*Capsicum annuum*) and its products are a popular spice that is widely consumed in the World (Saha et al., 2007). Turkey is one of the countries that produce a high amount of red pepper, such as India, Mexico, America and Spain. Red pepper powder is one of the most frequently used spices for the color, flavor and aroma of the food in Turkey (Aydın et al., 2007).

In the Southeastern Anatolia Region (GAP), pepper production is very common and is carried out in the form of field vegetables. Pepper (13%), which is in the 2nd place in terms of vegetable production area, is in the 3rd place in terms of production amount with 14% (TUİK, 2021).

Red peppers are the most susceptible to aflatoxin formation (Bullerman, 1979; Madhyastha and Bhat, 1984). The drying process of these peppers is carried out under primitive conditions and especially on the soil, and the dried peppers are collected by sweeping them from the ground. This process increases the possibility of contamination of peppers with soil-borne toxicogenic molds. The differences between the aflatoxin presence rates are due to the pepper types and drying methods.

However, spices such as pepper, turmeric, black pepper, coriander and dried ginger can also be contaminated before harvesting, after harvesting, during storage and transportation (Wiliams, 1984; O'Riordan and Wilkinson, 2008).

In tropical climates, spices can be contaminated by fungi, that is molds, depending on environmental conditions. The countries with the largest pepper producers in the world are located in the tropics. Therefore, there are suitable climatic conditions for the development of mycotoxin-producing molds in red pepper and its products (Marin et al., 2009). Natural drying conditions can determine the extent of this contamination and toxin formation. For this reason, as a result of leaving the pepper samples to natural drying in the soil under primitive conditions, they can be highly contaminated with molds. However, peppers are often dried in the open air under poor hygienic conditions (Ardıç et al., 2009). Especially *A. flavus* causes problems in agricultural products grown in tropical and subtropical climates. The researchers stated that after the molds create toxins, they cannot survive if the environmental conditions are not suitable, but the toxins can remain in the product (Taydaş, 1993). The use of modern drying systems while obtaining the product prevents the formation of toxins to a great extent (Yıldırım, 1996).

Red pepper is one of the products sensitive to aflatoxin formation due to the conditions it faces during production, harvesting, drying and further processing (Ardıç et al., 2009). Red pepper is the spice with the highest aflatoxin content (Marin et al., 2009). Many factors such as the climate of the region, product genotype and soil type are effective in the contamination of these peppers with mycotoxins (Hernández-Hierro et al., 2008).

Like many other products, red peppers can be contaminated with aflatoxins before harvest, after harvest, during storage and during transportation (Marin et al., 2009; Hernández-Hierro, 2008). In the Turkish Food Codex Legistlation numbered 2008/26 and 165/2010 on the maximum limits of contaminants in food products, it is stated that the maximum amount of AFB1 and total aflatoxin for whole and powdered red peppers are 5 μg kg-1 and 10 μg kg-1, respectively. (Anonymous, 2008-2010).

The production of red pepper used in the production of red flakes and powdered peppers, which are consumed fondly as a spice in our country, is made under very primitive conditions. After the red peppers collected from the field are cut into small pieces, they are dried on the soil and then ground into powder in the mills. It is sold to wholesalers in nylon and cloth sacks. Therefore, soil-borne toxicogenic mold contamination and toxin formation are very common in red peppers (Yıldırım, 1996).

Studies show that red pepper species in the genus *Capsicum* are among the risky products in terms of mold metabolites such as aflatoxin and ochratoxin, which have carcinogenic and teratogenic effects. Mold contamination in red pepper starts while it is on the plant and mold growth and toxin formation continue during the period until harvest and then during drying. It has been determined that the formation of aflatoxin begins while still on the pepper branch (Ünlütürk and Turantaş, 1998).

During the flowering period of red peppers, the spores of the fungus are transmitted to the pollen. In addition, as a result of insect damage, mold spores of the fungus can spread to the inner part of the peppers and develop in suitable environments and form toxins (FAO, 1990; Taydaş, 1993).

As a result of various researches, the determined aflatoxin levels of red peppers offered for consumption in Turkey are presented in Table 2 (Yentür and Er, 2012). When these values are examined; It has been observed that there are differences with the effect of factors such as food type, regional and seasonal characteristics.

Table 2. Aflatoxin levels of red peppers consumed in Turkey (Yentur and Er, 2012)

Agricultural Crops	**Sample Quantity (Positive Example)**	**Aflatoxin Type**	**Aflatoxin Levels**	**References**
Red pepper and products	100	AFB1	<0,025-40,9 µg kg-1	Aydın et al., 2007
Red pepper and products	75 (72)	AFB1	0,11-24,7 µg kg-1	Ardıç et al., 2008
Red pepper and products	23 (19)	TAF	1,79-6,55 µg kg-1	Bircan et al., 2008
Red pepper and products	190	AFB1	0,20-6,12 ppb	Yentür, 2010

In a study conducted in our country, a total of 127 red pepper samples; 33 fresh, 33 dry, 31 powdered, and 30 red pepper flakes, were examined. Aflatoxin B1 and aflatoxin B1 and aflatoxin B2 formations were observed in 83 and 2 of 127 red pepper samples, respectivelly. Aflatoxin B1 was found in 28 of 31 red pepper powder samples, no aflatoxin was found in 3 of them. The amount of aflatoxin B1 in the samples ranged from 0 to 28.5 ppb. Contamination rates of samples with *A.flavus* type mold were 9.09%, 70%, 90.32% and 83.33% in fresh, dry, powdered and flaked red peppers, respectively. It was determined that mostly *A. flavus* group molds were dominant in the environment. The rate of aflatoxins in fresh, dry, powdered and flaked red pepper samples, respectively were found to be 9.09%, 12.72%, 90.30% and 100%. Thus, it was determined that red pepper flakes had the highest aflatoxin ratio (Taydaş and Aşkın, 1995).

In a study conducted on crushed and dried red peppers in Bursa and Sakarya regions, aflatoxin B1 was found in 8 of 34 red pepper powder samples. The rate of aflatoxin presence is 23.5%. The amount of aflatoxin B1 in the samples varies between 0 - 15 ppb (Yıldırım, 1996).

In another study conducted on 2 red pepper varieties, the chemical compositions, aflatoxin levels and mold amounts of *Capsicum annuum* and *Capsicum frutescens* dried under natural conditions were compared. Of these, no aflatoxin was found in *C. annum*. In both pepper varieties, *Rhizopus oryzaze, Aspergillus niger*, *A. flavus*, *Geotrichum candidum* and *Saccharomyces spp*. identified as the dominant flora (Adegoke et al. 1996). In another study conducted on dried pepper samples of *Capsicum annuum* and *Capsicum frutescens*, While no damage and mold growth were observed on the surface of the pepper samples, it was reported that *A. flavus* contamination was high in the interior parts, which was invisible but determined by microbiological analysis (Helrich, 1990).

In a study conducted by Dokuzlu (2001), aflatoxin, B1, B2, G1 and G2 were analyzed in 30 red pepper. Aflatoxin B1 was detected in 13 of 30 samples and both aflatoxin B1 and aflatoxin G1 were detected in 1 sample. Various concentrations of aflatoxin were detected in 46.66% of the samples analyzed by thin layer chromatography and semi-quantitative procedure method. The amount of aflatoxin B1 in the samples was 5-25 ppb, and the amount of G1 was 15 ppb. Aflatoxin B2 and G2 were not detected. As a result, they recommended that the aflatoxin in red pepper are present and they may have some potential risks for human.

On the other hand, Bircan et al. (2008) found total aflatoxin in 19 of 23 peppers in the ratios of 1.79–6.55 μg kg-1, respectively. According to the results of the study by Yentür and Er (2012), the amount of aflatoxin B1 detected in 11 samples was found above the 5 ppb limit.

Also, in another study, during the project work in the Southeastern Anatolia Region (GAP) (Bilgili, 2017; Bilgili et al., 2017; Bilgili, 2018; Bilgili and Güldür, 2018), it has been observed that red pepper production is performed in very primitive conditions and fresh red peppers are left to dry under the sun for a short period of 3-5 days directly on the ground after being picked from their branches and then sold to factories. Thus, it is understood that mold growth and aflatoxin formation of fresh red peppers begin on the branch, and the red peppers are not picked on the branch when they are reddened, and they reach a much higher level as a result of drying on the soil, as a result of being left for a long time until they lose some moisture and harvested late. Considering these primitive conditions, it is seen that red peppers are a very open product to soil-borne toxigenic mold contamination and toxin formation.

