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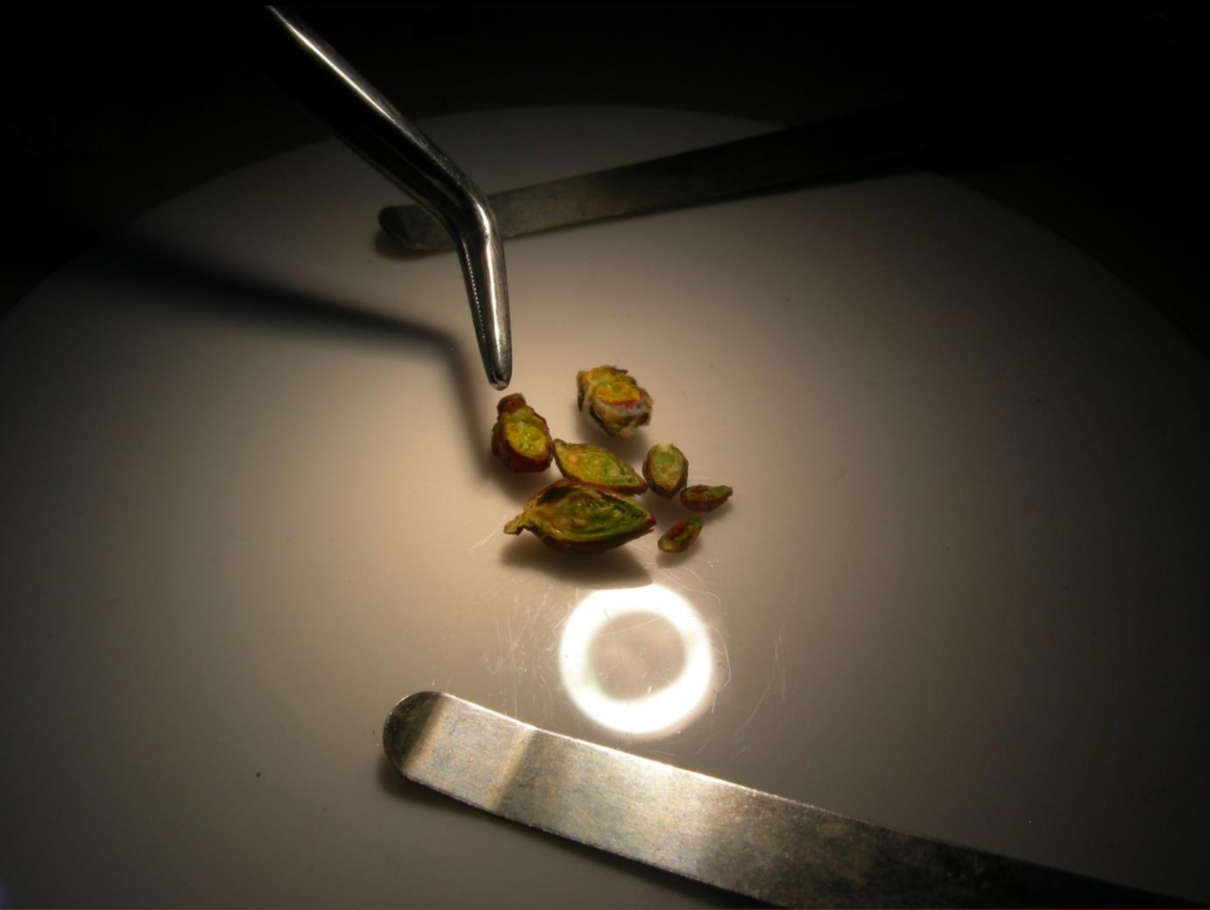

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PREFACE

Dear Reader,

In this book, current scientific studies conducted in the field of agriculture are included. It is possible for agriculture to be economically, ecologically and technologically sustainable by focusing on scientific studies. It is important for plant and animal productions being carried out in the light of science both on a macro and micro scale. The aim of organising this book is to ensure that agriculture is carried out in a more efficient and sustainable way in the light of new developments and to share the developments in the agricultural field with the scientific world. I hope that the book will add awareness and innovative approaches to studies in the field of natural sciences and agriculture. I thank all the authors who contributed to the preparation of this book titled “Focus On Agricultural Sciences”.

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CHAPTER 1

MATERIALS OF THE FUTURE, COMPOSITE PRODUCTION (*Anatolian Sweetgum* Tree) AND SOME BIOLOGICAL TEST APPLICATIONS

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1. INTRODUCTION

It is extremely important to use wood raw material correctly and consciously in order to solve the environmental problem that has become a world problem. What needs to be taken into consideration here is the correct and conscious use of wood material. At this point, wood plastic composites have a very important place. Reducing the use of plastic materials is an important issue for human health and nature because they remain intact in nature for many years and the damage they cause to the environment. Wood plastic composites; In terms of protecting forest existence, reducing the excessive and unnecessary use of wood materials, reusing wood and fiber waste as a material that is beneficial for society and human health, and considering the damage that plastic material causes to nature and the environment, wood-plastic composites are used for human health, environmental pollution and forest problems. It is a very important material for the preservation of its existence (Mengeloğlu et al., 2011). Composite material combining two or more materials by various methods, and generally has higher qualities than the materials that make it up, is called a composite material. Composite materials produced from wood; They are classified into two groups: wood composites produced with components such as cement or thermoset glues. Joints are made with the help of a press under heat. Wood material and plastic components such as polyethylene (PE), polypropylene (PP), polyvinyl chloride (PVC), and are used in the composition of thermoplastic-based wood composites (Mengeloğlu and Alma 2002; Mengeloğlu et al., 2000; Matuana and Heiden, 2004; Mengeloğlu et al. , 2008).

The new material formed by mixing lignocellulosic materials and plastic materials is called wood-plastic composite materials (Mengeloğlu et al., 2002).The word "lignocellulosic" here refers to a material that includes all kinds of wood materials, agricultural wastes and annual plants with a fibrous structure. In the production of wood-plastic

composites, wood pieces with a fibrous structure, which are generally found in the form of waste, are used (Youngquist, 1995). Generally, the production of wood plastic composites is carried out in two stages. These homogenized materials are finally turned into the final product by injection, extrusion and press molding methods (Aslan, 2008).
The process performed by keeping the wooden material in normal atmospheric conditions (any gas/nitrogen gas) for a period of time between 100˚C- 250˚C called (Yıldız, 2002). Plastic is made up of carbon (C), hydrogen (H), oxygen (O), nitrogen (N) and other organic or inorganic atoms, called monomers. A monomer can combine with different monomer molecules through polymerization to form a new molecule with a long chain structure. We can give polyethylene as an example as the simplest form of these molecules (Gürü et.al., 2006; Onaran, 2009).

Plastics have an amorphous structure. Due to these amorphous properties, it is very difficult for long and complex chains to adapt to other molecules around them and form a new structure. The chains of these plastics, which have an amorphous structure, are found entangled with each other. In some simple structured plastics, these chains can be found in a more ordered state. Small crystalline regions may form within the structure of plastics. These crystal structured regions are called crystallites. Mechanical properties increase depending on the degree of crystallization. If the cooling rate is slow, crystallization increases, resulting in an increase in mechanical properties (Akkurt, 2007).

The rapid decrease in forest/water resources, climate change and drought necessitate the use of wood materials at the highest efficiency/economicality. The optimum use of wood in a wide variety of areas can only be achieved through the production of composite materials.

One of the techniques used to increase the usability (preservation) ability of wooden materials is heat treatment. The usage scale was tried to be determined by applying various tests to obtain a composite material from heat-treated on wood.

2. MATERIAL AND METHOD

İn research, Anatolian sweetgum tree (*Liquidambar orientalis Miller*) wood was preferred. Care was taken the wood samples were backings, fungal damage. High density polyethylene (HDPE) was used as polymer plastic.

2.1. Heat Treatment

Anatolian sweetgum tree (*Liquidambar orientalis Miller*) samples conditioned for 3-4 months were heat treated with the thermo-D method. Before the process, the wood material was dried until its moisture content was 18% and 0%. Subsequently, heat treatment was applied to the wood material in a closed environment under saturated water vapor at a temperature of 185 °C-212 °C for 3 hours. After the heat treatment was completed, the wood material was cooled in a controlled manner.

2.2. Wood Plastic Composite Production

The wood material, which was heat treated and used as a control sample, was first chipped and then ground into flour in Willey mills. The ground samples were sieved in the shaker sieve. After the sieving process in the shaker sieve, the samples remaining over 60 mesh were used in production.

The heating zones of the extruder machine are set at 150-160-170-180 °C. After the mixture passed through the extruder machine, it was placed in a cold water bath to cool and harden. After the cooling process was completed, the pellets were passed through the crusher shown particle sizes were reduced. After the drying process was completed, the particles were placed in the mold and pressed at 175°C for 3 minutes.

After pressing was completed, the mold was left to cool under load (Tutuş et al.2010).

2.3. Biological Tests (Fungal Test)

Fungus tests to EN 113 (European Committee For Standardization). To create a nutrient medium, 48 g of malt extract agar was placed in a conical flask and diluted to 1 liter with water distilled. The mixture was sterilized 121°C and 20 min. After this, approximately 17 mL of solution was placed in each petri dish and after cooling, fungal mycelia were inoculated. *Coriolus versicolor* (White rot fungus) and *Coniophora puteana* (brown rot fungus) were used.

3. FINDINGS AND DISCUSSION

3.1.Biological Tests (Fungal Tests)

Weight losses of the heat-treated and non-heat-treated (control) groups against are given in Table 1.

Table 1. Weight loss (%)

Mixing Ratio İn Wood Plastic Composite	WHITE ROOT FUNGUS	BROWN ROOT FUNGUS
% 50 **Not Heat Treated Wood** + % 50 HDPE	12.69	17.21
50 % **Heat Treated Wood** -% 50 HDPE	3.76	5.37

HDPE: Recycled Polymers (Recycled High Density Polyethylene)

Due to the unheat-treated structure of the Anatolian Sweetgum tree, occurred brown rot fungus test (17.21%), and the lowest occurred in the heat-treated group in both groups (brown/white rot). The lowest heat-treated white rot fungus test.

Many microorganisms living in wood benefit from various compounds of the cell wall during their development process, causing the weight of the wood to decrease. Some fungi cause little weight loss

(1-3%) and minimal damage by first utilizing the storage substances or extractive substances in the parenchyma cells. while others are damaged by the complex chemical components of woody cell walls. Wood varies depending on the fungus type and tree species (Zabel and Morrell, 1992). Microorganisms living in wood. They cause density, hygroscopicity, electrical conductivity, acoustic properties, calorific value, change in dimensions and decrease in the resistance value of wood. In many cases these changes may be hidden and poorly defined. Addressing microbiological effects on wood properties enables their identification and biological It helps to define the roles and interactions of random factors in the degradation process (Zabel and Morrell, 1992; Eaton and Hale, 1993).

4. CONCLUSION

In this study, wood-plastic composites generally showed successful and positive results in the areas where they were used. The data obtained shows this material are a usable in many areas. Another important issue is protecting forest existence by reducing the use of wood raw materials. Wood plastic composites are also important in terms of being beneficial to the environment and people by protecting the existence of forests.

In studies to be carried out on this subject, the selection of raw materials should be made in accordance with the standards. The samples to be used should be processed by taking into account the characteristics of the raw material. When starting the study, sample selection, storage and all operations should be done with attention to this issue. All data, measurements and all operations must be carried out carefully, from the first stage of the study to the last stage. This issue is very important for the results of the study to be reliable.

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CHAPTER 2

LAVENDER (*Lavandula angustifolia Mill*.) PLANT AS AN EXTRACT ON WOOD MATERIALS AND ITS EFFECTS ON SOME TECHNOLOGICAL PROPERTIES

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1. INTRODUCTION

Exposure to chemical effects in the environment we live in poses serious threats. The importance of natural raw materials has increased. The use of natural building products in our homes, where we spend most of our lives, the toys used by our children, wooden products used in the workplace, etc. It has an important importance for our family and our own health. Recent years show that, along with the increase in diseases, the increasing interest in natural, healthy products and the increasing environmentalist attitude, the use of environmentally friendly, natural and healthy products in the production and use of wooden materials has gradually increased (Yılmaz, 2022). Resin and leaves obtained from the sweetgum tree were extracted with methanol under room conditions, and the obtained extracts were compared with the inhibition of acetylcholinesterase and butyrylcholinesterase enzymes, which are associated with Alzheimer's disease, with galantamine, which is used in the treatment of people with moderate Alzheimer's disease, and as a result, the resin and leaf extracts at a concentration of 200 ppm, respectively, inhibited the AChE enzyme (Gülsen et al. 2011).

Fungal disease agents that cause problems in apple and cucumber plants are Fusarium oxysporum f.sp. Different concentrations of plant extracts, including 5, 10, and 20 mg/ml in the control group, were used against cucumerinum (FOC) and Monilinia fructigena, and the Lethal Dose and Mycelium values were determined in the data obtained with this concentration. Resin and leaf extracts have shown antifungal activity at every concentration used against fungal disease agents. It was determined that as the dose of concentration increased, the Mycelium Growth Inhibition value increased. When resin and leaf extract were compared, resin extract was found to be more effective than leaf extract (Onaran, 2018). İmpregnation process was carried out with waste oils and its effect on the physical properties of the wood material after impregnation was investigated, and the physical properties gave positive results (Özkan Özkan et al. 2020). In a study conducted on Scots pine wood, it was determined that valex, which is hoped to be used as a herbal preservative, generally negatively affects the physical, mechanical and biological properties of the wood. While the toxicity effects of CCA and CBA-A in biological tests were found to be satisfactory, partial performance decreases in mechanical properties were observed (Şimşek, 2013). Studies have been carried out to determine the resistance properties of wood samples taken from oak, larch, cedar, fir, beech, Scots pine and red pine trees, which are among our important tree species, against screw and nail retention, and it has been stated that the specific gravity of woods has a great effect on their ability to hold nails well. As the specific gravity increases, the nail holding strength property increases (Ferah, 1995).

The effect of resin production on technologıcal structure of red pine wood was investigated, and it was observed that there was no significant difference in terms of air-dry and fully dry specific gravity, volume and density values between trees in which resin production was made and trees in which resin was not produced, in the north, south, east and west directions. (Öktem et.al. 1995).

Natural plants are used for a wide variety of purposes (phytotherapy, spices, tea, pesticides, dyes, oil utilization, industry, cosmetics, etc.). In addition to determining the impregnability and some technological properties of wood, which has a natural (organic) structure, by obtaining extracts from various concentrations of the lavender plant, which is known for its antioxidant/antibacterial properties, an attempt was made to create a natural protective structure in the wood material.

2. MATERIAL AND METHOD

While black pine wood (*Pinus nigra Arnold*) was used in experimental studies, extracts were prepared from lavender plant (*Lavandula angustifolia Mill.*) at various concentrations.

2.1. Preparation of Test Samples

While preparing the test samples, solid, knot-free and smooth-fibered slats of various sizes were obtained from larch logs. For the experiment, the slats were first brought to 20±^{0}C temperature and 65±3% relative humidity conditions according to conditioned to air dry (12%) humidity, and then passed through a planing machine to the desired thickness. The samples were conditioned again under the same conditions, down to air dry (12%) humidity, and measured using a balance with a precision of 0.01gr. Afterwards, the samples were dried in a drying cabinet at 103±2°C until they reached full dry weight, that is, 0% moisture, according to TS 2470/TS 2471 (1976).

2.2. Treatment

The treatment was performed in 30-minute vacuum/30-minute diffusion environment. The impregnation process was carried out in a laboratory environment by adapting the conditions ASTM-D 1413-76' standard. Accordingly, completely dry test samples were made in the natural preservative obtained from plant extracts for short, medium and long periods

2.3. Preparation of Plant Extract

The dried lavender plant was turned into powder. Powdered sweetgum leaves were extracted by brewing with distilled hot water (80˚C). After the mixture cooled, it was filtered with filter paper. The resulting filtrate was then dried under vacuum with a mill-dryer (lyophilizer) system and the crude extract was obtained. Different concentrations of the obtained extract were used in the impregnation process (Ceylan, 2020).

2.4. Mechanical Properties

While the bending strength/pressure strentgh test was carried out in accordance with the TS 2474/1976/TS 2595 standard and 20±20C/65±5% relative humidity to 12% moisture content. **3.**

FINDINGS AND DISCUSSION

3.1. Solution (Extract) Feature

Table 1. Extract Characteristics

Plant Extract	Solvent	Degree (°C)	pH		Density (g/ml)	
			İB	İA	İB	İA
1%	Water	22°C	5.8	5.8	0.912	0.912
3%			5.11	5.11	0.915	0.915

İB:İmpregnation Before **İA:**İmpregnation After

There was no change in pH and density of solution properties after impregnation and impregnation are given in Table 1.

