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Research Article

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Investigation of the Efficiency of Occupational Health and Safety Education of Agriculture Department Students in Vocational High Schools

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HIGHLIGHTS

- This study aims to investigate the effectiveness of occupational health and safety training prepared for students studying in the relevant departments of vocational high schools.
- It has been observed by this study that increasing OHS training in agriculture and making the curriculum interesting can encourage students who graduate from their fields to start working in the agricultural sector.

Abstract

The basis of occupational hazards and risks in agriculture, which is a high-risk sector, is due to the behavior of farmers based on a lack of knowledge. In this sense, farmers are required to have knowledge of occupational health and safety (OHS) in agriculture and to carry out their work with the following health and safety measures. The easiest way to achieve this is to implement these measures by making a habit of them together with technical experts working with the farmers in the field. In this context, it is important that agricultural, food, and laboratory technicians, who play an important role in ensuring soil and animal health and safety, acquire this information during their training. This study aims to investigate the effectiveness of occupational health and safety training prepared for students studying in the relevant departments of vocational high schools. Occupational health and safety training in agriculture was given to students from the agriculture and laboratory department of İstanbul Mehmet Akif Ersoy Vocational and Technical Anatolian High School, which was determined as a pilot school in Ankara, and the awareness of high school students in the field of occupational health and safety was measured and especially on OHS in pesticide use. The tests applied at the beginning and end of the training were analyzed at the end of the study and it was concluded that they gained the awareness to a large extent. While the awareness score was 55 in the test performed at the beginning of the training, the awareness score increased to 95 after the training.

Keywords: Vocational High School, Agriculture, Occupational Health, Occupational Safety, Awareness

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1. Introduction

Occupational health and safety (OHS) are one of the most important issues that need attention in the name of health and safety in every field in the world. Producing solutions by developing Occupational Health and Safety measures, which is one of the biggest needs in the industry, is an important problem that many countries face globally. According to the estimates research of the International Labor Organization (ILO), every 15 seconds an employee dies due to a work accident or occupational disease, and approximately 2.3 million workers die from work-related diseases in the working environment every year (ILO 2022). Each occupational accident and occupational disease hurt the country's economy. Although there are many steps to be taken for safe production, there are trained employees who can create strategies in every country. For this reason, examining the previous literature reviews by comprehensively and systematically understanding the research and development trends will increase the potential to predict the development and future trends in this field.

According to the data from the ILO, about 2.3 million years ago, the death rates of workers due to occupational accidents and diseases were higher (ILO 2022).

Occupational health problems continue to increase in low-income countries due to the transition from subsistence agriculture to industrialization, the working conditions of agricultural workers, and the lack of control of risks. To increase the controls and raise awareness, OHS public units have been established in many countries that provide the management structure related to Occupational Health and Safety. It is thought that the importance of these units is great because of the activities that can be done jointly with the state (Atusingwize et al., 2019).

The value of integrating it with the occupational health and safety activities necessary for the improvement of occupational health is increasing (Biswas et al. 2021). It is known that more than half of the people are in the working class. However, a significant number of people in this class also work in the agricultural sector. The determining factor for the health status of each class employee is the working environment. It is of great importance to draw attention to occupational health and safety, as the agricultural sector also creates a dangerous working environment. The success of the vocational training given to the new entrants to this sector, rather than the vocational training given to the employees who have gained many years of experience, results in a higher safety culture. It is known that occupational accidents and occupational diseases that employees may encounter with occupational health and safety training can result in minimum negativity (Olcay et al., 2021). In addition, it is very important to make progress in the field of OHS so that all kinds of work accidents and occupational diseases are recorded.

The shrinkage of agricultural lands per capita, climate changes, and the decrease in water resources in countries reveal the importance of the education given in Agricultural Vocational High Schools. Gaining the basic skills of modern and traditional agriculture is an important issue that needs to be prioritized. To ensure sustainable agricultural development, labor productivity must meet the basic needs of agricultural workers, as well as provide suitable working conditions for agricultural workers. Vocational high school students who will take part in the agricultural sector should have taken the basic equipment of the field as well as the basis of occupational health and safety.

Agricultural workers may be exposed to pesticides, insecticides, silage in silo holds, moldy straw and sugarcane, fungal spores, and chemicals such as ozone, methane, and ammonia. All these have a very negative effect on the respiratory tract. Against all these dangers, the dust in the environment should be cleaned, good ventilation should be done in the silo warehouses, and humidity and moldy environments should be destroyed. However, these measures are not enough to eliminate all dangers. Respiratory protective equipment must be used, especially when spraying or walking around these areas where there are other

respiratory risks. In addition to these, integrated pesticide management, good social medicine practices, vaccines, pest control, protective creams, good pesticide use practices, re-entering the land at the right time after pesticide use, identifying and separating carcinogens, labeling the boxes according to safety rules are the latest in terms of occupational health and safety. is extremely important.