In her study, Bilgili (2017) determined that *Aspergillus flavus*, *Aspergillus niger* and *Aspergillus sp.* were present in pepper plants grown in the GAP region in field studies (Figure 1). *Aspergillus niger*, one of the fungal isolates identified in pepper production areas during the 2013 and 2014 surveys was detected in the provinces of Şanlıurfa, Diyarbakır, Siirt, Gaziantep, Kilis and Şırnak; *Aspergillus flavus* was detected in Diyarbakir and Kilis provinces. 63 fields out of a total of

296 fields sampled (equaling to 21.28 %), has been found to be contaminated with *Aspergillus spp.*

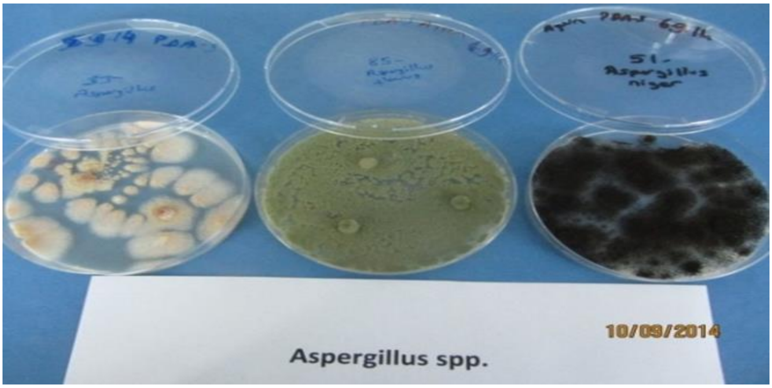

Figure 1. Appearance of *Aspergillus* spp. fungi, obtained from the diseased plant tissues in open field pepper cultivation in the GAP Region, growing in PDA-S in petri dish (Bilgili, 2017).

As a result, it has been determined by various studies that there is a contamination with aflatoxins in a large part of red pepper powder and this is a potential risk for human health. In addition, in scientific studies, it was determined that toxigenic mold contamination and aflatoxin production started to occur before harvest depending on environmental conditions and increased greatly during natural drying in the field.

6. Aflatoxin Management in Red Peppers

According to TUIK data (2021), pepper production in our country is 2 457,822 tons per year on an area of 815,632 decares, and it is produced in two ways as greenhouse cultivation and field cultivation. In our country, pepper is a very important and strategic product because it is consumed both for tomato paste and for drying, as well as for table and spice. For this reason, the pepper plant and its fruit must be free from various diseases and pests.

Aflatoxin formation starts while the pepper is still on the branch and continues during drying. Therefore, some precautionary measures should be taken. The measures that can be taken can be listed as follows;

i) First of all, measures should be taken to prevent the formation of AF.
ii) The problem can be reduced by the precautions to be taken during the drying phase.
iii) Care should be taken in drying

The drying process should be done not in the soil, but in modern drying systems, and as soon as the peppers are reddened, they should be collected and dried immediately, without waiting on the branch.

Before post-harvest storage, it is necessary to reduce the moisture content of red pepper to a certain level. Instead of drying on soil or cloth under the sun, it should be dried quickly and the humidity should be reduced to much lower than 10%.

iv) Drying the pepper by shredding is an important factor in reducing the AF level.
v) Harvest should be done on time and modern techniques should be used in the drying process.
vi) Contamination during and after harvest should be prevented.

vii) Before the products are taken to the warehouse, the rotten and damaged ones should be separated.

viii) If the storage and transportation processes are not carried out with low humidity before product processing, aflatoxin formation phases are the most common. Bird and insect attacks should be prevented before harvest.

ix) Damaged red peppers and garbage after harvest should be separated immediately. The product should not be placed in the warehouse when it is wet and care should be taken not to increase the moisture content.

x) The subject should be meticulously emphasized and the producer should be made aware.

xi) Drying method on cloth, soil and net made with traditional methods must be changed.

xii) Temperature and humidity controls should be made in the warehouses.

xiii) There should be no pests, insects and animals in the warehouse.

xiv) It must be absolutely avoided that the product shell is not damaged.

xv) Vacuum packaging should be used in product packaging.

xvi) Red Pepper, which fluoresces especially under UV lamps, can be separated by automatic tools and the aflatoxin content in the product can be reduced by up to 50%.

xvii) Aflatoxins are sensitive to UV radiation at 222, 265 and 362 nm. It shows the greatest absorption at 362 nm (Aşkın and Taydaş, 1996; Yıldırım, 1996).

xviii) Water activity (aw) plays a critical role in the inactivation and degradation of aflatoxins by γ beam radiation (Rustom, 1997).

xix) Recently, ozonation, which is an oxidation method for aflatoxin detoxification in foods, has been developed (Viladimir, 1989).

xx) Structural degradation or inactivation of aflatoxins is possible with chemicals.

CONCLUSION

Aflatoxins are mycotoxins that are commonly found in many foods, including spices. Foods can be contaminated with aflatoxins during product processing, storage and sale. Aflatoxins are generally stable in foods and resistant to temperature. When the conditions required for the formation of these toxins continue, the rate of contamination may increase. It does not seem possible to completely purify contaminated food from aflatoxins.

Contamination of foodstuffs with aflatoxins is a serious problem worldwide. Diseases that can result in death can occur in people who consume food contaminated with aflatoxins. Studies investigating the presence of aflatoxin have been carried out in different countries.

Aflatoxin levels in various foods in these studies may differ depending on climatic and regional reasons or food type.

Aflatoxins are the most toxic mycotoxins. Considering the harmful carcinogenic effects on human health, tolerance limits have been set for aflatoxin that can be found in foods in various countries. The European Community has accepted the limit value for aflatoxin B1 that can be found in human foods as 2 - 4 ppb (Rustom, 1997). In Turkey, as in many other countries, there are legal restrictions on aflatoxin contamination in foods. Therefore, in the Turkish Food Codex (TGK) Regulation, legal limits for Aflatoxin B1 (AFB1), Total Aflatoxin-TAF (B1, B2, G1 and G2) and Aflatoxin M1 (AFM1) have been determined for many foodstuffs (Anonymous, 2008). In our country, the highest acceptable value in spices was determined as 5 ppb for aflatoxin B1 and 10 ppb for the total amount of aflatoxin (Kumar et al., 2008; Anoymous, 2010).

Aflatoxins can reach humans through contaminated food and products obtained from animals fed contaminated feed, causing acute or chronic toxicity. Exposure level, age, gender, nutrition and some health factors affect the level of toxicity. Studies have reported that aflatoxins can be dangerous for human life and cause liver cancer due to their toxic, carcinogenic, teratogenic, hepatotoxic and mutagenic characteristics. Therefore, aflatoxin contamination remains important in terms of food safety. Long-term consumption of foods containing high amounts of aflatoxin may cause problems in terms of public health, as well as negatively affecting exports and causing economic losses in the country. Therefore, it is important to trace the formation of mycotoxins from production to consumption and to prevent the development of these fungi, which are transmitted in various ways, with advanced technologies and good practices (Banu and Muthumary, 2010; Yentür et al., 2006).

The main reasons for the increase in aflatoxin formation are the water activity and humidity values in fresh red pepper fruits and the suitability of the climatic conditions of the region. In addition, the fact that the temperature is at optimum values for toxin production during the drying process can be considered among the most effective reasons. In order to prevent the formation of toxins in this period, it can be suggested as the most effective solution that the drying process is carried out not in the soil, but in modern drying systems, and when the peppers are reddened, without waiting on the branch, they are collected and dried without losing time and stored under appropriate conditions.

As a result, it has been observed that red pepper powder, which is used especially for flavoring the dishes, poses a risk in terms of aflatoxin. In order to improve this situation, primitive methods should be avoided in the production of red pepper powder, especially the drying process should be done with modern techniques. In addition, due to the fact that red peppers are a product with export value, their high levels of toxins can cause various problems in terms of exports. It is clear that this situation will lead to economic losses in the country. This is extremely important for both public health and our exports.