3.2. Retention

The retention level of lavender plant extract on larch wood Table 2.

Table 2. Amount of Retention **(%)**

Solution Concentration	Vacuum/ Dıffussıon	Solver	Degree (°C)	Retention (%)	
				Mean	HG
1%	30/30 Minute	Water	22°C	0.56	A
3%				0.41	B

The highest retention value in larch wood was achieved at 1% solution concentration (0.56%). As the concentration increased, the retention level decreased.

Var et al. (2019) found the highest retention value in red pine wood treated with geothermal water as 2.773% in the SJ-5 40.9ºC treatment, while the lowest value was 2.565% in the SJ-1 23.0ºC treatment.

3.3. Mechanıcal Properties

3.3.1.Bending Strentgh-Pressure Strentgh Properties

Findings regarding bending strength and compression strength properties are given in Table 2.

Table 2. Bending Strentgh-Compression Strentgh (N/mm^2)

Plant Extract	Bending Strentgh		Compression Strentgh	
	Mean	HG	Mean	HG
Control	115.20	C	48.01	B
1%	116.45	B	50.42	C
3%	124.56	A	55.65	A

Regarding the bending strength and compressive strength properties, the bending strength was found to be higher than the control sample. The highest bending strength was determined in the 3% lavender plant extract (124.56 N/mm^2), and the lowest was determined in the control sample. In terms of pressure resistance feature, the highest pressure resistance was determined in 3 % extract (55.65 N/mm^2). This may be due to the anatomical structure of the wood and the oil structure in the lavender plant.

In a study comparing linseed oil and pomegranate seed oil, it was observed that pomegranate seed oil performed better than linseed oil after being kept in the air conditioning cabinet for 600 hours (Özgenç et al., 2013). In a study conducted with tall oil, it was stated that wooden poles did not deteriorate after being in contact with the soil for 5 years and showed protection as good as CCA (Tomak et al., 2012). It has been observed that cedar oil completely kills subterranean termites within a week and inhibits the growth of fungi (Eller et al., 2021). Additionally, wood samples treated with sunflower oil showed better UV performance compared to untreated samples (Nemeth et al., 2016).

4. CONCLUSION

The findings obtained had a positive effect on bending strength/compressive strength, which is one of the natural protective (extract) mechanical properties obtained from the lavender plant. We can say that it can be used as a protective and aesthetic surface / impregnation material in the furniture and construction industry, children's toys and many other areas. Although it is known that the negative effects of chemical-based varnishes/paints that are still used on human and environmental health are known, it is an inevitable fact that all surface treatments and preservatives used in the forest industry must provide a certain mechanical strength in all wood-related products used indoors and outdoors, in addition to providing an aesthetic appearance. The natural dye obtained can be used with brush and spraying methods; It will have positive effects on human and environmental health and will be cost-effective; It can be said that color tone adjustments can be made and it can also be used in the restoration of historical wooden works.

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CHAPTER 3

EFFECT OF PLANT DENSITY ON YIELD AND SOME QUALITY CHARACTERISTICS OF SILAGE MAIZE (*Zea Mays* L.)

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Introduction

Corn (*Zea mays* L.) is a versatile and high-yield crop used as a raw material for human food, animal feed and agro-based industries (Mandić et al., 2015; Sun, 2017). Improving feed production is essential for the sustainability of the meat and dairy industries (Feng, 2011; Sun, 2017). Due to its high yield, excellent feed quality and low production cost, corn is widely used in silage production (Cusicanqui & Lauer, 1999; Esfahani et al., 2014). The amount of corn used as animal feed worldwide has approximately doubled over the last 20 years (Jiang, 2018). In dairy operations, corn silage is a primary source of energy and fiber for dairy cows (Ferreira et al., 2014). The quality of feed and silage can be improved by adjusting plant density. Maintaining optimal plant density in silage maize varieties increases dry matter yield (Fischer et al., 2019). Lower plant densities can produce higher biomass per plant, but the reduced number of plants per unit area can decrease yield per unit area (Shi et al., 2016; Zhang et al., 2018). Achieving optimal yield and quality values requires correctly balancing yield per plant with the number of plants per unit area. Determining the most suitable plant density can also compensate for yield losses due to competition for light and nutrients between plants (Zhang et al., 2017). Increasing plant density reduces photosynthesis rate and dry matter accumulation per plant due to inter-plant competition but increases biomass yield per unit area by improving light capture and resource efficiency (Gao et al., 2017; Zhang et al., 2018). However, high plant densities that exceed the optimal ratio can lead to a reduction in leaf area and chlorophyll content per plant, limiting assimilation and decreasing dry matter accumulation (Jia et al., 2018; Xu, 2018).

To achieve the highest feed production values, plant densities of 4500-12500 plants per decare are recommended in different regions due to climate and soil conditions (Karasahin, 2014; Mandić et al., 2015; Stanton et al., 2007). Optimizing plant population by creating better canopy structure is an effective way to achieve high feed yield. However, increasing plant density can negatively impact silage quality (Liu et al., 2018; Mandić et al., 2015; Saponjic et al., 2014; Stanton et al., 2007; Sun, 2017; Wang et al., 2019). Reduced feed quality decreases feeding efficiency (Cusicanqui & Lauer, 1999; Dragičević et al., 2016; Stanton et al., 2007). As plant density increases, inter-plant competition reduces photosynthetic production, energy and nutrient accumulation, leading to increased weight of plant organs (leaves and stems) but a decrease in grain ratio (Li, 2018; Sun, 2017). This results in increased ADF and NDF content and a decrease in crude protein ratio, thereby lowering feed quality (Qiao et al., 2018; Yu et al., 2018). Therefore, optimizing plant density is an effective way to improve yield and quality.

The aim of this study is to determine the optimal plant density for silage maize varieties under the ecological conditions of Mardin Kızıltepe, to reduce production costs and obtain higher quality feed material.

Materials and Methods

Materials

The characteristics of the maize varieties used in the study are presented in Table 1.

Table 1. Varieties used in the experiment and their characteristics

Supplier Organization	Variety Commercial Name	Variety Characteristics
Sakarya Maize Research Institute	ADA 523	• FAO 650 group • Erect leaves • Yellow dent grain structure • Average plant height of 270-300 cm • Silage yield of 9-9.5 tons

Supplier Organization	Variety Commercial Name	Variety Characteristics
Tareks	OSSK 644	• FAO 650 group • Ready for harvest in 90-100 days • High protein content • Tall structure • High green forage yield
Limagrain (LG)	INDACO	• FAO 650 group • Ready for harvest in 90-100 days • Resistant to lodging • Fine kernels, long grains • High yield characteristics

Experimental Site

This study was conducted in the Köprübaşı neighborhood of the Kızıltepe district in Mardin province, following the wheat harvest of 2023, under second crop conditions. The experimental site is located to the south of Kızıltepe, approximately 23 km from the district center.

Climate Characteristics of the Research Site

In the Kızıltepe district of Mardin province, where the experiment was established, precipitation generally begins in October and continues throughout the spring season. The district experiences very hot and dry summer months, with relatively low levels of relative humidity. The meteorological data for 2023, during which the research was conducted, are presented in Table 2.

Table 2. Climate data of the research area over long-term and for 2023*

	years	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Temperature (°C)	2023	26.4	31.6	29.8	29.8	22.9	12.1	
	Long-Term Avg.	28.5	32.1	30.9	26.2	20.5	13.3	8.10
Precipitation (mm)	2023	31.6	3.90	0.00	0.00	0.00	35.9	
	Long-Term Avg.	35.3	0.73	0.20	1.47	24.5	33.29	33.5
Humidity (%)	2023	27.0	20.5	22.3	20.8	22.7	55.4	
	Long-Term Avg.	25.1	21.0	27.6	30.5	38.3	50.7	65.5

(*): Climate data for 2023 was obtained from the Mardin regional directorate of meteorology.

Soil Characteristics of the Research Area

Soil samples were collected from a depth of 0-30 cm and analyzed. The results are presented in Table 3. According to the analysis, the soil texture is clay-loam, the organic matter content is low, the potassium content is at an adequate level and the soil pH is slightly alkaline.

Table 3. Soil properties and analysis results of the research area

Soil characteristics	**2023**
Texture	Clay-Loam
pH	7.24
Salinity	0.30
Organic Matter	1.56
CaCO3 (%)	4.67
Nitrogen (N %)	0.82
Phosphorus (P_2O_5) (kg/da)	2.70
Potassium (K_2O) (kg/da)	2.54

Methodology

Experimental Design

The experiment was set up using a randomized block design with split plots, with three replications. The main plots consisted of varieties (ADA523, İNDACO and OSSK644), while the subplot treatments consisted of row spacing (12, 16, 20 and 24 cm). The total number of plots in the experiment was 36. Each plot is 6 meters long and consists of 4 rows, with an intra-row spacing of 70 cm.

Soil Preparation and Planting

After deep plowing, the experimental area was leveled with rotavators and prepared for planting. Pre-planting irrigation was performed to bring the soil to a suitable condition. Planting was done manually in rows. Row spacing was set at 70 cm and the plant spacing within the rows was adjusted to 12, 16, 20 and 24 cm.

Fertilization

Fertilizers were applied to the experimental plots with 20 kg/da of pure nitrogen (N) and 10 kg/da of pure phosphorus (P_2O_5). All of the phosphorus and part of the nitrogen were applied in the seed row during planting and the remaining nitrogen was applied by broadcasting when the plants reached a height of 65-70 cm. A 20-20-0 (NPK) fertilizer was used with the seed and a 46% (N) urea fertilizer was used for top dressing.

Irrigation and Maintenance

After soil preparation, the first irrigation was performed using the sprinkler method. Irrigation was carried out as needed when the plants showed signs of wilting and it was terminated 10 days before harvest.

Harvesting

Harvesting was done when the grain was at two-thirds of the milk stage. After removing the edge effects, the remaining plants were harvested by scythe.

Traits Examined in the Study

Plant Height (cm): For each harvested plot, the height from the soil surface to the top of the plant was measured in meters using a meter stick for 10 randomly selected sample plants and the average plant height was calculated.

Stem Diameter (mm): For each harvested plot, the stem diameter between the first two internodes was measured with a caliper for 10 randomly selected sample plants and the average stem diameter was calculated.

Green Forage Yield (kg/da): After removing the edge effects, the two central rows of plants were harvested by scythe and the yield was weighed to calculate the yield per decare.

Leaf Ratio (%): For the plots to be harvested, the leaves, stems and cobs of 10 randomly selected plants were weighed separately. The leaf weight was then expressed as a percentage of the total plant weight to calculate the leaf ratio.

Stem Ratio (%): For the plots to be harvested, the leaves, stems and cobs of 10 randomly selected plants were weighed separately. The stem weight was then expressed as a percentage of the total plant weight to calculate the stem ratio.

Cob Ratio (%): For the plots to be harvested, the leaves, stems and cobs of 10 randomly selected plants were weighed separately. The cob weight was then expressed as a percentage of the total plant weight to calculate the cob ratio.

Dry Matter Ratio (%): Fresh plant samples of 500 grams from each plot were dried in an oven set at 105°C until a constant weight was achieved. The dry matter ratio was calculated by weighing the dried plants.

Dry Matter Yield (kg/da): This was calculated based on the green forage yield and the dry matter ratio.

Crude Protein Ratio (%): Ground dry plant samples were sieved through a 1 mm mesh before analysis. The nitrogen (N) content was determined using the Kjeldahl method and multiplied by a factor of 6.25 to calculate the crude protein ratio.

Statistical analysis

The data obtained in the study were analyzed using the JMP 5.1 software program according to the split-plot design in randomized blocks. The LSD (Least Significant Difference) test was used for the grouping of differences between means.

Results and Discussion

Table 4. Variance analysis results of plant density on some yield and quality traits in silage corn varieties

Source	F		
	Variety	**IRS**	**IRS*Variety**
Plant height	4.07*	10.1**	2.50**
Stem diameter	52.3**	12.8**	1.25$^{N.S.}$
Green forage yield	790**	52.2**	20.0**
Leaf ratio	65.3**	9.61**	0.31$^{N.S.}$
Stem ratio	89.1**	13.6**	1.68$^{N.S.}$
Ear ratio	579**	40.3**	1.35$^{N.S.}$
Dry matter ratio	16.1**	13.1**	0.32$^{N.S.}$
Dry matter yield	283**	2.37$^{N.S.}$	5.73**
Crude protein ratio	20.0**	5.04**	0.38$^{N.S.}$

IRS: Intra Row Spacing, (**NS**): not statistically significant, (*****): statistically significant at $P \leq 0.05$ level, (******): statistically significant at $P \leq 0.01$ level

Based on the analysis results, it was determined that plant density had a statistically significant effect on plant height in silage maize varieties at the $P \leq 0.05$ level in terms of variety and at the $P \leq 0.01$ level in terms of intra-row spacing (IRS) and IRS*variety interaction. The effect on stem diameter was not statistically significant in terms of IRS*variety interaction, but was significant at the $P \leq 0.01$ level in terms of variety and IRS. The effect on green forage yield was not statistically significant, but was significant at the $P \leq 0.01$ level in terms of variety, IRS and IRS*variety interaction. The effect on leaf ratio was not statistically significant in terms of IRS*variety interaction, but was significant at the $P \leq 0.01$ level in terms of variety and IRS. The effect on stem ratio was not statistically significant in terms of IRS*variety interaction, but was significant at the *P*≤0.01 level in terms of variety and IRS. The effect on ear ratio was not statistically significant in terms of IRS*variety interaction, but was significant at the *P*≤0.01 level in terms of variety and IRS. The effect on dry matter ratio was not statistically significant in terms of IRS*variety interaction, but was significant at the *P*≤0.01 level in terms of variety and IRS. The effect on dry matter yield was not statistically significant in terms of IRS, but was significant at the *P*≤0.01 level in terms of variety and IRS*variety interaction. The effect on crude protein ratio was not statistically significant in terms of IRS*variety interaction, but was significant at the *P*≤0.01 level in terms of variety and IRS (Table 4). The variance analysis results related to the effect of plant density on various yield and quality characteristics of silage corn varieties are presented in Table 4.

The effect of plant density on plant height, stem diameter and green forage yield in silage maize varieties

Table 5. Effect of plant density on plant height, stem diameter and green forage yield in silage maize varieties.

Feature	Variety	Plant Density Applications (cm)				Avg.
		12	16	20	24	
Plant height (cm)	ADA523	276 bc	279 b	281 b	265 ce	275 AB
	İNDACO	275 b-d	277 bc	256 e	263 de	268 B
	OSSK644	281 ab	290 a	279 b	266 ce	279 A
	Avg.	**277 AB**	**282 A**	**272 B**	**265 C**	**274**
Stem diameter (mm)	ADA523	22.7 bc	22.9 bc	23.1 b	23.6 a	23.1 A
	İNDACO	20.8 e	20.8 e	22.1 cd	22.7 bc	21.6 C
	OSSK644	21.8 d	21.5 de	22.3 bd	22.7 bc	22.1 B
	Avg.	**21.8 B**	**21.7 B**	**22.5 A**	**23.0 A**	**22.3**
Green forage yield (kg/da)	ADA523	8425 a	8510 a	8121 b	7865 c	8230 A
	İNDACO	7344 e	7215 f	7422 e	7166 f	7287 C
	OSSK644	7858 c	8040 b	7910 c	7726 d	7884 B
	Avg.	**7876 AB**	**7922 A**	**7818 B**	**7586 C**	**7800**

Plant Height: As a result of plant density treatments and variety interactions, the highest plant height (290 cm) was observed in the OSSK644 variety with a 16 cm spacing, while the lowest plant height (256 cm) was recorded in the İNDACO variety with a 20 cm spacing. Among the varieties, the OSSK644 variety yielded the highest plant height (279 cm), while the İNDACO variety had the lowest height (268 cm). Among the plant density treatments, the highest plant height (282 cm) was observed with a 16 cm spacing, while the lowest height (265 cm) was recorded with a 24 cm spacing (Table 5). Küçük (2011) reported that in his study examining the characteristics of some corn varieties, the average plant height of the varieties ranged from 254 to 293.3 cm. Özata et al. (2012) found the plant height to be between 276 and 333 cm in their study investigating the silage yield and quality characteristics of single hybrid varieties.