Pesticides are biologically active chemicals that cause troublesome insects, animals, microorganisms, weeds, and other pests to die or change their behavior. The first substances used as pesticides were arsenic and sulfur. Later, it was linked to the use of botanical substances such as nicotine (Li et al., 2016).

It is known that hundreds of pesticides are used in the world. In the classification made by the World Health Organization, 33 of the 700 most used pesticides are harmful to human health, 48 are very dangerous, 118 are moderately hazardous and 139 are less dangerous. World pesticide consumption increased to 3.2 million tons in 2001. 75% of pesticide consumption belongs to developed countries and the USA, Western Europe, and Japan rank first among these countries. Considering the use of pesticides in Turkey by pesticide groups; it is seen that the most important group is insecticides with 47%, followed by herbicides with 24%, and fungicides with a share of 16% (Ahioğlu 2008).

It is known that pesticides are widely used in the agricultural sector to prevent harmful or harmful organisms. However, in addition to preventing this pesticide from harming the plant, it has negative effects in many areas from soil structure to the health of the pesticide applicator. Therefore, controlled use and correct use are of great importance. In recent years, despite the increase in the number of countries where important measures have been taken to prevent the unconscious increase in pesticide use, it is difficult to record developments that will eliminate the negative effects. For this reason, the inclusion of these issues in newly organized training gains importance in terms of increasing the precautionary elements (Wang et al., 2020).

The main objective of this study is to create occupational health and safety awareness to prepare the agricultural and laboratory department students at vocational high schools for their professions. In the application part of the study, three-day basic level OHS training was given to the students. The content of the training has been prepared specifically for Occupational Health and Safety in Agriculture, and the OHS titles for pesticide use are emphasized in the program.

This study, it was aimed to prepare vocational high school students and future agricultural workers with high awareness and increased knowledge of OHS. Since it is not possible to gain awareness of OHS in agriculture in all its dimensions with theoretical education alone, practical training of students in this field or providing internship opportunities will help to further expand their perspectives.

2. Materials and Methods

Occupational health and safety training in agriculture was given to 39 students from the agriculture and laboratory department of Borsa İstanbul Mehmet Akif Ersoy Vocational and Technical Anatolian High School, which was determined as a pilot school in Ankara, and the awareness of high school students in the field of occupational health and safety, and especially in pesticide use, awareness on OHS has been tested and evaluated for data analysis. In the training given to the students, verbal expression, visual content, and gamified expressions were used as methods. Before the training, the awareness of the students in the field of Occupational Health and Safety was determined by 20 questions and the content was adjusted according to these results. After the training and studies carried out after the awareness evaluation, a separate test was applied to follow the development status. The data obtained by these tests were evaluated by graphing. During the training, support was received from the high school teachers to attract the students to the subject at the maximum level, and the teachers in charge of the research were provided with high school education. In the awareness meetings held with the students, the fact that the training is visual and creative drama application shows that they are more interested.

To carry out the study first, information such as the ages of the students and the fields they studied were learned during the acquaintance at the beginning of the education. In the study, 39 students (15 girls and 24 boys) at Borsa İstanbul Mehmet Akif Ersoy Vocational and Technical Anatolian High School in Ankara's Çankaya district were interviewed, and tests were applied to monitor their awareness development at the beginning and end of the education. Attention was paid to the fact that the 9th and 10th-grade students selected were students of the agriculture and laboratory departments, and it was ensured that the teachers of the same field in the high school participated during the education.

Table 1. 3-day training program applied to students

1. Day	2. Day	3. Day
Pre-Test Practice, what is Occupational Health and Safety? OHS Historical Development (90 minutes)	Pesticide, Uses, and Health Effects (90 minutes)	Selection and Use of Applied Personal Protective Equipment in the Agriculture Sector (90 minutes)
General Description of Occupational Health and Safety in Agriculture (90 minutes)	Pesticide Label Information, Considerations for Pesticide Usage (90 minutes)	Example applications (90 minutes)
Risk Factors in Agricultural Enterprises (90 minutes)	Risk Management in Pesticide Applications (90 minutes)	Drama Application (90 minutes)
Occupational Diseases and Work Accidents (90 minutes)	Preventive Approaches in Pesticide Applications (90 minutes)	Mini-Exam and End of Training Knowledge Level Measurement Application (90 minutes)

In the 6 open-ended questions in the first test applied before the education; His basic knowledge of OHS training, pesticide identification, and personal protective equipment (PPE) was tested. With open-ended questions, it was predicted that the students would be able to express their thoughts without being within certain limits, and positive results were obtained. In addition, students were expected to rate their knowledge level. An OHS expert was also consulted to evaluate the content of the questions.