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CHAPTER 9

BIOLOGICAL CONTROL TO PESTS IN AGRICULTURE

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INTRODUCTION

Although legal, cultural, physical, mechanical, biological and chemical methods can be used to combat living factors that adversely affect yield and quality in plants, chemical control is the most widely used method due to its ease of use and rapid effect. The first examples of pesticide use date back to ancient times, and the fungicide and insecticide properties of sulfur have been known for over 3000 years. Arsenic compounds were discovered in ancient Chinese civilization A.D. It is recorded that it was used in 900 years. Many plant-derived substances and oils have been involved in plant protection practices since the 18th century. In our country, records of the control to locusts and phylloxera can be found in the 1800s. Later, with the emergence of synthetic pesticides, chemical control was mostly used in the solution of plant protection problems in our country as well as all over the world. Organic or synthetic pesticides with different active substances are used in the chemical control to living factors that cause losses in plants. As a result of widespread and repeated pesticide applications, resistant populations of pathogens and pests emerge, and higher doses or more effective pesticides are required to combat them. As a result of this vicious circle, increasing doses and applications threaten natural life and beneficial organisms by causing soil and water pollution, as well as causing damage to plants as a result of phytotoxicity. Pesticides cause environmental pollution by being carried to non-target areas both during and after application, and they threaten their life by reaching non-target organisms through the food chain. In addition, the losses during this application are reflected as economic damage to the producers (Abd-Elsalam and Alghuthaymi 2015). In addition to these, it is also known that the residues of pesticides in agricultural products threaten human health and cause various diseases, especially cancer.

Biological Control; It is keeping pests, diseases and weeds below the economic damage threshold with the help of other living things. In other words, it is to take preventive, restorative and supportive measures for the natural balance without completely destroying the living things that are harmful in nature. Natural enemies that are effective in biological control are gathered in three main groups as predators, parasitoids and pathogens. Predators are beneficial insects that directly feed on pests. Parasitoids are generally beneficial from the bee group, which are effective by laying their eggs in developmental stages such as eggs, larvae and pupae, which we call the adult or pre-adult stages of another insect. Pathogens, on the other hand, are the agents that cause disease in pests as well as in other living things. Disease-causing pathogens are living things such as fungi, bacteria, viruses, and nematodes. (Weeden et al., 2007). There are three basic approaches in biological control: protection of existing natural enemies and increasing their effectiveness, increasing and supporting the population of natural enemies, and importing natural enemies.

1. Classical biological control: It is carried out by bringing and placing biological control agents that are not naturally found in the region from their original geography.

2. Protective biological control: It covers the protection of beneficial species naturally found in the environment.

3. Mass biological control: In order to increase the population density, it includes mass production of the beneficial species and release to the region to be combated (Agrios, 2005 and Uneke, 2007).

1. Parasitoids and Biological Control

Organisms that develop on or inside another living thing while harming or killing their host are called parasites. Parasite is used in this broad sense, especially in the fields of medicine and veterinary medicine. Living things such as lice, fleas and bedbugs that harm their host but do not cause death are also considered as parasites. However, in the field of Entomology, the parasite causes the death of its host after completing its development. Because of this basic distinction, the term parasitoid has been used in the field of entomology since the 1970s. Organisms that carry out their entire development in or on the host and cause the death of their host in this process are called parasitoids. Parasitoids are absolutely dependent on their hosts for development.

1.1. Defensive Reactions

It can show host physical and physiological defense reactions to parasitoids. In physical defense reactions, shaking of the head and abdomen can be in the form of secretion of toxic sticky and caustic fluids from the body. These fluids can be secreted from some glands, as well as in the form of reflex bleeding. Ectoparasitoids do not have any problems laying eggs on their hosts, as they paralyze their hosts before laying eggs. Physiological counteracting reactions can occur to internal parasitoids in the form of phagocytosis, encapsulation, and melanin formation. However, physiological defense reactions are successful in some cases. Parasitoids can often easily overcome physiological defense reactions with some of the features they have and the inhibition reactions they show. If encapsulation is high in the host of a parasitoid, this parasitoid cannot be used very effectively in nature. For example, although *Anagyrus pseudococci* (Girault) parasitizes the host *Planococus citri* (Risso) at a high level, the adult emergence is low due to the high encapsulation, which causes its effectiveness in nature to be limited.

1.2. Uses of Parasitoids in Biological Control

Parasitoids are indispensable organisms in terms of their ability to search and find their hosts, to suppress pests in nature and to use them in biological control for direct control.

Parasitoids are generally used in 3 ways within the framework of the basic approaches of biological control. These; These are periodic release methods in case of placing a new parasitoid in the ecosystem, regulating protection and support activities to increase the effectiveness of an existing parasitoid species in the ecosystem, not being able to settle in the ecosystem or failing to show efficiency in certain periods due to its weak population.

Parasitoids are generally sensitive to insecticides and are adversely affected by applications. For this reason, benefiting from parasitoids in biological control can only be implemented within the framework of an integrated control program based on biological control to be applied to the agroecosystem. Within the framework of this program, while paying attention to the selection of selective and less toxic chemical preparations, on the other hand, an ecological selectivity can be created by shifting the applications to the periods in which the parasitoids parasitized hosts. This approach is very effective especially in egg and pupal parasitoids.

2. Predators and Biological Control

Creatures that need more than one prey throughout their lives, seek and find their prey, attack and kill their prey externally and kill them are called "predator", and the creature on which they feed is called "prey". They are species that are predators in many living groups such as insects, mites, spiders, reptiles (lizards, snakes), amphibians (frogs, salamanders), fish and birds, and they play an important role in establishing and maintaining biological balance in natural biological control. However, among these, predator insects and predator mites, "Biological Control", which is formed by the guidance of people, are the most used.

2.1. Predator Insects

Predator insects are free-living creatures and usually attack prey smaller than themselves. They need more than one, sometimes hundreds of individuals for their development. They usually lay their eggs near their prey. After the predator's nymphs or larvae hatch, they zealously seek, catch, kill and consume their prey. Predators kill most of their prey immediately, and some are first anesthetized and then consumed by eating or sucking. Although there are some exceptions, both pre-adult and adult stages of many predatory species are carnivores. Predator insects are divided into two groups according to their mouth structures: Biting-chewing and Biting-sucking. Bite-chewing mouthparts chew and swallow their prey after catching it. Bride beetles, soil beetles and mantises are examples of these. Those whose mouths are stinging-sucking immerse their mouthparts in their prey and suck out their body contents. Predators with this feature usually first immobilize their prey with severe toxins and digestive enzymes and then suck it up. Reduviidae, Chrysopidae and Syrphidae larvae are examples of this group. Predators are divided into three groups as monophagous, oligophagous and polyphagous according to the range of prey species they feed on. The prey range of monophagous species is quite narrow. It may often be specialized for one prey species (example of *Rodolia cardinalis* (Muls.) on *Icerya purchasi* Maskell). The prey range of oligophagous species is somewhat limited. They are usually specialized for several related prey species (such as coccinellids and syrphids that feed on aphids). Polyphagous species, on the other hand, have a wide range of prey species (chrysopids, praying mantises, etc.). Predator insects can be divided into groups as eggs, larvae-nymphs, pupae, adults or a combination of these, according to the developmental stages of the prey species they attack.

2.2. Uses of Predator Insects in Biological Control

Predatory insects have an important place in the biological control of pests that cause yield and quality loss in agricultural areas. Predators effectively seek, find and kill their prey in a short time. Since they have a fast search power, the need for the predator and the prey to coexist simultaneously does not cause too many problems. Monophagous predator types constitute an indispensable group for use in biological control for direct control. The best and most classic example of this is *Rodolia cardinalis*, which was used to bagged cochlea (*Icerya purchasi*) and was extremely successful. Polyphagous predators, on the other hand, play a very important role in the formation and protection of the natural balance, as they feed not on a single prey species, but on many prey species. Even if these do not provide complete natural pressure on a particular pest species, they prevent the reproduction of many pests. Therefore, they are considered as a kind of counterbalance in the harmful natural enemy complex. The superiority of polyphagous predators is that they can continue their existence by turning to alternative prey when the population density of their first-degree prey decreases or when such prey is not available in the environment. The negative aspects of these are their inability to respond to prey density changes, they are cannibalistic and can also feed on beneficial species. Therefore, general predators that feed on specialized natural enemies of pests can adversely affect the natural suppression of pest populations. Under the influence of biotic and abiotic variables that change in nature in a short time, it is very difficult to reveal the intra- and inter-species relations between general predators and the interactions between predators and their prey. For this reason, the effectiveness of general predators in natural biological control and biological control cannot be determined exactly in field conditions. However, in 75% of the studies conducted in nature, it was revealed that general predators significantly reduced the pest populations in the form of a single species or a group of species. On the other hand, predatory insects were identified as the main biological control agent in 11% of the classical biological control projects that were successfully carried out. Maximum attention should be paid to the protection and support of predators, which are indispensable for the formation and preservation of natural balance in both agroecosystems and natural ecosystems. For example, predators are very sensitive to insecticides and are adversely affected by pesticides. For this reason, if pesticides are absolutely necessary in any agroecosystem, care should be taken to select selective and less toxic drugs within the framework of integrated control programs, on the one hand, and on the other hand, care should be taken to shift the pesticide applications in front of or behind the periods when the predators are most intense. In addition to these, it is extremely important not to destroy the pollen and nectar producing plants in the garden and field edges, to grow them if such plants are not available, to create alternative prey, nests, food and winter shelters by artificial means in order to protect the presence of predators and keep their populations at a high level. Faunistic, taxonomic, bio-ecological, predator-prey relations, placement in the ecosystem, periodic releases, negative effects of drugs etc. on many predator species for biological control in Turkey. A lot of work has been done on different topics.