Plant Stem Diameter: As a result of plant density applications and variety interactions, the highest plant stem diameter (23.6 cm) was obtained with the 24 cm application for the ADA523 variety, while the lowest stem diameter (20.8 cm) was observed with the 12 and 16 cm applications for the İNDACO variety. Among the varieties, the highest plant density value (23.1 cm) was found for the ADA523 variety, while the lowest value (21.6 cm) was found for the İNDACO variety. Among the plant density applications, the highest value (23.0 cm) was observed with the 24 cm applications and the lowest value (21.7 cm) was observed with the 16 cm applications (Table 5). Budak & Soya (2003) reported that in their study conducted with four different silage corn varieties during the second crop growing season under the ecological conditions of İzmir-Bornova, the plant stem diameter ranged from 17.3 to 21.4 mm. Geren & Avcıoğlu (2000) reported that in their study on silage corn varieties under the ecological conditions of İzmir, the plant stem diameter ranged from 20.8 to 25.7 mm.

Green Forage Yield: As a result of plant density applications and variety interactions, the highest green forage yield (8510 kg/da) was obtained with the 16 cm application for the ADA523 variety, while the lowest yield (7166 kg/da) was obtained with the 24 cm application for the İNDACO variety. Among the varieties, the highest green forage yield (8230 kg/da) was found for the ADA523 variety and the lowest yield (7287 kg/da) was found for the İNDACO variety. Among the plant density applications, the highest yield (7922 kg/da) was observed with the 16 cm applications and the lowest yield (7586 kg/da) was observed with the 24 cm applications (Table 5). Soya et al. (2001) reported that in their study conducted to determine the yield and quality characteristics of silage corn varieties under the ecological conditions of İzmir, the green herbage yield ranged from 7.446 to 8.569 kg/da. Ergül & Soylu (2008) reported that in their study conducted to determine the yield and quality characteristics of silage corn varieties under the ecological conditions of Konya, the green herbage yield ranged from 7.594 to 10.348 kg/da.

The effect of plant density on leaf ratio, stem ratio and ear ratio in silage maize varieties

Table 6. Effect of plant density on leaf ratio, stem ratio and ear ratio in silage maize varieties.

Feature	Variety	Plant Density Applications (cm)				Avg.
		12	16	20	24	
Leaf ratio (%)	ADA523	18.5 e	18.7 e	19.4 de	20.1 cd	19.2 C
	İNDACO	20.4 b-d	20.6 bc	21.2 b	22.1 a	21.1 A
	OSSK644	19.8 cd	20.1 cd	20.6 bc	20.8 bc	20.3 B
	Avg.	**19.6 C**	**19.8 BC**	**20.4 AB**	**21.0 A**	**20.0**
Stem ratio (%)	ADA523	48.2 f	49.4 e	50.2 de	50.6 d	49.6 B
	İNDACO	52.3 bc	52.6 bc	53.1 a-c	53.3 ab	52.8 A
	OSSK644	52.6 bc	52.1 c	53.2 ab	53.9 a	53.0 A
	Avg.	**51.0 B**	**51.4 B**	**52.2 A**	**52.6 A**	**52.0**
Ear ratio	ADA523	33.3 a	31.9 b	30.4 c	29.3 c	31.2 A

(%)	İNDACO	27.3 de	26.8 d-f	25.7 f-h	24.6 h	26.1 C
	OSSK644	27.6 d	27.8 d	26.2 e-g	25.3 gh	26.7 B
	Avg.	**29.4 A**	**28.8 A**	**27.4 B**	**26.4 C**	**28.0**

Leaf Ratio: As a result of plant density applications and variety interactions, the highest leaf ratio (22.1%) was achieved with the 24 cm application for the İNDACO variety, while the lowest leaf ratio (18.5%) was obtained with the 12 cm application for the ADA523 variety. Among the varieties, the highest value (21.1%) was found for the İNDACO variety and the lowest value (19.2%) was found for the ADA523 variety. Among the plant density applications, the highest value (21.0%) was observed with the 24 cm applications and the lowest value (19.6%) was observed with the 12 cm applications (Table 6). Yılmaz & Hosaflıoğlu (1999) reported that in their study conducted to determine the yield and quality characteristics of silage corn varieties under the ecological conditions of Hatay, the leaf ratio ranged from 18.77% to 26.03%. Akdeniz et al. (2004) reported that in their study conducted to determine the yield and quality characteristics of silage corn varieties under the ecological conditions of Van, the leaf ratio ranged from 17.3% to 23.5%.

Stem Ratio: As a result of plant density applications and variety interactions, the highest stem ratio (53.9%) was achieved with the 24 cm application for the OSSK644 variety, while the lowest stem ratio (48.2%) was observed with the 12 cm application for the ADA523 variety. Among the varieties, the highest value (53.0%) was found for the OSSK644 variety and the lowest value (49.6%) was found for the ADA523 variety. Among the plant density applications, the highest value (52.6%) was observed with the 24 cm applications and the lowest value (51.0%) was observed with the 12 cm applications (Table 6). Karayiğit & Kızılşimşek (2005) reported that in their study conducted to determine the yield and quality characteristics of silage corn varieties under the ecological conditions of Kahramanmaraş, the stem ratio ranged from 42.0% to 53.0%. Küçük (2011) reported that in his study conducted to determine the yield and quality characteristics of silage corn varieties under the ecological conditions of Ankara, the stem ratio ranged from 45.32% to 52.04%.

Ear Ratio: As a result of plant density applications and variety interactions, the highest ear ratio (33.3%) was achieved with the 12 cm application for the ADA523 variety, while the lowest ear ratio (24.6%) was obtained with the 24 cm application for the İNDACO variety. Among the varieties, the highest value (31.2%) was found for the ADA523 variety and the lowest value (26.1%) was found for the İNDACO variety. Among the plant density applications, the highest value (29.4%) was observed with the 12 cm applications and the lowest value (26.4%) was observed with the 24 cm applications (Table 6). Küçük (2011) reported that in his study conducted to determine the yield and quality characteristics of silage corn varieties under the ecological conditions of Ankara, the cob ratio ranged from 23.84% to 32.48%. Kabakçı (2014) reported that in his study conducted to determine the yield and quality characteristics of silage corn varieties under the ecological conditions of Iğdır, the cob ratio ranged from 24.6% to 38.3%.

The effect of plant density on dry matter ratio, dry matter yield and crude protein ratio in silage maize varieties

Table 7. Effect of plant density on dry matter ratio, dry matter yield and crude protein ratio in silage maize varieties.

Feature	Variety	Plant Density Applications (cm)				Avg.
		12	16	20	24	
Dry matter ratio (%)	ADA523	28.1 b-d	28.7 ab	28.8 ab	29.7 a	28.8 A
	İNDACO	27.4 cd	27.4 cd	28.2 bc	28.8 ab	28.0 B
	OSSK644	27.2 d	27.3 cd	28.1 b-d	28.6 b	27.8 B
	Avg.	**27.6 C**	**27.8 C**	**28.4 B**	**29.0 A**	**28.2**
Dry matter yield (kg/da)	ADA523	2367 b	2442 a	2339 b	2336 b	2371 A
	İNDACO	2012 gh	1977 h	2093 ef	2064 fg	2036 C
	OSSK644	2137 de	2195 cd	2223 c	2209 c	2191 B

	Avg.	2172 B	2205 AB	2218 A	2203 AB	2200
Crude protein ratio (%)	ADA523	7.70 b-d	7.90 bc	7.90 bc	8.20 ab	7.93 A
	İNDACO	7.90 bc	8.10 a-c	8.50 a	8.50 a	8.25 A
	OSSK644	7.30 d	7.30 d	7.60 cd	7.70 bd	7.50 B
	Avg.	**7.60 C**	**7.80 BC**	**8.00 AB**	**8.10 A**	**7.90**

Dry Matter Ratio: As a result of plant density applications and variety interactions, the highest dry matter ratio (29.7%) was achieved with the 24 cm application for the ADA523 variety, while the lowest dry matter ratio (27.2%) was obtained with the 12 cm application for the OSSK644 variety. Among the varieties, the highest value (28.8%) was found for the ADA523 variety and the lowest value (27.8%) was found for the OSSK644 variety. Among the plant density applications, the highest value (29.0%) was observed with the 24 cm applications and the lowest value (27.6%) was observed with the 12 cm applications (Table 7). Ferreira et al. (2014) reported that in their study conducted in Argentina, examining the effects of plant densities on yield and yield parameters of two different corn varieties, the dry matter content ranged from 30.1% to 35%. Ergül (2008) found that in his study conducted under the ecological conditions of Konya, the dry matter content of silage corn varieties ranged from 24.4% to 32.1%.

Dry Matter Yield: As a result of plant density applications and variety interactions, the highest dry matter yield (2442 kg/da) was achieved with the 16 cm application for the ADA523 variety, while the lowest dry matter yield (1977 kg/da) was obtained with the 16 cm application for the İNDACO variety. Among the varieties, the highest value (2371 kg/da) was found for the ADA523 variety and the lowest value (2036 kg/da) was found for the İNDACO variety. Among the plant density applications, the highest value (2218 kg/da) was observed with the 20 cm applications and the lowest value (2172 kg/da) was observed with the 12 cm applications (Table 7). Güneş & Acar (2006) reported that in their study conducted to determine the yield and quality characteristics of some silage corn varieties grown as a second crop under the ecological conditions of Karaman, the dry matter yield ranged from 2193,4 to 2657,5 kg/da. Aydoğan (2010) found that in his study aimed at determining the silage quality of some local and hybrid corn varieties grown under the ecological conditions of Ordu, the dry matter yield ranged from 2000 to 2400 kg/da. Mandic et al. (2015) reported that in their study conducted to assess the effects of row spacing (20, 24 and 28 cm) on the yield and quality characteristics of two silage corn varieties, the dry matter yield ranged from 2104 to 2463 kg/da.

Crude Protein Ratio: As a result of plant density applications and variety interactions, the highest crude protein ratio (8.50%) was achieved with the 20 and 24 cm applications for the İNDACO variety, while the lowest crude protein ratio (7.30%) was obtained with the 12 and 16 cm applications for the OSSK644 variety. Among the varieties, the highest value (8.25%) was found for the İNDACO variety and the lowest value (7.50%) was found for the OSSK644 variety. Among the plant density applications, the highest value (8.10%) was observed with the 24 cm applications and the lowest value (7.60%) was observed with the 12 cm applications (Table 7). Ferreira et al. (2014) reported that in their study conducted in Argentina, examining the effects of plant densities on yield and yield parameters of two different corn varieties, the crude protein content ranged from 7.7% to 8.8%. Zayim (2020) found that in his study conducted to determine the reactions of four different corn varieties to different row spacings under the ecological conditions of Aydın-Söke, the crude protein content ranged from 7.6% to 8.9%.

Conclusions and Recommendations

Based on the results, plant density and variety interactions significantly influenced various agronomic traits in silage maize. The highest plant height was recorded in the OSSK644 variety with a 16 cm spacing, while the lowest was in the İNDACO variety with a 20 cm spacing. For stem diameter, the largest was observed in the ADA523 variety with a 24 cm spacing and the smallest in the İNDACO variety with 12 and 16 cm spacings. The ADA523 variety also yielded the highest green forage yield with a 16 cm spacing, whereas the İNDACO variety had the lowest yield with a 24 cm spacing. Leaf and stem ratios showed significant variation, with the highest leaf ratio in the İNDACO variety at a 24 cm spacing and the highest stem ratio in the OSSK644 variety with the same spacing. Ear ratio was highest in the ADA523 variety with a 12 cm spacing. The highest dry matter ratio and yield were observed in the ADA523 variety with 24 cm spacing, while the lowest dry matter yield was recorded for the İNDACO variety at 16 cm spacing. The crude protein ratio was highest for the İNDACO variety with 20 and 24 cm spacings. These findings suggest that optimizing plant density and selecting suitable varieties can enhance maize productivity and quality.

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CHAPTER 4

Nigella sativa: A REVIEW ON USAGE AGAINST DISEASES IN CULTIVATED FIELD CROP, VEGETABLE AND FRUIT PLANTS

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INTRODUCTION

Negative results of climate change, the growth rate of population, and the environmental risk of some customary plant protection methods as the usage of chemicals like pesticides that are non-compatible with nature, have guided researchers to find innovative technologies in terms of plant protection. Sometimes advanced technologies can be achieved by observing and remembering the oldest. The oldest and naturally obtained inputs for food preservation from microorganisms and for the protection of agricultural cultivated areas against plant diseases is *Nigella sativa*. The plant is one of the well-known plants in medicinal and aromatic plant topics. That is used in medicine, veterinary, and agriculture by increasing the resistance against diseases and directly in the remedy against some biotic disease factors. This valuable plant has become even more significant in recent years due to its natural origin, as organic agriculture, where there are not many options in the fight against diseases and pests, has gained importance. The use of plant extracts alone or in combination with other crop protection methods is becoming increasingly common, especially in fungal, bacterial, and viral plant pathogens. The chapter aims to evaluate the studies that have achieved success in plant biotic diseases by *Nigella sativa*'s compounds derived from different extraction methods in the last decades.

Nigella sativa L. is a Ranunculaceae family member and an industrial multipurpose plant. This plant has been known and used traditionally since ancient times. There are lots of scientific studies and reviews about its usage in human medicine (Pop et al., 2020; Rahmani et al., 2022) and in veterinary (Balikci, 2016; Raheem et al., 2021). *N. sativa* is used for bee foraging (Engels et al., 1994), environmental and ornamental purposes, and may include highly different active substances from close species (D'Antuono et al., 2002). The seeds of the plant include carbohydrates, proteins (including eight or nine essential amino acids), and fixed oil as nutritive composition besides essential oil, alkaloids, saponin, vitamins, and mineral elements (Ahmad et al., 2021; Forouzanfar et al., 2014; Tembhurne et al., 2014). As the works progress, it may be possible to talk about new features of the topics (Ahmad et al., 2021). On the other hand, studies on the protection of plants from pests especially in post-harvest steps aimed at storage have been carried out (Chaubey & Kumar, 2023; Zouirech et al., 2023). After the studies about protection from crop pests, plant protection from diseases at growth and storage steps have been discussed. The reasons for plant diseases are such as fungi, bacteria, and viruses, and they are currently being tried to be eliminated worldwide, mostly by methods such as the use of pesticides that are not environmentally friendly. The use of herbal products and oils, which scientists consider as one of the nature-friendly protection and fight methods, is becoming increasingly widespread in diseases, and *N. sativa* (Figure 1) is starting to take a significant place in these studies.

The chapter reveals the reported usage of the plant (*N. sativa*) extracts against plant diseases at the growth and storage steps of cultivated crop, vegetable, and fruit plants for researchers and other plant health-relevant people.

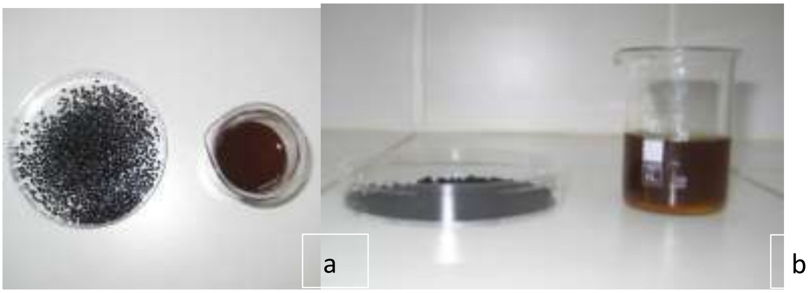

Figure 1. *Nigella sativa*; 3 g of seeds on each left and 30 mL of cold pressed oil on each right side; a) Top view, b) Front view

1. LITERATURE SEARCH

The literature search was conducted using various scientific databases by keywords such as "*Nigella sativa*", "*N. sativa*", "black cumin", "active compounds", "plant diseases", "plant pests", "botanical pesticides", "biopesticides", "field crop diseases", "vegetable diseases", "fruit diseases", and their cross combinations, which were published from the earliest reachable date to the present day in English.

2. *NIGELLA SATIVA* USAGE AGAINST DISEASES IN CULTIVATED FIELD CROP, VEGETABLE AND FRUIT PLANTS

2.1.*Nigella sativa usage against field crop diseases*

In one of the studies conducted on this subject; Hafez (2008) observed that when barley (*Hordeum vulgare* L. cv. Botond) leaves were sprayed with black seed oil from *N. sativa* after emulsification and dilution process, the disease severity of powdery mildew in barley (*Blumeria graminis* f.sp. *hordei*) which is one of the important diseases of barley decreased from 63,4% (control) to 9,4%. At the same time, the seed oil of *N. sativa* significantly inhibited conidial germination of barley powdery mildew compared to the control. It has been emphasized that the protective effect of the oil against powdery mildew was predominantly due to the repression of conidial germination. Subsequently reducing mycelial development was found to be significant. After these observations, it was possible to talk about a slight activation of the defensive behavior of the plant.