After the 3-day 18-hour training applied after the first test, another test was applied to monitor the awareness development. In this application, students were asked to answer the questions by imagining the environments in which they could work in the following years. They were asked to describe the dangers they may encounter in the working environment and the precautions they can take, to explain their thoughts on the selection of personal protective equipment and the hygiene of the working environment.

As indicated in Table 1, the content of the training has been planned specifically for the use of pesticides in agricultural areas and the continuation of work by occupational health and safety. The risks they may encounter in the field of agriculture and the precautions they can take are mentioned. Then, information was given about the personal protective equipment that should be used during spraying.

Since the working group is between the ages of 14-15, it has been given importance to gamify each application and educational content. Before the awareness development follow-up test, a creative drama application was made to evaluate a problem given by the educators in an agricultural study area that they determined.

3. Results and Discussion

The agricultural sector has a very special and important place in the country's economy, as it is an economic sector and makes significant contributions to the country's exports. On the other hand, because of the increase in food supply with the increasing population, the strategic importance of the agricultural sector is increasing, and ensuring sustainability in agriculture gains more importance. In this framework, more research and awareness studies are needed to solve the problems by considering the labor factor in the agricultural sector as a function of economic and social development.

One of the most important parameters in ensuring the sustainability of agriculture in our country will be possible by improving the occupational health and safety conditions of labor-intensive workers in the agricultural sector. Considering the contribution of the agriculture sector to the national economy and the raw material and capital it provides to the industrial sector, its direct interest in food production and nutrition, its high rate in the active labor force, its contribution to the protection of environmental health and the provision of ecological balance, it is seen that its sustainability concerns the whole country. When evaluated in terms of both economy and employment, it is seen that occupational health and safety in agriculture is an issue that cannot be neglected.

In Labor Law No. 4857 published in May 2003 (Anonymous 2003), agriculture and forestry enterprises are excluded from the scope (Labor Law 2003: 4/b). With the June 2012 publication of the Occupational Health and Safety Law No. 6331 (Anonymous 2012), which includes important changes in the occupational health and safety legislation in our country, all employees in the public and private sectors have been included in the scope of the Law and the necessary legal requirements for the protection of the health and safety of those working in the agricultural sector have been included. regulations have started to be implemented (Occupational Health and Safety Law 2012). However, the completion of legal regulations alone is not sufficient to prevent the risks of occupational accidents and occupational diseases occurring in this field. These arrangements will be possible with the development and implementation of solutions for raising awareness, raising awareness, and solving concrete problems related to occupational health and safety for those who work in the agricultural sector and who are candidates in the sector. In this context, the effectiveness of methods on how to increase OHS training in agriculture and make the curriculum interesting, and how to create environments where students who graduate from their fields can encourage to start working in the agricultural sector are examined in this study.

The evaluation of the awareness development monitoring test results of the 9th and 10th-grade students who received education in two different fields of the vocational high school was made by the OHS experts and educators. Since vocational high schools are less preferred by female students, the number of male students in the study is high. Considering the rate of 38.4% female students and 61.6% male students, it was determined that the answers given were not related to gender distribution.

It was observed that the student's awareness of "OHS and Pesticides" increased significantly with the tests and drama practice applied at the beginning and end of the education. The drama practice applied to ensure the long-term permanence of the acquired knowledge has greatly contributed to education. It was decided by the educators of the high school that it was a method that could be applied in later processes as well.

According to our observations during the study, we interpret that the students of the agriculture department are more prone and interested in pesticides than the students of the laboratory department. In the test applied at the beginning of the education, the students of the agriculture department gave conscious answers to the pesticide questions and showed that their perception levels on this subject were high. Since most of the participants were chosen as agriculture students, their interest in occupational health and safety training specific to agriculture was high. When the opinions of the students were taken at the end of the

training, positive feedback was encountered. It is possible to interpret the feedback as an increase in awareness of OHS. These data show that it has been concluded that education has achieved its purpose.

In the test applied at the beginning of the education, most of the students rated the occupational health and safety knowledge level in agriculture as "Average". In this test, while the students could not define the danger in agriculture, they increased their level of knowledge enough to both define and give examples in the test applied at the end of the education. It was determined that 71% of the students were more aware of personal protective equipment than other subjects.

The questions with the highest level of response in open-ended questions were personal protective equipment (PPE) questions. The reason for this is thought to be due to familiarity with the protective equipment. The visual content of the subjects is the reason for preference because it increases recall. It was very useful to show examples of personal protective equipment explained during the training.