3. Predator Mites As A Biological Warfare Agent In Practice

Although there are natural enemies with very different nutritional characteristics in the families in the Acarina order, most of the species used as biological warfare agents in practice are in the Phytoseiidae family. Today, the Phytoseiidae family, which has over 1600 identified species in 70 genera, is evaluated within the subfamilies Amblyseiinae, Phytoseiinae and Typhlodrominae (Zhang, 2003). Predator mites of the family Phytoseiidae, *Phytoseiulus persimilis* Athias-Henriot, which is specialized for its diet and feeds only on the mites of the genus Tetrancyhus; Again, in addition to the species mostly in the Tetranychinae subfamily, it has species that are used extensively in biological warfare in practice, such as *Neoseiulus californicus* (McGregor), which feeds on other small mites and pollen. Apart from the reported nutritional characteristics, predatory mites such as *Iphiseius degenerans* Berlese also show polyphagous feeding, feeding on mites from different groups, small arthropods and pollen. (McMurtry and Croft, 1997).

The use of predator mites as natural enemies to pests has been to increase their effectiveness in all war programs in open areas, rather than being produced and released according to classical biological warfare methods. One of the turning points was the discovery that organophosphorus insecticides used to apple borer in apple orchards in North America reduced the effectiveness of *Galendromus*

(Typhlodromus) occidentalis (Nesbitt), which is very effective in suppressing spider mites. (Hoyt, 1969; Vincent et. al., 2009). In the following years, *G. occidentalis* populations that developed resistance to organophosphorus drugs were evaluated as one of the main factors in establishing a successful all-controlling program to phytophag mites (Croft and Whalon, 1984). In the first attempts to use predator mites as a biological warfare agent to Tetranychid mites in indoor areas, the most important factor is the resistance of *T. urticae* to drugs. In the early 1960s, it was determined that the predator mite *P. persimilis* was quite effective in suppressing the reported pest, and small-scale greenhouse trials were carried out in 1968 for the application of biological warfare (Dosse, 1959: Bravenboer, 1963; Lenteren and Woets, 1988). In the following years, the first company to commercially produce predator mites was established (Anonymous, 1970; Hussey and Bravenboer 1971).

Apart from Phytoseiidae, there are soil-borne predator mites in species such as *Geolaelaps (Hypoaspis) aculeifer* Canestrini, *H. miles* (Berlese) and *Stratiolaelaps scimitus* (Womersley) in the Laelapidae family. are natural enemies that are effective on and commercially produced (Zhang, 2003; Berndt et al., 2004).

4. Entomopathogens

Many microorganisms exist as effective pressure elements on natural insect populations, and the use of these elements in the control of pests constitutes the basic idea of microbial control to harmful insect species. Microorganisms (bacteria, fungi, viruses, and protozoans) that are used as agents or are being studied to be used within the scope of this control, and entomophagous nematodes, which are not microorganisms, can be included in all three methods of biological control.

4.1.Fungi

Mitosporic entomopathogenic fungi in the Hypocreales order of the Ascomycota branch and the fungi in the Entomophthorales order of the Glomeromycota branch were the most emphasized in the microbial control of insects. Fungal spores attached to the insect cuticle form a penetration structure after germination and initiate the infection. The fungus that reaches the hemolymph usually multiplies in the hemolymph in a yeast-like manner and causes the death of the insect. The possibility of their production in artificial nutrient media at a relatively cheap cost has accelerated the development of mitosporic entomopathogenic fungi as bioinsecticides for the control of various pests (mainly pests found in greenhouses and soil). Most of them are *Metarhizium*, *Beauveria, Isaria* and *Lecanicillium* species.

4.2. Bacteria

The main entry of entomopathogenic bacteria into their hosts is orally. While they can stay in the digestive system, some are capable of penetrating up to the hemocole. In some diseases in which host death takes a long time, at least because of digestive system disorders, cessation of food occurs and insect damage can be prevented in the early period (Charles et al., 2000). Species that came to the fore in terms of biological control were *Bacillus thuringiensis* Berliner, *B. sphaericus*

Neide, *Paenibacillus popilliae* (Dutky) and *P. lentimorbus* (Dutky), Serratia species from the Entorobacteriaceae family. Entomopathogenic strains of *B. sphaericus* produce insecticidal toxin and infect the larvae of various mosquito species (*Culex, Anopheles, Mansonia, Aedes*) (Thanabalu et al, 1993). The first indicator in the insect is cutting from feeding. It shows its effect especially in the anterior part of the midgut, and swelling and disintegration of epithelial cells occurs after host death. Subsequently, it is possible for the bacteria to multiply and spread within the host under natural conditions.

4.3. Protozoa

The main route of entry to the hosts of entomopathogenic protozoa species is oral, and their infections can be local or systemic. They are usually highly host-specific, slow-acting and chronic diseases. However, they are important stressors in natural insect populations (Maddox, 1987; Brooks, 1988).

4.4. Viruses

Viruses enter their hosts mostly orally from the digestive tract, and some mechanically through parasitoids (eg Polydnaviridae). Vertical spread may also occur by transmission from adult females to eggs (eg *Neodiprion sertifer* NPV). It is also stated that they enter through other natural openings and wounds. Chronic diseases cause retardation in development, decrease in lifespan and fertility, and a general weakening of the insect. The viruses that have come to the forefront in terms of microbial control are the species in the Baculoviridae family.

4.5. Nematodes

The relationship of nematodes with insects can be in various ways, from accidental association to obligate parasitism. Insect parasitic nematodes enter their hosts directly through the cuticle or through natural openings (stigmas, mouth, anus). Some nematodes cause host death (eg Mermithidae, Steinernematidae) while others cause host sterility or reduced fertility (eg Sphaerularidae, Allantonematidae). The ones that come to the forefront in terms of microbial control are the members of the families Steinernematidae and Heterorhabditidae, which are in mutual relationship with bacteria in the genera *Xenorhabdus* and *Photorhabdus* (Enterobacteriaceae), respectively.

The fact that the production cost is generally higher than the production of chemical insecticides and their sensitivity to environmental conditions can be listed as limiting factors. In terms of commercial importance, nematodes constitute the second group of agents after bacteria (Flexner and Belnavis, 2000).

CONCLUSION

Although it is possible to use biological control to control some pests, chemical control is preferred because it is easy to apply and results in a short time. Excessive use of insecticides also causes ecological and economic problems such as the deterioration of the natural balance between living things in nature, the resistance of pests due to the use of the same type of insecticide (Uygun et al., 2010), their infiltration into groundwater in the soil and accumulation as toxicants in the air (Zeren and Erem, 2000). In addition to these, when the threat to human and animal health, drug residues in foodstuffs and high drug prices are added, the most environmentally friendly, cheap, promising, agroecosystem protective and sustainable alternative to chemical control seems to be the "Biological Control" method. This method means not only to get rid of the negative effects of chemical control, but also to benefit from beneficial micro and macro organisms that keep pests under pressure by 99% in nature (Uygun, 2001).

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CHAPTER 10

A MACRO LOOK TO CANOPY TEMPERATURE & LEAF TEMPERATURE: A REVIEW

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INTRODUCTION

Canopy temperature is a driver of plant function emerging as a result of interacting biotic and abiotic factors. Plant canopy temperature is partly regulated by evaporation and transpiration and is an indirect measure of transpiration rate and stomatal conductance. The determination of crop water status has positive effects on irrigation decisions. Infrared thermal imaging cameras are effective tools to monitor the spatial distribution of canopy temperature. Canopy temperature is often related to potential yield and is a possible yield indicator in breeding programs.

Plants must regulate leaf temperature to optimize photosynthesis, control water loss and prevent damage caused by overheating or freezing. Leaf temperature changes with incident light intensity. There is general concern that the rapid increase in atmospheric CO2 concentration will lead to reduced stomatal conductance and subsequent increases in leaf temperature.

Here in this review, a macro look to canopy temperature and leaf temperature is presented by the help of new data from international articles.