More than forty fungal isolates belonging to six genera have been obtained in the isolation experiments carried out from potatoes that plant used for both consumption and seed purposes, tubers that show signs of rot search and collected from sales points for search organic acids, and plant essential oils effects on the pathogens (Attia et al., 2019). The isolated fungi were purified and identified as *Alternaria* sp., *Fusarium* spp. *(F. solani*, *F. oxysporum, F. semitectum) Penicillium* sp., *Rhizoctonia solani*, *Sclerotinia sclerotiorum*. In the study, the pathogenicity tests have shown that *F. solani* and *S. sclerotiorum* were the most pathogenic fungi in the potato samples. *In vivo,* results have shown that *N. sativa* oil was the effective oil used in the study because it completely suppressed both the diseases caused by *F. solani* and *S. sclerotiorum* more than other used plant essential oils. The essential oils used in the study have ensured the highest quality sprouting of tubers and have reduced weight loss. In general, the treatment with both organic acids and plant essential oils has been passed on by researchers that it provided effective power on the two pathogens, and lessened the germination of tubers as well as the deprivation in the fresh weight of potato tubers throughout the time of the cold storage at 13°C, which is a very high storage temperature for potatoes, for two months (Attia et al., 2019).

Matloob et al. (2021) designed an experiment to eliminate root rot caused by *Rhizoctonia* in cotton with herbal extracts obtained from three different plants (*Anchusa officinalis*, *Trigonella foenumgraecum* L., and *N. sativa*). The samples of the plants were grounded in an electrical blender and kept in a refrigerator. A specific volume of each used plant was placed in a 1-liter glass flask, and the distilled water was added by 1:2 (v/v). The bottles were placed in a shaker at room temperature (24±1 ^{0}C) for 24 hours and then filtered with a clean cloth. 1, 5, and 10% concentrations of the plant extracts were used for the test. The sterilized media were cooled, and the plant extracts were added to these media. After that, the prepared media were poured into sterile Petri (9 cm in diameter). The pathogen *Rhizoctonia* was inoculated 0,5 cm in diameter to the culture. The results were obtained by measurement of the diameter of each colony, the rate of growth, and the percentage of inhibition. Researchers have stated that the second-highest decrease in the growth rate of the fungus was shown by the 10% concentration of black cumin seed extract with a 25.9% inhibition rate (Matloob et al., 2021).

The effects of eight plant extracts from the different plant parts of the plants (*N. sativa*, *Curcuma longa, Zingiber officinalis*, *Allium sativum*, *A. cepa, Azadirachta indica*, *Allamanda cathartica,* and *Aloe vera*), belonging to quite different families, were obtained from both water and ethanol extraction methods on control of *Magnaporthe oryzae oryzae* (MoO), which is an ascomycete, occurs in rice that the most basic grain product of Bangladesh has been examined. *Magnaporthe oryzae oryzae* was isolated from infected rice and identified based on the morphological structure in culture, for example, conidia morphology. In the case of water or ethanol extract of botanicals, 25 g, 50 g, and 100 g botanicals were prepared in 100 ml water or 100 ml ethanol separately. The preparations were applied at 1:4, 1:2, and 1:1 concentrations in PDA (Potato Dextrose Agar) culture plates, placed in 15-day-old mycelia discs of the cultured pathogen in the middle of Petri plates. Radial mycelia growth was recorded in one week, ten days, and two weeks after inoculation. As a result of the study, black cumin oil extracted from water or ethanol extraction methods has provided growth inhibition against the pathogen in different degrees after the other used plant extracts to control the disease (Nazifa et al., 2021).

Mosa et al. (2023) have developed O/W (Oil/Water) nanoemulsion fungicides based on cold-pressed black cumin *(N. sativa)* oil to prevent corn seeds from *Penicillium verrucosum* that produces Ochratoxin A. The oil was prepared using two types of surfactants, Tween 20 and 80, which are non-ionic and widely used as emulsifiers and stabilizers in industry. Ultrasonications were used to produce nanoemulsions at different sonication times as 0, 5, and 10 minutes. After the pathogen culture and identification, the prepared nanoemulsions were applied to plates *in vitro*, the mycelial growth was measured, and the data were reported as the percentage of inhibition. At the same time, some morphological and physiological parameters of maize seed at germination steps were evaluated after the treatments. Briefly, when *N. sativa* (O/W) was prepared with Tween-20, and Tween-80 at 10 minutes of sonication time, the result showed the highest effect on control of *P. verrucosum* with good morphological and physiological effects on maize seeds.

The seed extract of *N. sativa* and leaf extract of Neem have been applied to determine their antagonistic activities against *Tobacco Mosaic Tobamovirus* in *Nicotiana glutinosa*, and *Datura metel*. For this aim, the plant extracts were prepared and diluted in some concentration (1/2, 1/4, 1/8, 1/16, 1/32, and 1/64). After the inoculation of the virus, extracts and virus-infectious sap mixture were applied to leaves as mechanical inoculation. After 15 days, necrotic local lesions were observed and calculated as numbers. Resistance levels also have been obtained. The results have shown that *N. sativa* extract has a strong antagonistic reaction, especially in highly concentrated extraction. The resistance rate changed between 98.3%-66.6% from 1/2 extract dilution to 1/16 in *Datura metel*, and the data changed between 96%-40% from 1/2 dilution to 1/16 in *N. glutinosa* when *N. sativa* seed extract was used. At the end of the study, it has been emphasized that the active plant extract as seen in *N. sativa* and similar plants can be used as a bio-control agent for controlling plant pathogens such as plant viruses (Sadik et al., 2008).

2.2. *Nigella sativa usage against vegetable diseases*

Islam & Faruk (2012) have investigated the effects of plant extracts from various plant parts from *A. indica, A. cathartica, A. sativum, A. cepa, C. longa, N. sativa, Lawsonia alba, Z. oficinalis*, and *Aegle marmelos* on damping-off disease in eggplant, tomato, and chili paper vegetables. Seed treatments with leaf extracts of *A. indica*, *A. cathartica, L. alba, and A. marmelos,* clove and bulb extract *of A. sativum* and *A. cepa,* rhizome extract of *C. longa* and *Z. oficinalis,* and *N. sativa* seed extract were evaluated against pathogen *F. oxysporum* after purifying, and identifying, and inoculating to extracts treated seeds. Besides the effect on the disease, the seed germination and growth characteristics of tomato, eggplant, and chili seedlings were evaluated. As a result of the study, it has been stated that there was a decrease in the disease incidence in all applications including *N. sativa* seed extract treatment compared to the control. Although it was not the top impact, it was seen that *N. sativa* seed extract ranked in terms of effectiveness.

El-Sayed & Hafez (2013) have conducted two field experiments to examine the effect of black cumin seed oil, and seed meal on cucumber growing fields and related microorganisms. The seed meals were applied as a field soil amendment at rates of 0, 5, and 10 g per plant before planting, while seed oil in 0, 0.5, 1, and 1.5% solutions was applied as a foliar application three times every 10 days, starting within one month after planting. They noted that if cultured plants were enriched with the highest levels (10 g) of seed meal, and the highest level of (1.5%) seed oil, there was the lowest density in a total amount of fungi, together with some pathogenic species (*Fusarium, Rhizopu*s and *Aspergillus niger*).

A study has been conducted to develop environmentally favorable nanoemulsions of some plant oils and evaluate their effectiveness against post-harvest fruit rot in cucumbers caused by some fungal isolates such as *Galactomyces candidum*, *Alternaria tenuissima*, and *F. solani*. For this aim, *Syzgium aromaticum* clove oil, *N. sativa* seed oil, lemon, and orange oil were formulated as nanoemulsion and used against the post-harvest fruit rot fungi of cucumber. It has been stated that the mixture consisting (2:1) of nanoemulsions of clove and black cumin oils used in the study has caused a significant decrease in linear mycelial growth and completely inhibited conidia sporulation of the fungal isolates. In the second step, a 2% concentration of clove and black cumin (2:1) nanoemulsion formulation was applied to cucumber fruits as a soaking process before infecting them with fungal pathogens, and it has been concluded that it completely prevents post-harvest fruit rot of cucumbers. It has been emphasized that there was no toxicity in animal experiments, and the methods can be used safely on the pathogen in the cucumber at the post-harvest stage (Mossa et al., 2021).

Another study was conducted with cucumber at a plant growth step to investigate the effect of crude and nanoemulsions of clove, black cumin, lemon, and orange essential oils singly as well as in combination against the mycelial growth of *Botrytis cinerea* under a greenhouse. Essential oils nanoemulsion formulation containing clove + black cumin (2:1) at 5000 ppm was the best formulation that reduced the mycelial linear growth of *B. cinerea* by 61.0%. Additionally, nanoemulsion formulations of clove and black cumin essential oils (2:1) have decreased significantly the effect of disease severity of *B. cinerea*. As a result of the study, the foliar application of clove + black cumin nanoemulsion formulation is more promising than conventional fungicides compared to control in combatting gray mold caused by *B. cinerea* on cucumber fruits in greenhouse cultivation (Ziedan et al., 2022).

Aqueous plant extracts obtained from ginger (*Z. officinale*) rhizomes, black cumin (*N. sativa*) seeds, and chicory leaves by the relevant procedure have been used against the isolated *Colletotrichum capsici* from *Capsicum annuum* L. that causes anthracnose and reduction in the yield about 50% in Pakistan. The samples were prepared as 300 g of each plant powder and used at 5%, 10%, and 15% concentrations as aqueous solutions. In addition, two commercial fungicides were treated beside the control group, separately. According to the results, all treatments have shown positive results in suppressing the disease. Among the plant extracts used, *N. sativa* seed extract was also found effective in the inhibition of mycelial growth, spore inhibition, and disease incidence compared to the control. As a result of the study, it has been emphasized that the plant extracts used including *N. sativa* can be used to eliminate diseases in field conditions and it can be a cost-effective, and safe way (Fatima et al., 2023).

The effects of some medicinal plant extracts against black rot disease caused by *Xanthomonas campestris* pv. *campestris* have been investigated. For this aim, water and alcohol extracts from eight different plants including *N. sativa* seed extract were used. Water and alcohol extracts were prepared in various ratios with parts taken from the plants (shoot, leaf, stem, and seed). Both water and alcohol extracts of medicinal plants were assessed at different dilutions such as 1:0 (undiluted), 1:1, 1:10, 1:100, and 1:1000. Sterilized filter paper discs in 10 mm diameter were soaked in the prepared extracts, then they were placed on the Petri dishes surface. The sterilized medium was prepared, and bacterial colonies which were isolated from diseased cabbage plants were inoculated before this process. After 48 hours, the inhibition zones around the filter paper to which different diluted extracts were applied, were measured. In general assessment, alcohol extracts were found to be more effective than water extracts in the mean. In terms of *N. sativa* extract, the alcohol extract also has been found more effective than water extract and has a potential inhibition effect on the pathogen (*Xanthomonas campestris* pv. *campestris*) as non-dilution preparation (Kiran-Kumar et al., 2018).

Essential oils of onion (*A. cepa* L.) bulb, black cumin (*N. sativa* L.) seed, and eucalyptus (*Eucalyptus globulus* Labill) leaves have been used to determine their effectiveness against five fungi (*F. oxysporum* f.sp. *melonis*, *F.* solani, *F. verticillioides*, *S. sclerotiorum* and *R. solani*) isolated from muskmelon plant roots. All used plant extracts have been found effective in decreasing radial growth and spore germinations in all the isolated pathogens. When used concentration increased from 0 to 500 ppm, the effect also increased (Elgorban et al., 2015).

A study has been conducted to determine the antiviral activity of five medicinal plant extracts including *N. sativa* against watermelon plants infected with *Zucchini Yellow Mosaic Virus*. The extracts of the medicinal plant have been tested against the virus infection of watermelon seedlings after preparations as infusion and/or decoction methods. According to *in vitro* and *in vivo* screening *N. sativa* seed extracts which were prepared as decoction and infusion methods have reduced the *Zucchini Yellow Mosaic Virus* symptoms. In addition, the plant extract from both forms reduced virus concentration, infection percentage, and disease severity. According to the results, *N. sativa* has a robust preventive and suppressive effect against the disease symptoms (Elbeshehy, 2017).

2.3. *Nigella sativa usage against fruit diseases*

Diseases and quality loss in harvested plants at the post-harvest storage step have been observed frequently. An alternative method is *N. sativa* essential oil usage to prevent the harvested plant part, processed food against disease, and to reduce yield losses, it can be a safe choice (Bulca, 2014).

Two concentrations of cold-pressed seed oil of 300 and 600 ppm of *N. sativa* incorporated into starch-based edible coating were applied onto pomegranate arils to determine preservation of the quality (weight loss, total soluble solids, pH, vitamin C, etc.) factors in addition to observing microorganisms growth of pomegranate during storage. The pomegranate seeds with an aril layer have been covered with certain amounts of starch, glycerol, and black cumin oil. The control group was the untreated arils. All groups were kept under suitable conditions for 12 days. Results have shown that 300 ppm oil+starch coating significantly reduced browning and spoilage rates. The researchers have demonstrated that edible starch-based coating containing *N. sativa* oil is a good mixture to protect quality, prevent diseases, and maintain quality throughout the time of storage compared to the control (Oz & Ulukanlı, 2012).

Various plant oils have been applied to strawberries after harvest to reduce pathological losses caused by different fungi, especially *B. cinerea,* and to prevent fruit quality. For the study, excluding control samples, strawberries were sprayed with black cumin (*N. sativa*) and the other four plants' oils which were prepared at a concentration of 1000 ppm in pure water. After the application and eleven days of storage under appropriate conditions (1 ± 1^0C), a decrease in the suppression of the diseases was found in half (15.6%) than the control (31.28%). The researchers have stated that black cumin oil as a natural preservative in preventing post-harvest diseases is promising (Yılmaz, 2019).

In order to extend the storage life of two apple varieties, the possibilities of using *N. sativa* oil and extract instead of chemical fungicides such as Imazalil have been investigated. In the study, *N. sativa* oil and extract were extracted by solvent extraction method and sprayed on Red and Golden Delicious apple varieties at two concentrations (0.1% and 0.2%). The sprayed apples and the control that included Imazalil application were kept in a cold store at 0°C for six months. During these six months, total microbial count, mold and yeast, and some quality parameters were tested. Anti-microbial agents, especially *N. sativa* oil and extract, caused much lower mold and yeast content during the study than the control. At the end of the study, the researchers observed that the qualitative characteristics of the apple were preserved in the oil and extract applications. The study has stated that using *N. sativa* oil and extract which prevent microbial decay of apples can be a good alternative to using pesticides (Einafshar, 2019).

The effect of edible alginate coatings enriched with black cumin (*N. sativa*) seed extract has been investigated to preserve the quality of guava (*Psidium guavaja*) fruits for 16 days under suitable environmental conditions. The antibacterial activity of black cumin extract was proven by measuring the inhibition zone diameter against *Staphylococcus hominis* and *Escherichia coli*. The study has also shown that the application of alginate coating enriched with black cumin extracts suppressed the respiratory rate, weight loss, loss of hardness, and changes in the skin color of guavas. It has also been reported by the researchers that the fruits treated with alginate coating in a combination of black cumin extract caused to delay in the ripening index of guavas until the end of the storage period compared to control fruit samples treated with distilled water (Hasan et al., 2022).

3. CONCLUSION

When the studies carried out are examined, the compounds, especially seed oil obtained from *N. sativa* can be used for plant protection and combat against diseases in the cultivated areas, and at the storage steps. The advantages of using the extract to control diseases are being based on sustainable resources, being not expensive, having ease of preparation, being environmentally friendly, usable for large-scale fields, and being ideal for use in organic agricultural fields. In conventional farming, the extracts of the plant may also take place at Integrated Disease Management programs.

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CHAPTER 5

NITROGEN FERTILIZATION RECOMMENDATIONS USING OPTICAL SENSORS

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Introduction

Nowadays, as the agricultural sector faces increasing population and resource constraints, it has become important to increase productivity and adopt sustainable agricultural practices. In this context, many studies have been conducted focusing on how optical sensor technology can be used in various aspects of agriculture. Among these studies, the role of optical sensors in nitrogen fertilizer recommendation is particularly intriguing. Optical sensors have the ability to assess plant health by precisely measuring the chlorophyll levels of plants. This is a great advantage in identifying important nutritional problems such as nitrogen deficiency at an early stage. Optical sensors used in precision agriculture applications make it possible to apply the right amount of nitrogen fertilizer at the right time during plant growth periods. This aims to minimize environmental impact while increasing agricultural productivity and optimizing resource use. Nitrogen (N) fertilization plays a critical role in agricultural production to improve plant productivity and quality. Since conventional fertilization methods do not adequately take into account in-field and seasonal variability, nitrogen use efficiency (NUE) is often low. This can lead to both economic losses and environmental problems. Optimization of nitrogen fertilization is of great importance for developing sustainable agricultural practices and reducing environmental impact. This introductory chapter will highlight the potential of optical sensors in the agricultural sector, providing a basis for understanding how they offer a solution, particularly in the area of nitrogen fertilizer recommendation. In this context of the search for sustainable and efficient solutions for the future of agriculture, the advantages provided by optical sensor technology remain an important area of research and application. Optical sensors are advanced technologies that play an important role in the agricultural sector, offering a range of advantages and improving agricultural practices.

Today, the agricultural sector is looking for more efficient, sustainable and environmentally friendly solutions in the face of growing population and food demand. In this context, optical sensor technology offers the potential to make agricultural practices smarter and more effective. One of the primary advantages is the ability of optical sensors to continuously monitor plant health. By measuring plants' chlorophyll levels, these sensors can assess photosynthetic activity and detect early signs of plant health. This provides the possibility to quickly respond to problems such as disease, pests or nutrient deficiencies. Furthermore, the integration of optical sensors on agricultural machinery enables precision agriculture applications. These sensors collect data on vegetation and soil characteristics in the field, enabling farmers to create field-based management strategies and develop accurate fertilization plans. This increases productivity while optimizing resource use. Optical sensor technology saves time and costs in agricultural practices. Automated data collection and analysis features help farmers make faster and more accurate decisions. This increases labor productivity and enables operations to be managed more effectively. Optical sensors increase agricultural productivity as well as reduce environmental impact. Excess nitrogen use can lead to both economic losses and environmental pollution. A study in the eastern plains of India has shown that by using NDVI sensors, fertilization strategies can be optimized to achieve high yields and nitrogen use efficiency [(B. Mitra et al., 2023).Optical sensors are expected to find wider application in agricultural production and become standard. In particular, the development of sensor algorithms for various plant species and different agricultural environments will increase the effectiveness of this technology. Furthermore, the development of low-cost sensors and increasing their applicability on small-scale farms will support the widespread adoption of this technology. The use of optical sensors offers an innovative and sustainable approach to nitrogen management in agricultural production. This technology improves fertilizer use efficiency while supporting environmental sustainability and providing economic benefits. In the future, these sensors are expected to find wider application and become standard in agricultural production.

Optical sensors determine the nitrogen status in the plant by measuring the degree of greenness and chlorophyll content of plant leaves. These sensors estimate nitrogen deficiency or sufficiency in plant tissue using indices such as the Normalized Difference Vegetative Index (NDVI). For example, GreenSeeker and SPAD sensors help determine the right amount and timing of nitrogen application by analyzing the reflectance and absorption characteristics of plant leaves [(Masina Sairam, 2023).Optical sensors enable site-specific nitrogen management by considering in-field variability. The WheatN.1.0 algorithm developed at Oklahoma State University uses NDVI measurements to predict grain yield and nitrogen needs. This approach determines application rates using mid-season forecasts and the response index and can thus increase nitrogen use efficiency by 15% [(W. Raun et al., 2005).
This algorithm provides farmers with more accurate and efficient fertilization strategies on a field-by-field basis. There are many studies supporting the use of optical sensors for efficient nitrogen management in agricultural production. For example, research in Egypt has shown that nitrogen fertilization in maize production can be optimized through the use of the GreenSeeker sensor. This sensor guided the correct nitrogen dose application at growth stage V9 (when the 9th leaf collar is fully opened), thereby reducing fertilizer use and achieving similar yields (A. Ali et al., 2018).Another study conducted in northwest India revealed that the use of the GreenSeeker sensor resulted in high nitrogen use efficiency and yield in wheat production. In this study, sensor-guided fertilizer applications resulted in higher yields and nitrogen recovery efficiency compared to conventional methods. The use of optical sensors is also important for environmental sustainability. Proper fertilization and irrigation minimizes environmental impacts and preserves soil

quality. This is a critical factor for long-term agricultural sustainability. In conclusion, optical sensors are helping farmers adopt smarter and more sustainable farming practices by providing the advantages of modern technology in agricultural practices. These sensors will continue to play a more efficient, environmentally friendly and effective role in the future of agriculture.

1. Optical Sensor Technology

Basic principles and working mechanisms

Optical sensor technology encompasses a field that can make various measurements using the properties of light and electromagnetic radiation and has a wide range of applications. This technology is used in many sectors such as industry, medicine, environmental sciences and agriculture. In this article, the basic principles and working mechanisms of optical sensors will be reviewed.

Light and Electromagnetic Radiation

Optical sensors are based on the properties of light and radiation in the electromagnetic spectrum. These sensors are generally designed to detect and measure light at specific wavelengths. Sensors that can operate in different regions of the electromagnetic spectrum can use various wavelengths, such as infrared, ultraviolet and visible light.

Basic Principles

The operating principles of optical sensors vary widely, but in general, they are based

Optical sensors can be divided into different classes according to their mechanism of operation. Photodiodes work as photosensitive semiconductor devices and convert light into electrical signals using the photovoltaic effect. Spectrometers determine material properties by measuring the spectral components of light. In addition, fiber optic sensors can measure over long distances by transmitting light through fiber optic cables.

Application Areas and Future Perspectives

The application areas of optical sensor technology are quite wide. It is used in many fields such as medical imaging, industrial automation, environmental monitoring and agriculture. In the future, smaller, more sensitive and customizable sensors are expected to emerge by combining nanotechnology and advanced materials.

Optical sensor technology is a diverse field in terms of its basic principles and operating mechanisms. These sensors can be designed to suit different application requirements and used in a wide range of industries. This paper aims to understand the basic principles of optical sensor technology and to evaluate the future potential of this technology.

Various types of optical sensors and their characteristics

A.SPAD Meter (Soil Plant Analysis Development):

Features:

- A portable device that measures the amount of chlorophyll in plant leaves.
- It evaluates the leaf color index using an optical sensor.
- It has the ability to make instant measurements and present data in numerical values.

Areas of Use:

- Monitoring and evaluation of plant nutrition status.
- Identifying plant stress and planning appropriate interventions.
- Determining and optimizing fertilization strategies.

Figure.1. Konica Minolta SPAD meter

Principle of operation: The Konica Minolta Spad-502Plus Chlorophyll meter works by measuring the relative amount of chlorophyll present by measuring the absorbance of the leaf between two wavelengths. The chlorophyll meter serves growers and researchers who want to conduct field tests quickly and easily.

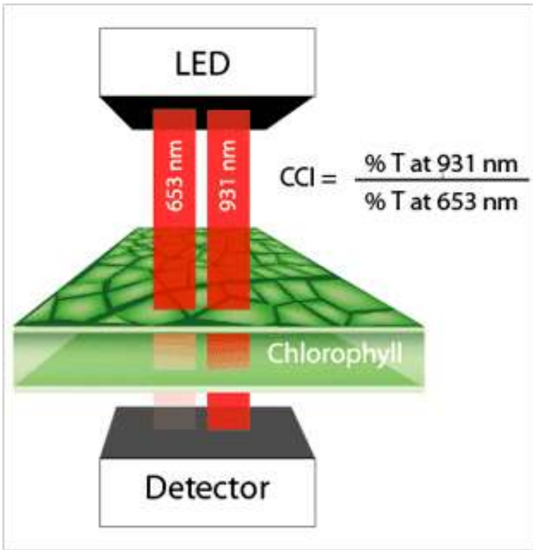

Figure.2. SPAD working mechanism

Among the ways to minimize nitrogen fertilizer losses, methods such as determining fertilizer doses according to plant needs (according to plant and soil analyses), determining a fertilization strategy in accordance with the amount and distribution of annual rainfall, preferring split applications, and applying fertilizer to a certain depth of the soil whenever possible can be listed (Mosier et al. 1996). Especially in crops such as maize, which are produced under irrigated conditions, large losses of nitrogen fertilizer increase production costs and cause environmental pollution. These reasons necessitate urgent measures to be taken. In order to increase the efficiency of nitrogen fertilizer use under these conditions, important researches have been carried out in recent years on the use of advanced technologies. The basic approach of such researches is to determine the nitrogen requirements of plants during phenological development periods and thus to supplement the deficiencies caused by the removal of previously planned and applied nitrogen doses from the soil for various reasons. For this purpose, intensive researches are carried out on two methods and the results are tried to be put into practice. These methods are: (1) SPAD method, (2) spectral reflectance method.

The SPAD meter method, which is based on the principle that there is a relationship between leaf chlorophyll levels and the nitrogen nutrition status of the plant, has been shown to be the most reliable method to detect nitrogen deficiency in the phenological period of crops. Fischer (2001) reported that the chlorophyll meter (SPAD-502), which is used to determine the chlorophyll content and nitrogen content of the leaf, is a cheap, fast and non-destructive method and that the most suitable measurement time is the post-flowering period when the chlorophyll content reaches the highest level.

The use of chlorophyll meter (SPAD-502) for determining nitrogen fertilizer requirements is increasing day by day. However, studies on this subject are limited in our country. Although the use of SPAD-502 is a cheap, fast and easy method to determine the nitrogen requirement of crops, it should be kept in mind that the data obtained with this instrument vary according to regions, species and varieties, agricultural systems applied, irrigated and barren conditions and that calibration studies are necessary for these different situations.

b. GREENSEKER

One of these techniques is GreenSeeker technology, which has been introduced in the world in recent years and has gained increasing importance. The GreenSeeker sensor reflects NDVI (Normalized difference vegetative index) data. The GreenSeeker sensor is suitable for small plot studies and is preferred for its high resolution and high reliability (Huang and Han., 2014). The GreenSeeker handheld crop sensor is an active light source optical sensor (GreenSeeker Handheld Crop Sensor 1) used to measure plant biomass and display it as NDVI value (Normalized Vegetation Diversity Index). At the same time, the GreenSeeker handheld crop sensor assesses the health and vigor of a crop and provides information on the amount of fertilizer to be applied.

As the world's population continues to grow, soil resources remain static, requiring the application of technologies that maximize production, protect the environment and feed the world. GreenSeeker™ technology allows the producer to apply only the N fertilizer needed to their crops, maximizing production and reducing production costs. This technology has been used worldwide in precision agriculture where the application of fertilizers, pesticides, plant growth regulators and defoliants is based on crop condition and field conditions (Rutto and Arnall., 2015)

A high NDVI value indicates that the plant is not under stress or that the plant is healthy. 5 NDVI (Normalized difference vegetative index) value is determined by the formula NDVI=(NIRRED)/NIR+RED). NIR is the intensity of infrared light and RED is the intensity of red light (Dobos et al., 2012). In this formula, NIR is the reflectance in near infrared = the reflectance in near infrared (770± 860nm) and R= the reflectance of red wavelengths = red wavelenghts (620± 680nm) (Ray and Pokharna., 1999). The NDVI value ranges from -1.0 to +1.0, with a high positive value representing healthy green vegetation and a low value (close to zero or a slightly negative value) representing a vegetation-free surface, such as water, snow, frost or clouds (Mather and Koch., 2011; Huang and Han., 2014). Hence, a higher NDVI value implies a greener cover and a lower NDVI value implies losses in crop vigor and development. Since NDVI is related to many vegetation characteristics (canopy coverage, chlorophyll density, biomass, leaf area index, annual net primary productivity, etc.), it is possible to predict crop yields.

Features:

- A sensor that measures chlorophyll levels in plant leaves in the field in real time.
- Creates a field map thanks to GPS integration.
- Provides instant data access to farmers via mobile application or computer.

Areas of Use:

- Real-time mapping of plant growth data.
- Instant monitoring and evaluation of plant health.
- Developing and implementing field-based plant nutrition strategies

Figure.3. Handheld Greenseeker

Figure.4. Hand-held Greenseeker

Principle of operation: GreenSeeker works by measuring infrared and red light reflected from plants to assess their health and vitality. The device emits beams of red and infrared light for short periods of time and measures how much of this light is reflected by the plants. Since most healthy green plants absorb red light and reflect infrared light, the strength of the light detected is a direct indicator of the plant's health status. The device samples the scanned area as long as the trigger is pulled and when the trigger is released, it displays the measured value on the LCD screen as an NDVI (Normalized Difference Vegetation Index) reading ranging from 0.00 to 0.99 (Url1-Url2).

GreenSeeker plays an important role in determining the nitrogen needs of crops and therefore more precise fertilization applications. This can both reduce costs for farmers and minimize environmental impact. Furthermore, GreenSeeker can also be used to determine side-fertilization rates, especially using NDVI values, which indicate the health of vegetation (URL3). This is a critical factor in increasing efficiency and environmentally friendly practices in agricultural production.

c. Spektroradyometre

Figure.5. Spectroradiometer

A spectroradiometer is a light measurement instrument that can measure both the wavelength and amplitude of light emitted from a light source. This instrument distinguishes the wavelength according to where the light strikes the detector array, allowing the full spectrum to be obtained in a single acquisition. Factors affecting the accuracy and performance of spectroradiometers include system calibration, software and power supply, optics and measurement engine. These instruments have basic components such as input optics, an input slit, sorting filters, a collimator, a grating or prism, focusing optics, a detector and a control and recording system (url4).

Specifications:

- It is a sensor that measures the electromagnetic spectrum at specific wavelengths.
- It analyzes the spectral properties of light reflected from vegetation.
- It can make precise measurements at various wavelengths.

Areas of Use:

- Spectral analysis of plant health and its use for disease or pest detection.
- Vegetation monitoring and identifying changes in agricultural landscapes.
- Identifying and optimizing plant nutrition strategies.

These sensors offer farmers significant advantages to manage and optimize their agricultural operations more effectively. High-precision measurements and real-time data access provide powerful tools to increase productivity and sustainability in agriculture.

Plant Nutrition and the Role of Nitrogen

The importance of nitrogen in plants

Plant nutrition includes nutrients that are essential for the growth, development and reproduction of plants. Among these nutrients, nitrogen is one of the basic building blocks of plants and plays a key role in many biochemical processes. Nitrogen is an essential building block in the synthesis of protein, nucleic acids, chlorophyll and other important components of plants. Protein is an essential building block for the growth and development of plants and contains nitrogen. Nucleic acids are the building blocks of genetic material and are critical for plants to reproduce. In addition, chlorophyll is the pigment that converts light into energy in photosynthesis and contains nitrogen.

Symptoms of Nitrogen Deficiency

Nitrogen deficiency can cause various symptoms in plants. Symptoms such as slow growth, pale colored leaves, yellowing of young leaves (chlorosis), low yield and reduced fruit quality can be associated with nitrogen deficiency. This occurs when plants are unable to perform their normal functions due to the key role of nitrogen in plant growth and metabolism.

Nitrogen is of great importance in plant nutrition and is a vital element for plant growth. Nitrogen deficiency can prevent plants from growing and reproducing in a healthy way. Therefore, providing nitrogen in the right amounts and in appropriate forms is important to increase productivity and quality in crop production.

Use of Optical Sensors in Fertilizer Management

Optical sensors are increasingly used in agricultural applications and play an important role, especially in fertilizer management. Remote sensing technology uses optical sensors to monitor large areas of agricultural land quickly and effectively. The work by Baret and Borgeaud (2000) details how indices such as NDVI (Normalized Difference Vegetation Index) can be used to assess the health and yield potential of vegetation. These indices are calculated from data collected by optical sensors and serve as an indicator of the photosynthetic activity of plants.

Another important use of optical sensors is in plant nutrition. Samborski, Tremblay and Hollinger (2009) reported that nitrogen deficiency can be detected by measuring the light reflected from plant leaves. This method is an important step in reducing environmental impacts by helping to avoid over-application of fertilizers on agricultural land.

In precision agriculture, optical sensors are critical for more effective management of inputs such as water and fertilizers (Mulla ,2013) emphasized that optical sensors enable site-specific management of agricultural practices by instantly monitoring soil properties and plant health. This enables more efficient use of resources and reduces environmental impact.

Measurement of Chlorophyll Levels in Plants

Optical sensors can assess plant health by directly measuring chlorophyll levels in plants. Chlorophyll is the essential pigment used in the photosynthesis process of plants. Chlorophyll meters estimate the amount of chlorophyll per unit area of leaf surface. Chlorophyll meters produce a dimensionless value that correlates strongly with the actual amount of chlorophyll in the leaf (KALAJI et al., 2017). Optical sensors determine chlorophyll levels by analyzing light reflected or absorbed from plant leaves. These measurements reflect the photosynthetic capacity and overall health of plants, providing valuable information for determining fertilization needs.