Plant functional diversity is strongly connected to photosynthetic carbon assimilation in terrestrial ecosystems. However, many of the plant functional traits regulating photosynthetic capacity, including foliar nitrogen concentration and leaf mass per area, vary significantly between and within plant functional types and vertically through plant canopies (Kamoske et al., 2021). Canopy structure explains the relationship between photosynthesis and sun-induced chlorophyll fluorescence in crops (Dechant et al., 2020). Ecological research heavily relies on coarse-gridded climate data based on standardized temperature measurements recorded at 2 m height in open landscapes. However, many organisms experience environmental conditions that differ substantially from those captured by these macroclimatic temperature grids (Haesen et al., 2021). Water is a crucial element for plant growth, metabolic processes, and general health. Water-deficit, typically simplified by drought stress, is the most critical photosynthetic source of stress that restricts plant growth, crop yield, and food product quality (Awais et al., 2021).

1. Canopy temperature

Canopy temperature is a key driver of plant function that emerges as a result of interacting biotic and abiotic processes and properties. However, understanding controls on canopy temperature and forecasting canopy responses to weather extremes and climate change are difficult due to sparse measurements of canopy temperature at appropriate spatial and temporal scales (Still et al., 2021).

Canopy temperature is an indirect measure of transpiration rate and stomatal conductance and may be valuable in distinguishing differences among genotypes in response to drought (Bazzer & Purcell, 2020). Canopy temperature has been related to water-use and yield formation in crops. However, sun illumination angle, ambient temperature as well as rapidly changing clouds or other environmental conditions make it difficult to compare measurements taken even at short time intervals.

This poses a great challenge for high-throughput field phenotyping (Perich et al., 2020).

Canopy temperature is an important variable directly linked to a plant's water status. Recent advances in Unmanned Aerial Vehicle and sensor technology provides a great opportunity to obtain high-quality imagery for crop monitoring and high-throughput phenotyping applications (Chang et al., 2020).

2. Canopy temperature & water relation

The determination of crop water status has positive effects on irrigation decisions. Drought can decrease the production of crops, whereas over-irrigation can waste water. It is desirable to schedule irrigation when the crop suffers from water stress (Yang et al., 2021). The ability to avoid dehydration is a drought resistance mechanism becoming increasingly more important even in temperate regions. In wheat, dehydration avoidance can be associated with a maintained canopy cooling during dry periods. However, in an average year under temperate conditions, drought periods are rather short which makes it difficult to routinely screen for drought avoidance using canopy temperature (Anderegg et al., 2021).

Drought-stressed plants display reduced stomatal conductance, which results in increased leaf temperature by limiting transpiration (Melandri et al., 2020). Normalized crop canopy temperature, termed crop water stress index, was proposed over 40 years ago as an irrigation management tool but has experienced limited adoption in production agriculture (King et al., 2020). The crop water stress index is a reliable indicator of water status in plants and has been utilized for stress monitoring, yield prediction, and irrigation scheduling. Despite this, however, its use is limited because its estimation requires baseline temperatures under similar environmental conditions, which can be problematic (Kumar et al., 2021). Canopy water use efficiency (above-ground biomass over lifetime water loss) can influence yield in wheat and other crops. Breeding for canopy water use efficiency is difficult because it is influenced by many component traits (Sexton et al., 2021).

Plant canopy temperature is partly regulated by evaporation and transpiration from the canopy surface and can be used to infer changes in stomatal regulation and vegetation water stress (Javadian et al., 2022). Crop canopy temperature measurement is necessary for monitoring water stress indicators such as the Crop Water Stress Index. Water stress indicators are very useful for irrigation strategies management in the precision agriculture context. For this purpose, one of the techniques used is thermography, which allows remote temperature measurement. However, the applicability of these techniques depends on being affordable, allowing continuous monitoring over multiple field measurement (Gimenez-Gallego et al., 2021).

As the drought conditions persist and water continues to become less available, the development of methods to reduce water inputs is extremely important (Haghverdi et al., 2021). Infrared thermal imaging cameras are effective tools to monitor the spatial distribution of canopy temperature, which is the basis of the crop water stress index (CWSI) calculation (Luan et al., 2021).

Continuous measurement of canopy temperature is an important indicator of plant water status of crops and the ability to predict canopy temperature will assist in the implementation of this technology for guiding crop irrigation scheduling. By noting that canopy temperature is related to its environmental weather variables which change over time of the day and have different effect or contribution to canopy temperature (Shao et al., 2019).

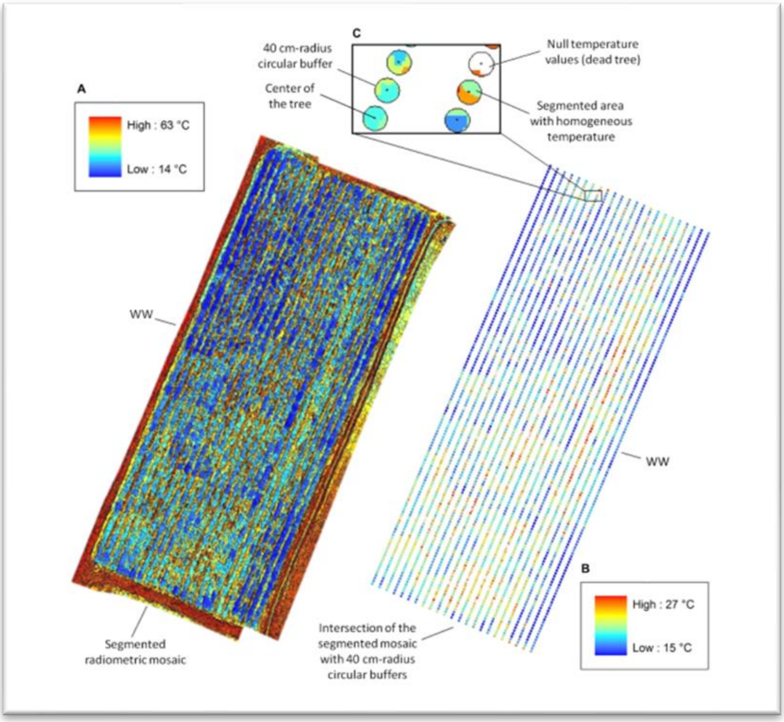

Fig 1. Canopy temperature extracted from segmented radiometric mosaics. (A) segmentation of the radiometric mosaic with temperature range between 14 and 63◦C. (B) Intersection of the segmented mosaic with 40 cm-radius circular buffers centered on the trees with Canopy temperature ranging between 15 and 27◦C (C) View of the intersection for six trees (Ludovisi et al., 2017).

3. Canopy temperature & crop yield relation

Canopy temperature depression (CTD = canopy temperature – air temperature), transpiration and canopy greenness have much to do with crop yields, and they have been widely used to estimate crop yields. However, the issues relating to the best measurement time to predict crop yields have seldom been addressed (Hou et al., 2019). To identify drought-tolerant crop cultivars or achieve a balance between water use and yield, accurate measurements of crop water stress are needed (Zhang et al., 2019). Canopy temperature is often related to potential yield and is a possible yield indicator in breeding programs. However, it is difficult to evaluate genetic variations of canopy temperature accurately in large-scale investigations, such as breeding programs, because canopy temperature is strongly affected by environmental conditions (Ohnishi et al., 2021).

Changes in leaf anatomy and ultrastructure are associated with physiological performance in the context of plant adaptations to climate change (Habermann et al., 2019). For potatoes, canopy temperature as a surrogate of stomatal conductance has been highlighted as an essential physiological indicator for optimizing irrigation timing. However, assessing how this trait could help improve yield prediction will help develop future decision support tools. In the future, the incorporation of Canopy temperature combining low-cost infrared devices/sensors with spatial crop models, satellite image information, and telemetry technologies, an adequate decision support system could be implemented for water requirement determination and yield prediction in potatoes (Ninanya et al., 2021).

The seed yield of oilseed rape (*Brassica napus*), an important edible and industrial oil source, is derived mainly from the photosynthetic products of siliques. High temperatures in the pod-development stage threaten the oilseed rape production. Potassium fertilization reduces silique canopy temperature variation in Brassica napus to enhance seed yield (Hu et al., 2021).

4. Leaf temperature

Leaf temperature changes with incident light intensity (Kang et al., 2020). High temperatures alter the thermal sensitivities of numerous physiological and biochemical processes that impact plant growth and productivity (Dewhirst et al., 2021). Leaf optical properties impact leaf energy balance and thus leaf temperature (Richardson et al., 2021).

There is general concern that the rapid increase in atmospheric CO2 concentration will lead to reduced stomatal conductance and subsequent increases in leaf temperature. Such an increase in leaf temperature is expected to adversely impact a plethora of processes connected to leaf metabolism and microbial/fungal communities on leaves (Konrad et al., 2021). Leaf temperature is a key variable governing plant physiological processes, such as photosynthesis and respiration. Further, very high temperatures can lead to leaf necrosis (Fauset et al., 2019). A stable leaf temperature provides plants with a suitable microenvironment for photosynthesis. With global warming, extreme temperatures have become more frequent and severe;

therefore, it is increasingly important to understand the fine regulation of leaf temperature under heat stress (Song et al., 2020). Leaf temperatures of water-stressed plants were 6 to 8°C higher than those well-watered, with differences among species in the study of Graf et al., (2021).

A growing number of leaf traits can be estimated from hyperspectral reflectance data. These include structural and compositional traits, such as leaf mass per area and nitrogen and chlorophyll content, but also physiological traits such a Rubisco carboxylation activity, electron transport rate, and respiration rate (Khan et al., 2021).

Biogenic Volatile Organic Compounds are reactive hydrocarbons emitted by living organisms, mainly by vegetation, in numerous physiological processes. Biogenic Volatile Organic Compounds interact with the atmosphere in various ways, and are important for the regional air quality and climate because they can contribute to tropospheric ozone, prolong the lifetime of methane, and enhance aerosol formation and growth. Production and emission of biogenic Volatile Organic Compounds from plant leaves is highly regulated by temperature (Simin et al., 2019).

Trichomes are epidermal structures with a large variety of ecological functions and economic applications. Glandular trichomes produce a rich repertoire of secondary metabolites, whereas non-glandular trichomes create a physical barrier on the epidermis: both operate in tandem against biotic and abiotic stressors. A deeper understanding of trichome development and function would enable the breeding of more resilient crops. a single monogenic mutation that modifies trichome density, a desirable trait for crop breeding, concomitantly improves leaf gas exchange and reduces leaf temperature (Gasparini et al., 2021).

Calcite-silicon mediated particle film could enhance the resilience of crops to adverse environmental conditions and may contribute to preserve terroir elements in highly reputed growing areas. The study of Amato et al., (2020) showed that foliar application of calcite silicon-mediated processed particles films can be used in arid regions to mitigate leaf temperatures in grapevines.

Plants must regulate leaf temperature to optimize photosynthesis, control water loss and prevent damage caused by overheating or freezing. Physical models of leaf energy budgets calculate the energy fluxes and leaf temperatures for a given set leaf and environmental parameters. These models can provide deep insight into the variation in leaf form and function (Muir, 2019).

5. Conclusions

For winter cereals, under temperate conditions, drought periods are rather short which makes it difficult to routinely screen for drought avoidance using canopy temperature.

Most of the canopy temperature studies are on high temperature effects. Very limited study subject the low temperature effect on canopy.

Canopy temperature measurements is not well accepted and standartised. Instead, leaf temperature measurements are more valuable for stress determination and escape management and genotype selection activities.

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CHAPTER 11

CAMELINA (*Camelina sativa* L.) OIL QUALITY

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1. INTRODUCTION

Non-food oilseed crop Camelina contains 35–45% storage oils in dry weight in seed. Camelina is rich in α-linolenic acid. Its fatty acids are unsaturated fatty acids (mono unsaturated and mostly polyunsaturated are in total greater than 55%) and saturated fatty acids (9-11%). Has multiple uses in feed technology for substitution or supplementation of oils for animal diets of fish and broilers, biodiesel production, jet fuel production, biopolymer industry. It is more tolerant to soil salinity than traditional crops, such as canola. Camelina (*Camelina sativa* L. Crantz) is an oilseed crop of *Brassicaceae* family. It can be cultivated in winter or spring season. This species is well adapted to difficult climate conditions has resistance to pests and diseases which affect other *Brassicaceae* crops. Phytoalexins of the plant is probably responsible for its extraordinary defense system (Popa et al., 2017). It is more tolerant to soil salinity than traditional crops, such as canola (Heydarian et al., 2016). Camelina contains 35–45% storage oils in dry weight in seed. It is an emerging oilseed crop (An & Suh, 2015). The oil has 90% unsaturated fatty acids contents which makes it suitable to produce oleochemicals and biopolymers (Li & Sun, 2015). Camelina is rich in α-linolenic acid (Jaskiewicz et al., 2014). Camelina is a non-food oilseed crop. But it is a biofuel energy resource. Its productivity in wide spectrum soil and climatic conditions and low agri-input requirement makes it economical for biofuel production (Kumar et al., 2012).

Camelina oil contains unsaponifiable fraction represented by tocopherols, sterols and a saponifiable fraction consisting in fatty acids.

Its fatty acids are unsaturated fatty acids (mono unsaturated and mostly polyunsaturated are in total greater than 55%) and saturated fatty acids (9-11%). Major fatty acids of camelina oil are linolenic, linoleic, oleic and eicosenoic acids. In comparison with other *Brassicaceae* plants, camelina oil has a low content of erucic acid. Camelina oil, due to its composition, has multiple uses in various industries: feed technology for substitution or supplementation of oils for animal diets of fish and broilers, biodiesel production, jet fuel production, biopolymer industry (paints and varnishes) and cosmetic industry (Popa et al., 2017). The most common extraction methods for camelina are mechanical extraction, solvent extraction and enzymatic extraction. A new method is supercritical-CO2 extraction (Popa et al., 2017).

Fig. 1. Camelina holds promise for biofuel and bees

Kurasiak-Popowska & Stuper-Szablewska, (2020) was conducted a two-year field experiment with 66 spring and 9 winter biotypes of *C. sativa* in Poland. Fatty acid profile, eight flavonoid aglycones and 12 phenolic acids were analysed. There were significant differences among spring and winter cultivars for the concentration of total flavonoids, phenolic acids and fatty acids in the camelina seeds. Total concentration of flavonoids in the spring forms was between 404±38.5 and 429.9±13.8 mg/kg. This parameter for winter biotypes were between 507.3±51.4 and 526.4±10.4 mg/kg. Phenolic acid concentration ranged between 2043.6±62.and to 2174.0±145.2 mg/kg for spring forms and between 3936.0±210.8 and 3704.7±195.4 mg/kg for the winter forms. Linoleic acid was 14% of total fatty acid content in spring and 16% of winter ones. Contents of α-linolenic acids were similar (37–38%).

Camelina seed oil is rich in vitamins, unsaturated fatty acid, phytosterols and polyphenols but all bioactive compounds are not soluble in oil. Kurasiak-Popowska et al., (2019) analysed the transmission of bioactive compounds to oil and pomace in seeds. Eight flavonoid aglycons, 11 phenolic acids, three carotenoids, and 19 fatty acids were analyzed. More than 80% of flavonoids entered oil, whereas 20% remained in the pomace as a result of pressing. For phenolic acids of seeds, average 50% of these compounds passed to oil. Among all the searched phenolic acids, highest contents of chlorogenic, caffeic, and sinapic acids were found both in camelina seeds and oil. More than 70% of fat-soluble carotenoids were extracted from camelina seeds with oil.

2. Fish feed

Facing a bottleneck in the growth of aquaculture, and a gap in the supply and demand of the highly beneficial n-3 long-chain polyunsaturated fatty acids (LC-PUFA), sustainable alternatives to traditional marine-based feeds are required (Betancor et al., 2018). Camelina oil is a potential replacement for fish oil in aquaculture feeds. Camelina oil is high in α-linolenic acid (18:3n-3) (35%), with an omega-3/omega-6 (n-3/n-6) ratio near 2 (Toyes-Vargas et al., 2020). Apart from oil, safflower seeds also have soybean quality meal (Avram et al., 2015).

Although high-oleic seed oil is preferred for industrial use, most seed oil is high in polyunsaturated fatty acids (PUFAs) and low in monounsaturated fatty acids (MUFAs) such as oleic acid. Oil from Camelina contains 60% PUFAs and 30% MUFAs (Lee et al., 2021). Camelina oil is a rich source of omega-3 fatty acids with valuable nutritional properties (Piravi-vanak et al., 2021).

Camelina is an orphan oil crop with high potential for yield improvement through breeding and biotechnological approaches. Seed size and oil content of camelina are particularly low compared with high-yielding oil crops such as rapeseed (*Brassica napus* L.) (Hölzl & Dörmann, 2021). *C. sativa* was genetically engineered to produce eicosapentaenoic acid and docosahexaenoic acid at levels similar to fish oil (Osmond et al., 2021). Eicosapentaenoic acid and docosahexaenoic acid are important components of cell membranes. Since humans have limited ability to synthesize these components and must obtain from diet, basicly from fish oil. Dietary eicosapentaenoic acid and docosahexaenoic acid intakes are constrained by the size of fish stocks and by food choice (West et al., 2019). Eicosapentaenoic acid (20:5n-3) and docosahexaenoic acid (22:6n-3) are important for leukocyte function (West et al., 2021).