Plant Health Monitoring with Optical Sensors

Optical sensors can continuously monitor the overall health of plants. These sensors can quickly detect changes in plants and allow for early intervention in potential problems. Indicators such as color changes, changes in growth rate and fluctuations in chlorophyll levels provide important information about plant health.

Optical sensors provide live monitoring of plant nutrient status, enabling precise fertilization techniques to be applied (Raun, Solie, Johnson, Stone, Mullen, Freeman, Thomason and Lukina 2002) emphasized that optical sensors can be successfully used to integrate decision support systems in the management of nitrogen fertilization. This approach contributes to making fertilizer use more efficient and consequently minimizing environmental impacts.

Optik Sensör Verilerini Kullanarak Gübre Tavsiyesi

The data provided by optical sensors can be used to make efficient and precise decisions in plant nutrition management. Plant health measurements and sensor data provide essential information to optimize fertilization strategies and fertilize according to the needs of the plants. This aims to use resources more efficiently and reduce environmental impacts.

Optical sensors are a powerful tool for monitoring plant health and optimizing fertilizer management. Based on spectral analysis technology, the sensors measure the intensity at specific wavelengths of light emitted or reflected by plants. These measurements are based on the fact that the reflectance properties of the plant canopy, particularly in the visible light spectrum, are highly correlated with the chlorophyll content. Since chlorophyll is a component of nitrogen, these spectral features are critical for the study of nutrient deficiencies in plants (Abulaiti et al., 2020).

The spectral data obtained are used to calculate specific vegetation indices, such as the Normalized Difference Vegetation Index (NDVI), providing important information on the nutritional status of plants and potential crop yields (Heege et al., 2008). Through calibration procedures, these vegetation indices are evaluated to analyze the nutritional status of the plant, especially in terms of nitrogen, and to predict crop yields. (Colaço and Bramley, 2018).

Conclusion

The integration of optical sensor technology into nitrogen fertilization strategies is an innovation that has the potential to improve efficiency and environmental sustainability in the agricultural sector. By precisely determining the instantaneous nutritional status of plants, this technology enables needs-based and efficient nitrogen fertilization. The application of this approach aims to promote more efficient use of nitrogen by plants, while avoiding the environmental problems that can result from over-fertilization.

In the literature, it is reported that the use of optical sensors improves plant health and yield, helps to optimize the uptake of nitrogen by the plant and thus contributes significantly to agricultural sustainability (Raun et al., 2005; Cao et al., 2015). Furthermore, the use of this technology is also seen as an effective method to reduce nitrogen-induced environmental impacts. Reduction of greenhouse gas emissions and protection of water resources are among the potential environmental benefits of using optical sensors in nitrogen management.

The widespread acceptance and application of this technology is considered an important step towards achieving the goals of efficiency and sustainability in agricultural production. However, for this potential to be fully realized, steps need to be taken to improve the technological infrastructure, adjust agricultural policies to support these new approaches, and inform and educate farmers about these technologies.

In conclusion, the use of optical sensors in nitrogen fertilization recommendations could revolutionize agricultural practices. This technology can contribute to the goals of increasing the sustainability of the agricultural sector and reducing its environmental footprint. However, the effective implementation of this innovative approach requires extensive training, policy support and integration of technological advances

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CHAPTER 6

PRECISION AGRICULTURE AND APPLICATIONS

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Introduction

Precision agriculture (PA) is a farming management concept based on observing, measuring and responding to inter- and intra-field variability in crops. PA is also sometimes referred to as precision farming, satellite agriculture, as-needed farming and site-specific crop management (SSCM). Agriculture production systems have benefited from incorporation of technological advances primarily developed for other industries. The industrial age brought mechanization and synthesized fertilizers to agriculture. The technology age offered genetic engineering and automation. The information age brings the potential for integrating the technological advances into precision agriculture (PA) (Whelan, 1997). The factual base of PA-the spatial and temporal variability of soil and crop factors within a field*/has been appreciated for centuries. Before the completion of agricultural mechanization, the very small size of fields allowed farmers to vary, treatments manually. However, with the enlargement of fields and intensive mechanization, it has become increasingly more difficult to take account of within-field variability without a revolutionary development in technologies (Stafford, 2000). PA is conceptualized by a system approach to re-organize the total system of agriculture towards a low-input, high-efficiency, sustainable agriculture (Shibusawa, 1998). This new approach mainly benefits from the emergence and convergence of several technologies, including the Global Positioning System (GPS), geographic information system (GIS), miniaturized computer components, automatic control, in-field and remote sensing, mobile computing, advanced information processing, and telecommunications (Gibbons, 2000). Agricultural industry is now capable of gathering more comprehensive data on production variability in both space and time. The desire to respond to such variability on a fine-scale has become the goal of PA (Whelan, 1997). After more than 10 years of development, PA has reached a crossroad with much of the necessary technology available but with the environmental and economic benefits yet unproven (Stafford, 2000). Many technological innovations have been presented but development of agronomic and ecological principles for optimized recommendations for inputs at the localized level is generally lagging. Many farmers are uncertain as to whether to adopt available PA technologies on their farms. Motivations for widespread uptake of PA technologies may come from strict environment legislation, public concern over excessive use of agro-chemicals, and economic gain from reduced agricultural inputs and improved farm management efficiency. After all, success of PA technologies will have to be measured by economic and environmental gains.

Figure 1 John Deere autonomous tractor navigates crops without a driver

How does precision agriculture work?

To do its job, precision agriculture relies upon specialized equipment, software and IT services. This includes accessing real-time data about the conditions of the crops, soil and ambient air, along with other relevant information such as hyperlocal weather predictions, labor costs and equipment availability. The real-time data is collected via sensors in fields that measure the moisture content and temperature of the soil and surrounding air. Satellites and robotic drones can also provide farmers with real-time images of individual plants.

What are the benefits of precision agriculture?

After data is collected, predictive analytics software uses the collected data to provide farmers with guidance about crop rotation, optimal planting times, harvesting times and soil management.Agricultural control centers can integrate sensor data and imaging input with other data to provide farmers with the ability to identify fields that require treatment and determine the optimum amount of water, fertilizers and pesticides to apply.This helps the farmer avoid wasting resources and prevent run-off, ensuring that the soil has just the right number of additives for optimum health while also reducing costs and controlling the farm's environmental impact. Today, nearly 50% of all farmers in the United Kingdom are using one or several precision agriculture techniques in their operations but in many other counties, farmers are just starting to learn about precision farming technologies. Alexey Bogatyryev, FieldBee CTO points out that farmers who use conservative methods will have a hard time competing with other farming companies and following farming technologies with the required minimization of chemical use. Even organic farming, which requires a lot of mechanical operation (like in row crop cultivation) now needs high precision and speed. Agriculture professionals who are only planning to take advantage of all the benefits brought about by precision farming techniques often need to invest money upfront to purchase drones, accurate navigation systems, auto-steering technology for tractors, remote sensors, agriculture software, and more. But before you can shell out a significant portion of your profits on new tech, you need to understand the advantages it's going to bring you. Below, we will talk about 5 main benefits of precision farming.

Use fewer resources

Precision farming technology allows farmers to minimize the amount of fertilizer, pesticides, herbicides, water, seeds, etc., used in the field by using resources only in parts of the fields where they are necessary.

Improve yields and profitability

By optimizing the use of fertilizers, pesticides, and irrigation in different sections of the fields, farmers can increase their harvests and ensure that their crop yields are as high as they can possibly be. As a result of reduced use of resources and improved yields, farms can become significantly more profitable. For instance, simply using a tractor autosteer system can increase profits by 120 euros per hectare.

Improved sustainability of precise farms

Precise agriculture technologies are significantly more eco-friendly than conventional farming practices. As a result, farmers can manage their land sustainably, improve long-term land values, and even make their products more attractive to customers who are growing increasingly wary of fruits and vegetables grown with the use of chemicals.

Accurate yield predictions

The use of precision farming technology can help farmers make accurate predictions regarding crop yields, ideal seeding and harvesting times, etc. This information allows farm owners to make better agronomic decisions.

More free time

Farmers who use autosteering technology, remove sensors, and other gadgets can let technology take care of routine tasks and instead focus their attention on the business side of farming or spend more time with their families.

In today's world, it's virtually impossible for farms to remain profitable without using precision farming methods, as evidenced by the wide adoption of precision farming technologies in developed countries. With decreasing costs of solutions, precision farming technologies have become a must-have for all arable and orchard farmers. Start your farm's journey towards improved sustainability, higher profitability, and increased yields today with FieldBees' precision farming products.

Key Components of Precision Agriculture

1. **Satellite Technology and GPS:** GPS allows farmers to accurately navigate to specific locations in the field, year after year, to collect soil samples or monitor crop conditions. Crop advisors use rugged data collection devices with GPS for accurate positioning to map pest, insect, and weed infestations in the field

2. **Sensors and Internet of Things (IoT):** Applications of integrated IoT and smart sensors for precision farming. IoT-based smart sensors can accurately monitor environmental factors such as temperature, moisture, and humidity. Some sensors can assess soil quality by determining nitrate levels and water content.

3. **Drones and Remote Sensing:** The drone survey allows the farmers not to keep track of their crops only but also monitor

the movements of their cattle. Thermal sensor technology helps find lost animals and detect an injury or sickness. Drones can carry out this function favorably, and this adds comprehensively to the production of vegetation.

4. **Automated Machinery:** An automation system is an integration of sensors, controls, and actuators designed to perform a function with minimal or no human intervention. The field concerned in this subject is called Mechatronics which is an interdisciplinary branch of engineering that combines mechanical, electrical, and electronic systems.

5. **Data Analytics and Farm Management Software:** Modern agriculture increasingly relies on data analytics to improve crop management by utilizing information from sensors, drones, and equipment. It increases yields, resource efficiency, and sustainability by enabling precision in planting, irrigation, and pest control and improving decision-making through predictive insights.

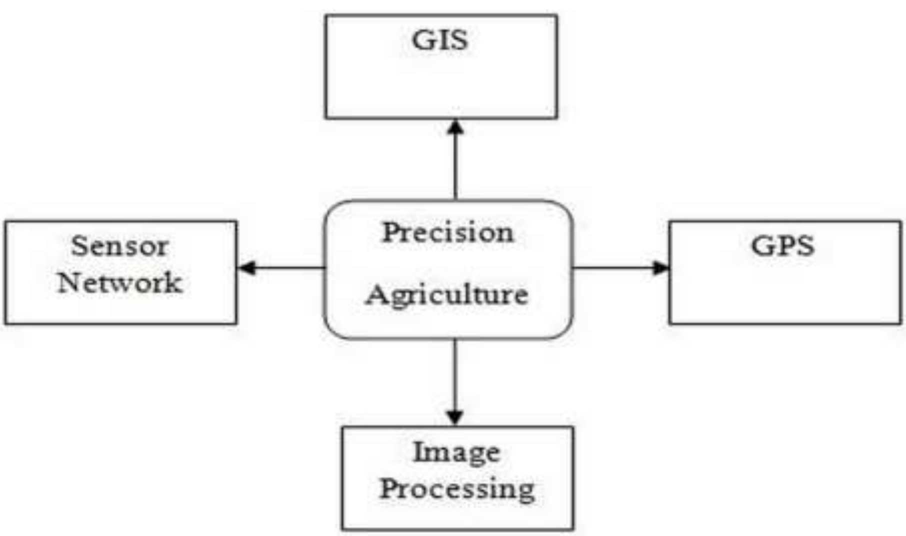

Figure 2 Components of precision agriculture

Precise application Implementation of precision agriculture to date has utilized existing "eld machinery and added controllers and GPS to enable spatially variable application. Thus, conventional spray booms have been used for patch spraying (Paice, 1998) and spinning disc applicators for variable fertilizer application (e.g. Amazone ZA-M spreader). The potential of precision agriculture will lead, however, to demands for the development of novel, precise application techniques to achieve the precision and reliability in material placement that follow from the precision and accuracy achievable by positioning and sensing systems. The conventional spinning disc fertilizer spreader, for instance, can hardly be described as &precise, Conventional spray nozzles typically deposit liquid over a half-meter diameter circle. The variability in the physical characteristics of granular and powder materials may mean that development of novel techniques is concentrated on liquid delivery systems.

Positioning systems in the early days of precision agriculture, GPS was unreliable for dynamic positioning within the "eld. Typical position resolution with differential operation was 5 m (2] r.m.s. value) with a skewed Gaussian error distribution extending out to tens of meters (V, B, & P, 1991). The incomplete constellation of satellites accentuated the problem of signal obscuration by trees and buildings (G & J, 1995)and multi-path resections were a significant cause of poor positioning. GPS receivers were bulky and expensive. In 2000, the general perception is that GPS is a mature technology with considerable, sophisticated processing power built into commercial receivers that have reduced in price very significantly (handheld, 12 channel GPS receivers are now available at less than $100). The satellite constellation is complete and receivers typically receive signals from 8 to 12 satellites above the horizon. Most receivers used in precision agriculture are 12 channel and use phase smoothed pseudo-range positioning with claimed sub-meter accuracies. A typical example is the Trimble Ag132 receiver with integral deferential receiver*http://www.trimble. com/precise/Agri/index.htm (mention of commercial products is for illustrative purposes only and implies no endorsement). Thus, GPS is seen to be an available tool that needs little further development. The new millennium will, however, see important developments in positioning to bennet precision agriculture. Some aspects of precision agriculture, such as avoidance of spray overlap and application control near sensitive areas such as "eld margins, will be practiced at a smaller and smaller scale requiring higher resolution positioning. Targeting of "eld inputs to some crops will be at the plant scale and even down to leaf scale requiring much enhanced reliability and accuracy of dynamic positioning. Traceability will require recording precise application information tagged with very accurate position data. Positioning resolution is seriously limited by the deliberate downgrading, known as selective availability (SA), of satellite signals by the US Department of Defense (B L. R., 1997a). Although deferential mode compensates for much of the downgrading, there will be sign"-cant gains when SA is turned off. A US Presidential Decision Directive (H & R, 1998)indicated that this would happen in 2006. However, a Whitehouse press release issued on 1 May 2000 (http://www.whitehouse. gov/library/PressReleases.cgi date"0 and brieng"0) stated that SA was turned o! on that day. The Russian GLONASS positioning system (B L. R., 1997a)is not downgraded but reliability of the system is in doubt because of maintenance issues. There are some combined GPS/GLONASS receivers available commercially which give enhanced positioning but they are expensive and are unlikely to be taken up for precision agriculture. A European global navigation satellite system (GNSS), &Galileo', has been under discussion for some time (J, A, & R, 1998)and is now being subjected to a &dentition study' funded by the European Union and the European Space Agency which is due to report in December 2000. The plan is for the system to be developed by a public} private partnership and be operational by 2008 (A, 1999). Such a system should provide improved positioning accuracy and reliability compared to GPS. Possible technical enhancements in GNSS in the new millennium must be set in the context of the advanced technology and processing power already incorporated into GPS receivers. The accuracy of the standard IMPLEMENTING PRECISION AGRICULTURE IN THE 21ST CENTURY 269 JAER=20000577=Jolly=VVC positioning service based on pseudo-range calculation of the clear acquisition signal from the satellites is limited by the repetition rate (1)023 MHz) of the pseudo-random binary code transmitted on one satellite carrier (the L1 signal). If civilian access were allowed to the Precise Positioning Service where the precise (P) code is transmitted on the L2 signal at 10 times the rate (10)23 MHz) then a Signiant improvement in positioning accuracy could be achieved. Kinematic GPS, where position is determined by measuring the phase shift in the satellite carrier signal between transmission and reception, gives the potential for centimeter accuracy. The wavelength of the carrier is about 19 cm and so phase shift measurement to 1% would yield a range measurement of 2 mm (C, 1996). However, kinematic GPS has not been used in precision agriculture so far because of cycle ambiguity and cycle slip with momentary loss of satellite signal. Phase shift smoothing is, however, being used in current pseudo range receivers to improve position resolution. By using a double-delicensing technique (Langley, 1996), real-time kinematic (RTK) GPS is possible to provide high resolution dynamic positioning. The robustness of RTK GPS will certainly be improved and come into regular use in precision agriculture. Similarly, integration of navigation systems (C, 1996)will be enhanced to provide reliable and robust positioning*if one system fails to reach its positioning speciation momentarily, then there is at least one other system to take over. Such systems have been developed using GPS and other "eld machinery navigation data such as velocity and heading (V & C, 1996). Future systems are likely to integrate visual (camera-based) navigation (B, A, T, & F, 1998)with GPS for precision application at the individual plant level.