For humans a daily intake of up to 500 mg omega-3 (n-3) long-chain polyunsaturated fatty acids (LC-PUFA) is recommended, amounting to an annual requirement of 1.25 million metric tonnes for a population of 7 billion people. The annual global supply of n-3 LC-PUFA cannot meet this level of requirement and so there is a large gap between supply and demand. The dietary source of n-3 LC-PUFA, fish and seafood, is increasingly provided by aquaculture but using fish oil in feeds to supply n-3 LC-PUFA is unsustainable. Therefore, new sources of n-3 LC-PUFA are required to supply the demand from aquaculture and direct human consumption. One approach is metabolically engineering oilseed crops to synthesize n-3 LC-PUFA in seeds. Transgenic Camelina sativa expressing algal genes was used to produce an oil containing n-3 LC-PUFA to replace fish oil in salmon feeds. The oil had no detrimental effects on fish performance, metabolic responses or the nutritional quality of the fillets of the farmed fish (Betancor et al., 2015).

Currently, one alternative for dietary fish oil in aquafeeds is vegetable oils that are devoid of omega-3 (n-3) long-chain polyunsaturated fatty acids (LC-PUFAs). Entirely new sources of n-3 LC-PUFA such as eicosapentaenoic and docosahexaenoic acids through de novo production are a potential solution to fill the gap between supply and demand of these important nutrients. *Camelina sativa* was metabolically engineered to produce a seed oil with >20% EPA and its potential to substitute for fish oil in Atlantic salmon feeds was tested. The eicosapentaenoic oil from transgenic Camelina seed oil could be used as a substitute for fish oil (Betancor et al., 2015).

3. Different applications

Oils with high levels of saturated fatty acids are in demand for structured lipid elaboration, whereas ω-7 fatty acids like palmitoleic or asclepic acids are of interest for other applications, such as in oleochemistry and biolubricant production. Several strategies have been followed to increase the levels of saturated and ω-7 fatty acids in the camelina plant. The increase in intraplastidial desaturase activity through CsSAD co-expression forced the desaturation of palmitate, inducing the accumulation of important amounts of ω-7 fatty acids (Rodríguez-Rodríguez et al., 2021).

Chitosan blend films were produced by incorporating camelina seed oil at different concentrations to chitosan matrix to produce natural bio-based edible films enriched with various plant additives to overcome synthetic film drawbacks in food packaging industry (Gursoy et al., 2018).

4. CONCLUSIONS

Non-food oilseed crop Camelina contains 35–45% storage oils in dry weight in seed. Camelina is rich in α-linolenic acid. Its fatty acids are unsaturated fatty acids (mono unsaturated and mostly polyunsaturated are in total greater than 55%) and saturated fatty acids (9-11%). Has multiple uses in feed technology for substitution or supplementation of oils for animal diets of fish and broilers, biodiesel production, jet fuel production, biopolymer industry.

Camelina seed oil is rich in vitamins, unsaturated fatty acid, phytosterols and polyphenols. Camelina oil is a potential replacement for fish oil in aquaculture feeds. High levels of saturated fatty acids content of camleina oil makes it suitable to oleochemistry applications and biolubricant production.

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CHAPTER 12

A MACRO LOOK TO CROP LEAF SENESCENCE: A REVIEW

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1. Introduction

The length of the growing season has a large influence on the carbon, water, and energy fluxes in crops. Photosynthetic, gas exchange and water supply capacities of leaves is tightly coordinated. Leaf senescence targets to remobilize previously acquired nitrogen, carbon and mineral resources out of the senescing tissue into developing parts of the plant. Stressful environmental conditions often initiate early leaf senescence as an adaptive mechanism. Leaf senescence has a significant impact on agriculture. Leaf senescence is a highly complex process, and its disruption might lead to premature or delayed leaf senescence and result with reduced or increased crop yields.

The length of the growing season has a large influence on the carbon, water, and energy fluxes of global terrestrial ecosystems. While there has been mounting evidence of an advanced start of the growing season mostly due to elevated spring air temperatures, the mechanisms that control the end of the growing season in most ecosystems remain relatively less well understood (Lu & Keenan, 2022).

Plants have leaves that are specialized organs to capture light energy. This energy is used to support photosynthesis, a process in which carbon dioxide from the atmosphere is incorporated into organic compounds in the plant to allow the plant to grow. Other parts of the plant, such as the stem, flowers, or seeds are also able to conduct photosynthesis to contribute to growth in many plant species (Henry et al., 2020). Tight coordination in the photosynthetic, gas exchange and water supply capacities of leaves is a globally conserved trend across land plants (Deans et al., 2020).

2. Leaf senescence

Senescence in plants is often described as the last step in the life history of a plant. However, senescence takes place from early on throughout development and a plant can sacrifice older leaves for the sake of the whole plant. Leaf senescence aims at remobilizing previously acquired nitrogen, carbon and mineral resources out of the senescing tissue into developing parts of the plant, before the leaf eventually dies and is shed. Before anthesis, sequential leaf senescence leads to the repartitioning of nutrients from older leaves to newly developing non-reproductive organs. After anthesis, monocarpic leaf senescence governs nutrient reallocation to the now developing reproductive organs and, therefore, has a very critical impact on yield. During monocarpic senescence, potentially all the leaves of a plant can undergo senescence, leading to the death of the whole plant (Zentgraf et al., 2021).

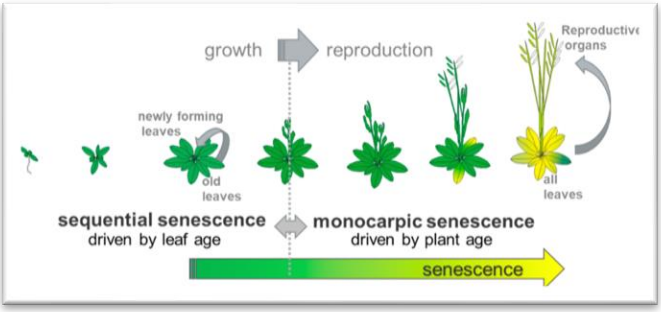

Fig. 1. Leaf senescence in the model plant *Arabidopsis thaliana*. Leaf senescence takes place all over development. At the transition from the growth to reproduction phase, senescence is switched from sequential to monocarpic senescence (Zentgraf et al., 2021).

Leaf senescence has a significant impact on agriculture. When facing harsh environmental conditions, monocarpic plants often initiate early leaf senescence as an adaptive mechanism to ensure a complete life cycle. Upon initiation, the senescence process is fine-tuned through the coordination of both positive and negative regulators (Zhang et al., 2022a). Leaf senescence is a highly complex and meticulous regulatory process, and the disruption of any factor involved in leaf senescence might lead to premature or delayed leaf senescence and thus result in reduced or increased crop yields (Zheng et al., 2021).

The optimal timing of leaf senescence is crucial to both minimise risks of low temperature events and to maximise carbon gain during the growing season. As abiotic conditions are currently changing at unprecedented rates, it is important to study how leaf senescence of different species is responding to these changes in order to forecast future growing season length and carbon sequestration potentials. In contrast to flowering phenology, data on autumn events are scarce (Bucher & Römermann, 2021). Leaf senescence is determined by various environmental and endogenous signals. Leaf senescence can determine plant productivity and fitness (Yan et al., 2021).

3. Chloroplasts

Leaf yellowing is a visual indicator of senescence due to the loss of the green pigment chlorophyll. During senescence, the methodical disassembly of macromolecules occurs, facilitating nutrient recycling and translocation from the sink to the source organs, which is critical for plant fitness and productivity. Leaf senescence is a complex and tightly regulated process, with coordinated actions of multiple pathways, responding to a sophisticated integration of leaf age and various environmental signals. Many studies have been carried out to understand the leaf senescence-associated molecular mechanisms including the chlorophyll breakdown, phytohormonal and transcriptional regulation, interaction with environmental signals, and associated metabolic changes. The metabolic reprogramming and nutrient recycling occurring during leaf senescence highlight the fundamental role of this developmental stage for the nutrient economy at the whole plant level. The strong impact of the senescence-associated nutrient remobilization on cereal productivity and grain quality is of interest in many breeding programs (Lee & Masclaux-Daubresse, 2021).

In photosynthetic plant cells, chloroplasts act as factories of metabolic intermediates that support plant growth. Chloroplast performance is highly influenced by environmental cues. Thus, these organelles have the additional function of sensing ever changing environmental conditions, thereby playing a key role in harmonizing the growth and development of different organs and in plant acclimation to the environment. Moreover, chloroplasts constitute an excellent source of metabolic intermediates that are remobilized to sink tissues during senescence so that chloroplast dismantling is a tightly regulated process that plays a key role in plant development. Stressful environmental conditions enhance the generation of reactive oxygen species by chloroplasts, which may lead to oxidative stress causing damage to the organelle. These environmental conditions trigger mechanisms that allow the rapid dismantling of damaged chloroplasts, which is crucial to avoid deleterious effects of toxic by-products of the degradative process (Dominguez & Cejudo, 2021). Loss of chlorophyll is a hallmark of leaf senescence, which may be regulated by chloroplast catabolic genes, including NON-YELLOW COLORING 1 (NYC1)-like (NOL). Comparative transcriptomic analysis revealed that NOL-mediated functional stay-green in perennial ryegrass was mainly achieved through the modulation of chloroplast catabolism, light harvesting for photosynthesis, photorespiration, cytochrome respiration, carbohydrate catabolism, oxidative detoxification, and abscisic acid biosynthesis and signaling pathways (Yu et al., 2021a).

Leaves are the primary food-producing organs for a plant that carry out photosynthesis and contribute to biomass and grain yield. Leaf senescence is a developmentally regulated physiological process but early leaf senescence is known to negatively affect plant yield. The cuticle is an outer waxy protective layer on the leaf surface which protects plants from pathogens attack as well as dehydration (Adeel Zafar et al., 2021).

4. Regulation of leaf senescence

During leaf senescence, the final stage of leaf development, nutrients are recycled from leaves to other organs, and therefore proper control of senescence is thus critical for plant fitness (Wang et al., 2021b). Leaf senescence can be triggered by multiple abiotic stresses including darkness, nutrient limitation, salinity, and drought. Recently, heatwaves have been occurring more frequently, and they dramatically affect plant growth and development. However, the underlying molecular networks of heat stress-induced leaf senescence remain largely uncharacterized (Li et al., 2021a). Low light conditions not only induce leaf senescence, but also photosynthetic acclimation (Wu et al., 2021).

Leaf senescence, the last stage of leaf development, is a type of postmitotic senescence and is characterized by the functional transition from nutrient assimilation to nutrient remobilization which is essential for plants' fitness. The initiation and progression of leaf senescence are regulated by a variety of internal and external factors such as age, phytohormones, and environmental stresses. Significant breakthroughs in dissecting the molecular mechanisms underpinning leaf senescence have benefited from the identification of senescence-altered mutants through forward genetic screening and functional assessment of hundreds of senescence-associated genes via reverse genetic research in model plant *Arabidopsis thaliana* as well as in crop plants. Leaf senescence involves highly complex genetic programs that are tightly tuned by multiple layers of regulation, including chromatin and transcription regulation, post-transcriptional, translational and post-translational regulation. Due to the significant impact of leaf senescence on photosynthesis, nutrient remobilization, stress responses, and productivity, much effort has been made in devising strategies based on known senescence regulatory mechanisms to manipulate the initiation and progression of leaf senescence, aiming for higher yield, better quality, or improved horticultural performance in crop plants (Guo et al., 2021).

Leaf senescence has a direct impact on many important agronomic traits. Despite decades of research, identity of the senescence signal and the molecular mechanism that perceives and transduces the signal remain elusive (Hao et al., 2022). In wheat, leaf senescence is a developmental process that involves expressional changes in thousands of genes that ultimately impact grain protein content, grain yield and nitrogen use efficiency. The onset and rate of senescence are strongly influenced by plant hormones and environmental factors e.g. nitrogen availability. At maturity, decrease in nitrogen uptake could enhance nitrogen remobilization from leaves and stem to grain, eventually leading to leaf senescence. Early senescence is related to high grain protein content and somewhat low yield whereas late senescence is often related to high yield and somewhat low grain protein content. Early or late senescence is principally regulated by up and down-regulation of senescence associated genes. Integration of external and internal factors together with genotypic variation influence senescence associated genes in a developmental age dependent manner (Sultana et al., 2021). Protein degradation is an integral process of leaf senescence, and this catabolism is strongly associated with proteases in diverse plant species (Wang et al., 2021a).

Accelerated or premature leaf senescence induced by dark conditions could be associated with chlorophyll degradation and regulated by hormones. Our results suggested that SL and ethylene interactively regulated leaf senescence, mainly by controlling chlorophyll degradation induced by darkness in perennial ryegrass (Hu et al., 2021).

5. Phytohormones & genetic process

Leaf senescence is an intrinsic biological process of plants. The phytohormones salicylic acid and ethylene are known to promote senescence (Yu et al., 2021b). Endogenous salicylic acid regulates leaf senescence, but the underlying mechanism remains largely unexplored. The exogenous application of salicylic acid to living plants is not efficient for inducing leaf senescence. NPR1-WRKY46-WRKY6 signaling cascade plays a critical role in PBZ/SA-mediated leaf senescence in *Arabidopsis* (Zhang et al., 2021a). Phytohormone gibberellins also regulate leaf senescence (Fan et al., 2021). Jasmonic acid plays an important role in regulating leaf senescence (Yang et al., 2021). Abscisic acid induces chlorophyll degradation and leaf senescence; however, the molecular mechanism remains poorly understood (An et al., 2021). Plant hormones strigolactones (were recently reported to induce leaf senescence (Takahashi et al., 2021). The flag leaf and grain belong to the source and sink, respectively, of cereals, and both have a bearing on final yield. Premature leaf senescence significantly reduces the photosynthetic rate and severely lowers crop yield. Cytokinins play important roles in leaf senescence and determine grain number (Zhang et al., 2021b).

Leaf senescence is a highly complex genetic process that is finely tuned by multiple layers of regulation. Among them, transcriptional regulation plays a critical role in controlling the initiation and progression of leaf senescence (Kan et al., 2021). Expression of chlorophyll catabolic genes during leaf senescence is tightly controlled at the transcriptional level (Yu et al., 2022).

Age-dependent changes in reactive oxygen species levels are critical in leaf senescence. While H2O2-reducing enzymes such as catalases and cytosolic ASCORBATE PEROXIDASE1 (APX1) tightly control the oxidative load during senescence, their regulation and function are not specific to senescence (Chen et al., 2021a). Cross talking between natural senescence and cell death in response to pathogen attack is an interesting topic (Li et al., 2021b).

6. Applications

Phytoextraction by harvesting dead leaves is a novel cadmium phytoremediation strategy in tall fescue (*Festuca arundinacea*), which provides feasibility for the phytoremediation of cadmium-polluted soils and cleaner food production. The highest cadmium in dead leaves is the result of cadmium accumulation during the process of leaf senescence (Zhang et al., 2022b).

Melatonin is a pleiotropic agent with crucial functions reported in a variety of stress responses and developmental processes (Chen et al., 2021b). Delaying early leaf senescence is important for improving photosynthetic efficiency and crop productivity. Melatonin, a multitasking bio-stimulator, participates widely in plant development and stress responses. In recent years, the cumulative researches show that melatonin has the ability to delay senescence in plants. Melatonin biosynthesis in senescing leaves employs an alternative pathway and is significantly regulated by light. Melatonin increases the thickness of leaf cuticle, wax accumulation and the ratio of palisade/spongy of senescing leaves to maintain intact leaf structure. Melatonin eliminates free radicals through a scavenging cascade reaction and induces antioxidants and antioxidant enzymes; and provides better protection against lipid peroxidation via arranging parallel to the bilayers at high concentration. Meanwhile, melatonin's ability to ensure high photosynthetic efficiency is predominantly attributed to the reduction of chlorophylls and chloroplast proteins degradation, and the acceleration of chlorophyll de novo synthesis. The dual role of melatonin-regulated autophagy is beneficial for maintaining cellular homeostasis. NACs, WRKYs and DREBs play essential roles in melatonin-controlled transcriptional reprogramming of senescing leaves. Additionally, melatonin improves the activity of cytokinin and auxin; and inhibits the action of abscisic acid, ethylene and jasmonic acid to impact indirectly leaf senescence. Epigenetic modification may be part of mechanisms of melatonin-mediated alterations in gene expression (Zhao et al., 2021).

Deep fertilizer application is an effective strategy for minimizing gaseous losses and improving the nutrient use efficiency and grain yields. A fertilization depth of 25 cm was found to delay maize leaf senescence and enhance the grain-filling capability by improving the antioxidant defense system and photosynthetic capacity of the leaves after silking, thereby increasing the maize yield and resource utilization efficiency (Wu et al., 2022).

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ISBN: 978-625-8405-81-1