How can precision tech help agriculturists, especially small farmers?

Roughly half of the country's large-scale row crop producers use tractor guidance. In contrast, small farms are largely not adopting tractor guidance technologies.

There is substantial room for increased adoption on small farms, which would potentially lead to economic and environmental savings because decreases in costs often lead to increases in profits. We have learned that on-farm efficiency is especially effective for these small-scale systems. Tractor guidance offers more spatially precise understanding of tractor operations, which lead to reduced operator fatigue, higher yield, and the ability to work longer workdays during inclement conditions. Altogether, these changes may significantly lessen a small farm's fuel, labor, repair, and maintenance costs.

A tractor tills a cover crop as part of a field trial for a tractor-guidance system experiment at the ARS Dale Bumpers Small Farms Research Center, Booneville, AR. Photo by Larry Huddleston

Not all agricultural sectors receive information on technology at the same rate. There is a need for identifying potential adoption and appropriateness of technologies that can automate production while improving the economic and environmental impacts of production systems at all scales. The small farm systems have the greatest potential for adoption and will impact the greatest numbers of farms that's why we are promoting 'big data for small-scale farmers.

What are some examples of precision agriculture?

Tractor guidance (also called autosteer) is a precision agriculture technology that uses GPS and can result in accuracy within one centimeter when planting, spraying herbicide, or applying fertilizer. This improved precision during field activities can result in fewer overlaps (areas in the field with double application) and gaps (or skipped areas in the field) and overall improved efficiencies (both economic and environmental).

Another example of a precision agriculture tool is variable rate technology, which allows crop producers to apply variable rates of fertilizer across a field. Similarly, yield monitoring systems record yield data (grain and grain moisture) on a combine during harvesting. Today's yield monitoring systems provide operators with a user interface that includes a spatial map that displays the grain yield of the harvested

additional farm-level information for managing risk and more precisely managing fertilizer, seed, and herbicide.

The tractor-guidance screen as seen during a fertilizer application; the blue lines are the areas covered by the tractor. Photo by Dr. Mike Popp, University of Arkansas

THE ENVIRONMENTAL BENEFITS OF PRECISION AGRICULTURE

Its environmental benefits are significant and can help to protect our natural resources for future generations. As precision agriculture technologies continue to develop, we can expect to see even greater environmental benefits in the years to come.

A study by the American Farm Bureau Federation found that farmers who use precision agriculture technologies achieve the following environmental benefits:

- 4% increase in crop production.
- 7% increase in fertilizer placement efficiency.
- 9% reduction in herbicide and pesticide use.
- 6% reduction in fossil fuel use.
- 4% reduction in water use.

Here are some examples of how precision agriculture can benefit the environment:

1. Water Conservation

Water is a precious resource essential for sustaining life and supporting agricultural productivity. With growing concerns over water scarcity and the need for sustainable farming practices, it has emerged as a powerful solution.

By leveraging advanced technologies such as sensors and data analytics, it empowers farmers to manage water resources more efficiently and responsibly.

Precision Agriculture Water Management and Irrigation Techniques

Water scarcity is a pressing global issue, exacerbated by factors like climate change and population growth. Agriculture accounts for a significant portion of water usage, making efficient water management in farming a critical concern.

Traditional irrigation practices often involve excessive water application, leading to wastage, soil erosion, and waterlogged fields. It aims to address these challenges by adopting data-driven strategies to optimize water usage.

a. Sensor Technology:

It relies on advanced sensor technologies, such as soil moisture sensors, weather stations, and crop health sensors.

These sensors are strategically placed throughout the fields and collect real-time data on soil moisture levels, weather conditions, and crop health. The data gathered is sent to a centralized system for analysis and decision-making.

b. Data Analysis and Insights:

The real power of precision agriculture lies in data analysis and gaining valuable insights. Through sophisticated data analytics and machine learning algorithms, farmers can understand the water needs of different areas within their fields.

They can identify variations in soil moisture levels, enabling them to make informed decisions about irrigation schedules and water application rates.

c. Drip Irrigation:

Drip irrigation is a precise and efficient water delivery method. It involves the slow and steady application of water directly to the root zone of plants through a network of tubes and emitters.

With data-driven insights, farmers can regulate the flow rate of water based on the specific water requirements of different crops and soil types, reducing water wastage significantly.

d. Sprinkler Irrigation:

It optimizes sprinkler irrigation by using data to adjust the direction, intensity, and timing of irrigation events.

By fine-tuning these parameters, farmers can ensure water is applied uniformly across the fields, avoiding overwatering and runoff.

e. Variable Rate Irrigation (VRI):

VRI systems, integrated with precision agriculture, allow farmers to apply water at variable rates based on site-specific needs.

By dividing fields into management zones, farmers can precisely adjust the water application rates in response to varying soil types, crop types, and moisture levels.

Benefits of Precision Water Management

By harnessing the power of sensors, data analytics, and precise irrigation techniques, farmers can optimize water usage, conserve this precious resource, and enhance agricultural productivity. Some of the benefits include:

- **Water Savings:** Precision agriculture's targeted approach to water application results in significant water savings. By applying water only where and when it is needed, farmers can reduce overall water consumption while maintaining or even increasing crop yields.

- **Soil Health and Conservation**: Overwatering can lead to soil erosion and nutrient leaching, negatively impacting soil health. It helps maintain optimal soil moisture levels, promoting healthier soil structure, better nutrient retention, and reduced erosion.
- **Reduced Environmental Impact:** By minimizing water runoff and the use of chemicals that may contaminate water bodies, it contributes to a healthier environment and reduced ecological impact.

Spatial and temporal variability

Variabilities that have significant influences on agricultural production can be categorized into six groups.

Managing variability

Managing the variability can be achieved by two approaches: the map-based approach and the sensor-based approach. With available technologies of GPS, remote sensing, yield monitoring, and soil sampling, the map-based approach is generally easier to implement. This approach requires the following procedure: grid sampling a field, performing laboratory analyzes of soil samples, generating a site-specific map, and, finally, using this map to control a variable-rate applicator. A positioning

Management zone

Site-specific applications of agricultural inputs can be implemented by dividing a field into smaller management zones that are more homogeneous in properties of interest than the field as a whole. A management zone is defined as 'a portion of a field that expresses a homogeneous combination of yield-limiting factors for which a single rate of a specific crop input is appropriate' (Doerge, 1998). Thus, management zones within a field may be different for different inputs, and delineation of

Impact of precision agriculture

The impact of PA technologies on agricultural production is expected in two areas: profitability for the producers and ecological and environmental benefits to the public.

Engineering innovations

While agronomists are playing the leading role in PA development, engineers have worked diligently to provide technologies needed to implement PA practices. Engineering innovations for PA involve development of sensors, controls, and remote-sensing technologies.

Information management

After more than a decade of research and practice, PA has accumulated a huge amount of data and is now facing a serious problem of 'data overflow'. For the spatial/temporal information that has been collected, there is an urgent need for tools specifically designed for data storage, processing, management, and analysis. There is also a strong need for data-exchange standardization.

Worldwide applications

PA research started in the US, Canada, Australia, and Western Europe in mid-to-late 1980s. Although a considerable research effort has been expended, it is still only a portion of farmers who have practiced any type of PA technologies. Implementation of PA has mainly been through utilization of existing field machinery by adding controllers and GPS to enable spatially-variable applications. To date, the leading application of PA still is the site-specific application of fertilizers.

Conclusion:

A precision agriculture farm Precision agriculture is a crop management concept. It should be implemented as such on a farm-wide basis and practised for all "eld operations concerned with the growing of crops. Environmental legislation with regard to the minimization and optimal use of inputs and market pressures for traceability and audit trails in the new decade will force producers to seriously consider precision agriculture as a solution. Alongside these pressures will be that of optimizing the use of technologically sophisticated equipment. Thus, machinery and equipment replacement policies will be on the basis of utilizing equipment as widely as possible in all "eld operations. Procedures for the integration and interpretation of the masses of spatially related data must be established both for generating rational treatment maps and as decision support to the manager. The economic and environmental benefits of taking account of within "eld spatial variability appear obvious although they have yet to be generally proved in "eld trials and experiments. Much of the technology is in place but there will be further important developments in the new decade, particularly in the area of sensing and mapping variability. It is essential that complementary research and development in agronomy, crop and soil science are successful in denning, explaining and making recommendations for variable application of inputs at the very localized level.

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CHAPTER 7

LOSSES OCCURRING DURING PEANUT HARVEST AND PRECAUTIONS TO BE TAKEN

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Introduction

Peanuts, belonging to the legume family, are considered a valuable source of nutrients due to their content of fats, proteins, carbohydrates, vitamins, and minerals. Additionally, they are recognized as a beneficial plant that enhances soil quality (Prasad et al., 2009; Parlak et al., 2022). Peanuts, whose fruits grow underground, are cultivated worldwide in tropical, subtropical, and warm temperate climates (Stalker, 1997; Ademiluyi et al., 2011). Being oilseed plants with challenging harvests, various factors contribute to losses during the harvesting of peanuts. Improving peanut harvesting techniques can ensure high productivity, but to achieve this, it is essential to first identify the harvest losses (Dos Santos, 2021).

Harvesting consists of two stages: uprooting and collection. Harvest losses occur when plants are uprooted from the soil (using a tractor or uprooting machine) and laid out in the sun. This situation is influenced by factors such as harvest timing, climate, maturity, and soil conditions (Zerbato et al., 2017). During the harvesting and separation of pods process by the harvesting machine, a high level of product losses can occur for peanuts (Silva et al., 2008). Mallikarjuna Swamy et al. (2006) reported that optimal maturity should be considered for the harvest of peanuts to preserve the genetic material and obtain healthy seeds. One of the most crucial points in cultivating peanuts (*Arachis hypogaea* L.) is to harvest at the right time to achieve maximum quality and yield (Wright et al., 2009). Ansari et al. (2015) reported that the optimal fruit maturity percentage for Runner peanut varieties is 70-80%, for Virginia varieties is 60-65%, and for Spanish varieties is 75-80%.

The uneven ripening of pods underground complicates the maximum ripening period for the shells (Kaba et al., 2014). Harvest in the plant occurs 120-150 days after sowing, depending on the variety (Oyelade et al., 2011). The losses during harvest arise from the peanuts left in the soil. In peanuts, it has been noted that injuries, breakages, and shedding during harvesting result in harvest losses of approximately 18%. (Abass et al., 2014; Daba et al., 2023). A delay in harvesting after the physiological maturity of the plant can result in the weakening of gynophores, causing many peanuts to remain in the soil (Singh and Oswalt, 1995). In this case, if gynophores are weak or diseased, they can break, leaving peanuts in the soil. Additionally, delayed harvesting can lead to deterioration and loss of peanut quality.

Harvesting begins when approximately 70% of the peanuts have reached maturity. The harvesting machine first loosens the plant and then cuts the main root. If peanut plants are uprooted too early, the peanuts may not fill out properly. Wright and Porter (1991) reported that harvesting peanuts too early could reduce yield by 15%, and its economic value by 21%. If the harvest is too late, the shells of the peanuts remain in the soil during the digging process (Tsusaka et al., 2016).

Harvest losses in peanuts occur at various stages such as harvesting, threshing, cleaning, sorting, packaging, transportation, storage, processing, and marketing. Post-harvest pod losses are estimated to be between 16-47% during harvesting and between 5-50% during drying (Anonymous, 2023). Abass et al. (2014) and Daba et al. (2023) reported in their studies that peanut harvesting takes several days, and approximately 1.5% of peanut shells are lost due to pests and rodents. They also mentioned that this situation leads to both harvest losses and yield reductions. The force of the gynophore, soil and weather conditions, planting date, pests, plant population, and diseases cause yield losses during harvesting.

The high-water content in the shells and soil also directly affects the harvest. Therefore, while high soil water content can reduce fruit losses after digging, it should be noted that it may negatively impact the machine's operational performance. In the case of excessively dry and hard soil, harvest losses become inevitable (Jordan et al., 2013). Losses during the uprooting of the plant can occur both below and above the ground. Losses also occur during manual uprooting of the plant in the field. Mishamandani et al. (2014) reported that the combine harvester used during peanut harvesting provides a 39% cost reduction and a 96% time saving compared to manual uprooting and digging methods. Due to the shallow operation of the machine's blades, losses may occur below ground level when peanuts are cut. In both methods, the highest share of losses is represented by exposed pods left on the soil (Azmoodeh-Mishamandani et al., 2014).

1.1. Calculation of Harvest Losses

Losses can occur while uprooted plants are shaken to remove soil and when they are placed in rows of peanut piles. These losses are typically observed above ground. Adjusting the uprooting machine for optimal performance requires significant operator skill (Voltarelli et al., 2017; Roberson, 2023). A study conducted at the Peanut Belt Research Station in 2018 showed that for every 1 km/h increase in ground speed beyond 3 km/h during peanut harvesting, losses could occur. Harvesting at lower speeds may help reduce losses, but it will increase the time required for digging. Padmanathan et al. (2006) designed a peanut combine harvester operated by a tractor, and through evaluation under various working conditions, they demonstrated that the maximum harvesting efficiency achieved when the combine harvester was operated at a speed of 1.5 km/h was 92.3%.

In peanut plants, for calculating the amount of loss in mechanical harvesting, it is necessary to separately calculate uprooting (under-ground) losses and collection-threshing (above-ground) losses. A 1 m^2 frame is used for sampling.

Field Yield = $(A+B+C)$ *1000 (kg/da)

A= the weight of harvested peanuts with shells on a 1 m^2 area of uprooted plants (kg)

B= the weight of freely lying (fallen) peanuts on the soil surface in a 1 m^2 area (kg)

C= the weight of peanuts located below the soil surface in a 1 m^2 area (kg)

D= the weight of peanuts with shells on the soil surface in a 1 m^2 area after the threshing machine pass (kg)

% Disassembly Loss = $(C/(A+B+C)) * 100$

% Collection and Threshing Loss = $((D-B)/A) *100$ can be calculated (Mishamandani et al., 2014).

The farmer should decide on the optimal balance between reducing harvest losses and increasing uprooting time (Roberson, 2023). The losses incurred during uprooting are also influenced by the soil tillage system used, soil texture, soil moisture conditions during inversion and drying, and the maturity of peanuts. Uprooting losses in peanut crops can vary between 15% and 30% of the potential yield (Ortiz et al., 2013). This study will shed light on the causes of peanut harvest losses and the necessary measures to prevent them.

1.2. Considerations During Harvest

- Harvesting the fruit before it ripens causes the fruit to have a lower peel percentage and lower fat and protein content,
- Timely harvesting (determining ripeness through the shell-out method). Delay in harvesting results in retaining more unripe pods in the soil and obtaining lower yields,
- Immature peanuts should not be harvested as they are susceptible to fungal diseases,

- Peanuts should be harvested on sunny days and humid/wet weather conditions should be avoided,
- It should be harvested when there is sufficient moisture in the soil,
- Stacking of harvested peanuts should be avoided to prevent mold growth that causes aflatoxin contamination,
- Peanut varieties should be dried in separate places, taking care not to mix them while harvesting in the field,
- Broad beans should be dried in the field for 7-10 days without losing the appropriate moisture content, as excessive drying causes the peanuts to split during storage (Anonymous, 2023).

1.2. Conclusion

To minimize post-harvest losses, it is important to harvest when the soil contains sufficient moisture, optimize the use of harvesting machinery, use varieties with durable gynophores, start harvesting when the fruits reach a ripeness level of 55-60% (shell-out peeling), collect pods left in the soil, and reduce harvest losses by adopting better mechanical methods and determining row spacing so that the machine's wheels can pass through. At the same time, to reduce harvest losses, attention should be paid to starting harvesting when the average moisture content of peanuts falls below 18-20% during threshing, maintaining a forward speed of 3-7 km/h for the uprooting machine, ensuring a forward speed of 4-5 km/h for the harvesting machine, and keeping the rotation speed of the picking unit in the range of 70-80 rpm. These values may vary based on the product's moisture content, harvest timing, machine model, and working conditions.

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CHAPTER 8

CAUSES OF EXCESS NITRATE IN FEED AND WATER USED IN RUMINANT NUTRITION

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INTRODUCTION

Nitrate toxicity is more common in ruminants than in other animals. The main reason for this is the reduction of nitrate to nitrite by microorganisms in the rumen(Ayaş, 2024). Plants used in ruminant nutrition may contain large amounts of nitrate. Reasons such as exposure of plants to excessive amounts of nitrogen, situations that inhibit growth and cause stress, differences in nitrate between plants' vegetation period and plant parts, and the tendency for some plants to accumulate nitrate increase nitrate levels in plants(Oruç & Ceylan, 2001; Sulak & Aydın, 2005). There is a risk of nitrate toxicity in dietary changes without an adaptation period in ruminant feeding. In current studies, nitrate can be added to ruminant diets to combat enteric methane release(Ayaş, 2023). But there is a risk of toxicity. Detailed information will be given below about the causes of nitrate toxicity in ruminants.

1. Factors Affectıng Nıtrate Accumulatıon in Forage Plants

Plants absorb the nitrogen in the soil in the form of nitrate and ammonia. Most of this nitrogen taken in is converted into plant protein during photosynthesis in the leaves (Sulak & Aydın, 2005). The process of converting nitrate into protein occurs as follows: Nitrate is first converted into nitrite by the enzyme nitrate reductase. Nitrite is converted to ammonia by the enzyme nitrite reductase. Afterward, ammonia is converted into amino acids for protein synthesis, and finally protein is synthesized from amino acidsSulak & Aydın, 2005). Although plants take nitrogen from the soil throughout the day, photosynthesis occurs during the day when there is light. Without photosynthesis, nitrogen cannot be converted into protein. Therefore, nitrate accumulates in plants during the night. Nitrate levels in plants peak in the early morning hours. When photosynthesis begins, the nitrate level decreases and the protein level increases. Every plant contains a small amount of nitrate, but for different reasons, nitrate can accumulate in plants to a level that harms animals. Sulak & Aydın, 2005). There are four main reasons for nitrate accumulation in plants: exposure of plants to excessive amounts of nitrogen, situations that inhibit growth and cause stress, differences in nitrate between the vegetation period of plants and plant parts, and the tendency of some plants to accumulate nitrate (Oruç & Ceylan, 2001; Sulak & Aydın, 2005).

1.1. Exposure of Plants to Excessive Amounts of Nitrogen

Plants need nitrogen to survive (Ekici, 2011). However, in some cases, when they are exposed to excessive amounts of nitrogen, they store nitrogen in their bodies as nitrate. It can cause nitrate toxicity in living beings, especially ruminants, that feed on plants containing large amounts of nitrate. There are two main reasons why the amount of nitrogen in the soil is excessive. The first is the use of artificial fertilizers more than necessary, the second is the increase in the amount of nitrogen in the soil due to livestock activities.(Günal, 2019).

1.1.1. Excessive Use of Artificial Fertilizers

Using excessive nitrogen fertilizer causes nitrate accumulation in plants. In a study conducted by Yılmaz et al., 13.2% of the agricultural enterprises in the villages in Isparta use fertilizer after having soil analysis done, while 57.1% of them use fertilizer with the idea that the more fertilizer is used, the higher the yield (Yılmaz et al., 2009). As a result, nitrate accumulation in plants increases. The use of artificial fertilizers has been increasing from the past to the present. This is close to the world average in our country, as it is the case all over the world. In Turkey, excessive fertilizer is used in provinces such as Konya and Adana. Most of the fertilizers used are nitrogenous fertilizers(Şahin, 2016). These fertilizers are stored as nitrates in plants. Therefore, nitrate toxicity may occur in animals.

1.1.2. Excess Nitrogen in The Soil Due To Livestock Activities

One of the main causes of nitrogen pollution all over the world is livestock activities. The largest share in this area belongs to dairy cattle enterprises. Although it varies depending on the content of the ration, productivity, and age, a cattle releases an average of 83-118 kg of nitrogen into the environment annually through urine and feces(Netherlands, 2012). According to a study conducted by Van Horn et al., a cow that gives an average of 8200 kg of milk during lactation excretes 109 kg of nitrogen per year through urine and feces(Van Horn et al., 1991). The main source of nitrogen pollution in cattle farms is ammonia. Ammonia released from the litter consists of approximately 90% urine nitrogen and 10% fecal nitrogen. (Lockyer & Whitehead, 1990). While most of this ammonia evaporates, the ammonia remaining in the soil turns into ammonium in the aqueous environment and then is converted first into nitrite and then into nitrate by some microorganisms. It increases the amount of nitrate, that is, the amount of nitrogen, in the soil(Günal, 2019). Nitrogenous compounds found in excess in the soil pass to plants and can increase the nitrate level of plants. Due to reasons such as excessive irrigation, precipitation, high soil permeability and groundwater resources being close to the surface, nitrate in the soil mixes with groundwater and nitrate toxicity may occur as a result of animals consuming this water(Günal, 2019).

1.2. Situations That Prevent Growth And Cause Stress in Plants

Plants need nitrate to grow. In situations where growth is inhibited and causes stress, nitrate begins to accumulate in the plant. Situations that inhibit plant growth and cause stress are explained below.

1.2.1. Insufficient Light, Cloudy and Foggy Weather

In cloudy and foggy weather and when there is insufficient light, photosynthesis slows down or stops. However, nitrate storage process continues in plants. Since there is no photosynthesis, plants cannot convert nitrate into protein and nitrate accumulates in the plant(Hall, 2018). Nitrate accumulated in plants can reach levels that can cause toxic effects in animals.

1.2.2. Low Temperature

Plants need a temperature of 55ºF or 12.7ºC to continue their growth. Plant growth slows or may stop when the ambient temperature is less than 12.7ºC. However, nitrate uptake from the soil continues and as a result, nitrate accumulation in plants increases(Hall, 2018; Sulak & Aydın, 2005). Nitrate accumulated in plants can reach levels that can cause toxic effects in animals.

1.2.3. Molybdenum Deficiency

Molybdenum is a component of the nitrate reductase enzyme in plants. Nitrate reductase activity decreases in molybdenum deficiency. Nitrate cannot be reduced to nitrite and nitrate begins to accumulate in plants. (Hall, 2018). Nitrate accumulated in plants can reach levels that can cause toxic effects in animals.

1.2.4. Drought

Drought is both a stress factor for plants and prevents growth. Nitrate accumulation in plants increases during dry months. In addition, some plants such as corn, oats, sorghum and millet accumulate large amounts of nitrate in drought(Hall, 2018).

1.2.5. Other Conditions That Cause Nitrate Accumulation in Plants

As a result of the use of herbicides, especially the application of 2.4 D drugs to meadow pastures and agricultural lands, the nitrate content of plants temporarily increases. Nitrate levels in plants increase in situations such as high pH in the soil(İnce & Türkmen), excess potassium, and deficiencies in iron, manganese and phosphorus elements(Bilal & Özpınar, 1994; İnce & Türkmen). Nitrate levels in plants change depending on the day and night effect. Since photosynthesis occurs during the day, nitrate levels are low. However, during the night hours when photosynthesis is not taking place, the nitrate level increases at night as the plant continues to take up nitrate through its roots. With the start of photosynthesis in the early morning hours, nitrate levels in plants peak and begin to decrease. The time when the lowest nitrate concentration in plants is near sunset.

1.3. Nitrate Differences Between Plant Vegetation Period and Plant Parts

Nitrate levels are high in young plants. As the plant ages, nitrate levels decrease. There are large differences between plant parts in their ability to accumulate nitrate. In plants, nitrate accumulates mostly in the roots and stems. The amount of nitrate in the leaves is moderate. Nitrate levels are very low in seeds and fruits(Sulak & Aydın, 2005). Nitrate accumulation increases as the plant body gets closer to the soil.

1.4.Plants That Tend to Accumulate Nitrate

Every plant accumulates some nitrate. However, some plants accumulate more nitrate than others. A study reported that the nitrate level in the meadowsweet plant grown under the same environmental conditions was 1100 ppm, while the nitrate level in the kelptail plant was approximately 3 times that of the meadowsweet plant(Ebert et al., 1980). Plants with high nitrate levels used in animal nutrition: oats, beets, soybean, sunflower, barley, sweet clover, rye, potato, sudangrass, wheat, corn, triticale, and carrots(Hall, 2018; Sulak & Aydın, 2005). The amount of nitrate is very high in some plants that are generally used in human nutrition but are also used in animal feeding as greengrocer residues. 6000-7000 ppm nitrate can be found in arugula(Hmelak Gorenjak & Cencič, 2013), 3000-5000 ppm in lettuce(YEH et al., 2013), and 2000-

3000 ppm in spinach(Winter et al., 2007). Plants that tend to accumulate nitrate are shown in Table 1

Table1: Common Nitrate Accumulating Plants

Amaranthus spp.	Pigweed
Amskinckia spp.	Tarweed
Ambrosia spp.	Ragweed
Avena sativa	Oats
Beta vulgaris	Beets
Brassica spp.	Rutabaga, rape, broccoli, turnip
Chenopodium spp.	Lamb's quarters
Cirsium arvense	Canada thistle
Convolvulus spp.	Bindweed
Datura spp.	Jimsonweed
Daucus carota	Wild carrot, Queen Anne's lace
Eleusine indica	Goose grass
Eupatorium purpureum	Thoroughwort
Glycine max	Soybean
Gnaphalium purpureum	Purple cudweed
Helianthus annuus	Sunflower
Hordeum vulgare	Barley
Ipomoea batatas	Sweet potato
Kochia spp.	Firebush
Lactuca serriola	Prickly lettuce
Linum spp.	Flax
Malva parviflora	Small mallow
Melilotus officinalis	Sweet clover
Panicum capillare	Panic grass
Polygonum spp.	Smartweed
Rumex spp.	Dock
Salsola iberica	Russian thistle
Secale cereale	Rye
Solanum spp.	Nightshades, potato
Solidago spp.	Goldenrods
Sorghum spp.	Johnson grass, milo, sudangrass

Stellaria media	Chickweed
Tribulus terrestris	Puncture vine
Triticum sativum	Wheat
Urtica dioica	Stinging nettle
Verbesina encelioides	Golden crownbeard
Zea Mays	Corn

2. Transıtıon Between Measurement Unıts Used in Nıtrate Analysıs

Several different measurement units are used when determining the nitrate level in nitrate analysis. These are: potassium nitrate, sodium nitrate, nitrate nitrogen, and nitrate ion. In comparing different studies with each other, these measurement units need to be converted into each other(Hall, 2018). For example, to convert the value of potassium nitrate to nitrate ion, it is necessary to multiply it by 0.615. The corresponding formulas of different measurement units are given in Table 2.

Table 2: Transıtıon Between Measurement Unıts Used In Nıtrate Analysıs

Chemical Name	Multiplication Value	Chemical Equivalent
Potassium Nitrate	0,615	Nitrate Ion
Sodium Nitrate	0,725	Nitrate Ion
Nitrate Nitrogen	4,45	Nitrate Ion
Nitrate Nitrogen	1	Nitrate Nitrogen
Nitrate Ion	1,626	Potassium Nitrate
Nitrate Ion	1,379	Sodium Nitrate
Nitrate Ion	0,225	Nitrate Nitrogen

3. Nıtrate Levels in Feeds and Water Used in Anımal Nutrıtıon

There is some nitrate in the feed used in animal feeding. However, in some cases it can reach toxic levels. In general, roughage contains more nitrate than concentrated feed(Sulak & Aydın, 2005). In a study conducted by Oruç et al.(Oruç & Ceylan, 2001), the nitrate levels of the feeds used to feed cattle in the Bursa region were investigated and the nitrate levels in the feeds are given in Table 3.

Table3: Nıtrate Levels Determıned As NO_3-N In Feed (In Dry Materıal, Ppm)

Feed Type	Average	Maxımum	Mınımum
Daıry Cattle Concentrated Feed	90	271	9
Beef Cattle Concentrated Feed	96	276	3
Calf Starter Feed	69	164	4
Wheat And Barley Straw	210	1036	13
Green Clover	708	1166	208
Drıed Clover	399	1731	42
Drıed Oats	139	413	26
Dry Meadow Grass	27	57	8

Table 3 shows the large difference between the minimum and maximum value of nitrate level in all feedstuffs. However, the average nitrate-nitrogen concentration in concentrated feeds does not exceed 100 ppm. However, the nitrate-nitrogen concentration in roughage is higher than in concentrated feed. The nitrate nitrogen level in green clover samples is almost 9-10 times the nitrate-nitrogen level in concentrated feeds. In the study conducted by Kaya et al.(Kaya et al., 1989), on the nitrate level in sugar beet pulp, it was reported that the nitrate level in beet pulp was at a level that would harm animals. In the study by Bilal and Özpınar(Bilal & Özpınar, 1994), the nitrate level in beet pulp was reported to be 3039 ppm. This study supports the study of Kaya et al. However, in the study conducted by İnce et al.,(İnce & Türkmen)it was stated that the nitrate level in beet was high, but the nitrate passed into the water during the sugar production stage from the beet and the nitrate level in the beet pulp was low. In a study by Antczak et al.(Antczak-Chrobot et al., 2018), it was reported that the average nitrate level in beet pulp was 34.35 ppm. Current publications state that the nitrate level in beet pulp is low. In the same study, the nitrate level in molasses was 2376.17(Antczak-Chrobot et al., 2018), suggesting that the excess nitrate in beet is removed from the pulp during sugar production and accumulates in the molasses. In a study conducted by Oruç et al.(Oruç & Ceylan, 2001), it was emphasized that the hay used in farms in Bursa contained nitrate at the level of 1036-1731 ppm and that this level could cause chronic nitrate toxicity.

4. The Effect of Some Processes on Roughage on Nitrate Levels

The processes carried out on roughage can be summarized as making hay and turning it into silage.

4.1. Effect of Drying on Nitrate Levels in Roughage

It has been reported that the drying process applied to forage plants does not cause a significant change in the nitrate level of the plants(Seay, 1996).

4.2. Effect of Silage-Making Process on Nitrate Level in Roughage

Nitrate found in silage plants is used as a source of NPN by organisms during silage fermentation and is converted into microbial protein. In addition, some of the nitrate dissolved in water is removed by silage leachates(Hall, 2018). Thus, the nitrate level in silage can be reduced by 30% or more(Sulak & Aydın, 2005). A fermentation period of 30-60 days is required for this reduction to occur(Hall, 2018). However, even if this fermentation period occurs and the nitrate concentration decreases, some silages may still contain toxic levels of nitrate(Hall, 2018).

5. Nıtrate Level in Water

There is no nitrate in the natural structure of water. However, due to some reasons, water may be contaminated with nitrate. The main reasons for this contamination are the use of excessive or incorrect nitrogenous artificial fertilizers and the leakage of animal fertilizers in livestock enterprises(Günal, 2019). However, in cases where the amount of sand in the soil is high and the groundwater is close to the surface, the possibility of contamination of groundwater with nitrate increases(Almasri & Kaluarachchi, 2005; Liu et al., 2009; Yesilnacar et al., 2008). Deep groundwater is less contaminated with nitrate compared to near-surface groundwater(Oruç & Ceylan, 2001). 2-20% of the nitrogen in fertilizers thrown into the soil is released into the atmosphere through evaporation, 50-70% is used by the plant, 15-25% is combined with organic compounds in the soil, and 2-10% is released into the surface and It has been reported that it enters groundwater(Akkurt et al., 2002). While the maximum nitrate concentration in water consumed by people in the European Union is determined as 50 mg/L, the maximum nitrate concentration in waters consumed by people in Turkey is determined as 45 mg/L according to TS 266(Varol et al., 2008). The maximum nitrate level in the water used to feed farm animals has been reported as 100 ppm nitrate nitrogen. (Nitrite et al., 1981; Rasby et al., 1996). It has been reported that nitrate levels in water are safe below 100 ppm in terms of ruminant feeding, but may have toxic effects when it exceeds 1000 ppm(Hall, 2018). The fact that the nitrate level in the water is low compared to roughage should not deceive us. Because the nitrate in water is rapidly converted into nitrite by microorganisms in the rumen.

However, the rate at which nitrate is converted to nitrite in plants is much slower. For this reason, even if the nitrate level in water is half of that in plants, it can have a toxic effect(Crawford et al., 1966; Hall, 2018). High amounts of nitrate may also be present in the liquids leaking from fermented forage sources during silage formation. Nitrate toxicity can be observed in ruminants that consume silage leachate.

6. Adaptation to Nitrate Diets in Ruminant Nutrition

An adaptation period is needed to prevent the harmful effects of nitrate-rich diets. In a study, ruminants adapted to a nitrate diet in an average of 6 days(Allison & Reddy, 1984). However, it has been reported that adaptation disappears in a short time(Nolan et al., 2016). There is no standard adaptation protocol. In a study conducted by Hulshof et al., nitrate content was increased by 0.5% in the ration dry matter every 4 days, up to 2.2%(Hulshof et al., 2012). In a similar study, dietary nitrate content was increased by 0.5% in ration dry matter every seven days, up to 2.1%(Van Zijderveld et al., 2011). In order to reduce the risk of toxicity, the dose of nitrate added to the ration can be increased gradually and the adaptation period can be extended.

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