In addition to the training, it was interesting for the young people to listen to the experiences of the educators. During the interviews held at the end of the training, the student's requests for internships in this field and department visits arose.

With the applied training, the youth, who are the agricultural and laboratory workers of the future, have a basic level of occupational health and safety knowledge. However, by knowing pesticides, the use of which has increased in recent years, they have grasped the seriousness of pesticide use in agriculture.

The effectiveness of the training can be seen more clearly by showing the results of the tests applied at the beginning and end of the training graphically. The answers given to the open-ended questions of the first test administered to a total of 39 students are shown in Figure 1, Figure 2, and Figure 3.

“What is the first word that comes to your mind when you think of occupational health and safety?” The answer with the highest rate to the question was "Health and Accident". However, the least that comes to mind is “Efficiency” with 3%. It is thought that these results are due to the words in the question evoking information about the subject.

Figure 1. Write the first word that comes to your mind when you say OHS

According to the information shown in Figure 2, it is seen that students mostly understand that it is a drug when they hear the word pesticide. They associated this word with at least 'insect'. However, considering that it is also related to the department they are studying, it is seen that they know that it is a drug used in agriculture and may leave residues.

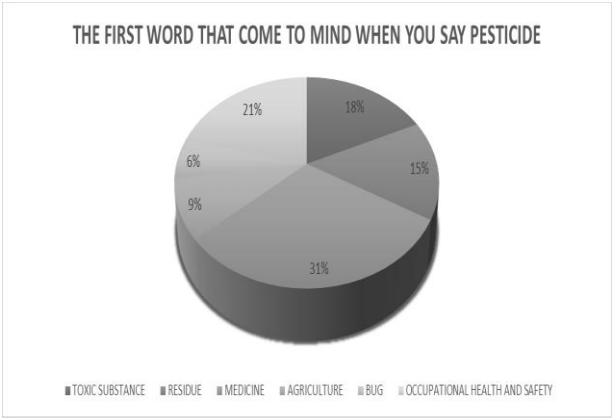

Figure 2. The first word that comes to mind when you say pesticide.

Evaluation of personal protective equipment by students is given in Figure 3. First, the abbreviation PPE was opened during the training, and it was seen that the first words that came to mind were personal equipment (gloves, glasses, masks, etc.). It is also seen that there are students who use the expressions at the root of the question in their answers. One of the topics of discussion on the agenda, the supervision of the use of PPE is also among the answers of the youth.

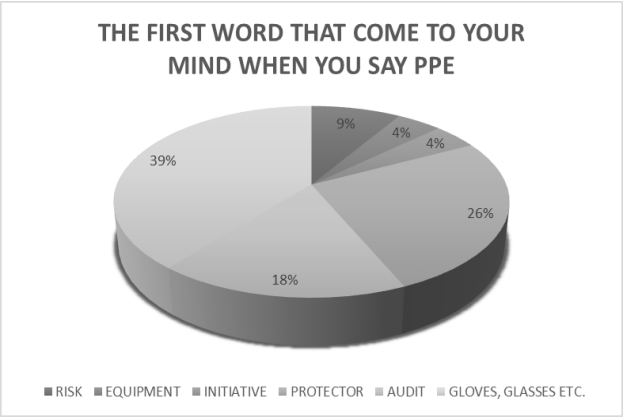

Figure 3. The first word that comes to your mind when you say PPE.

In the awareness assessment made by the students at the beginning of the education, it was interpreted that they had mastered the basic concepts and it could be observed that they were highly interested in the subjects they could visualize in their minds. According to the information given by high school teachers, it can be interpreted that they have mastered the basic objectives of occupational health and safety because they are familiar with the expressions in their curriculum.

The percentiles of the answers to the test administered at the end of the training are shown in Figure 4, Figure 5, and Figure 6. According to the information in Figure 4, in the answers given by the students who received OHS training in agriculture, among the dangers that agricultural workers may be exposed to, 25% of the total participants were "Construction machinery and equipment". "Poisonings/respiratory problems",

which followed this with 19%, are thought to be caused by the pesticide issue included in the education. The dangers (insect bites, natural disasters) that young people hear around them are also among the answers. Since people working in the production, storage, transportation, and sale of pesticides, practitioners using pesticides, agricultural workers working in pesticide-used areas, consumers who eat food containing pesticide residues, and people from all segments of society exposed to pesticides contaminating the environment, studies are carried out considering different risks. To determine these risks, the acute (immediate), subacute (short-term), and chronic (long-term) toxicity of pesticides on animals are examined. The answers given by the students show that they have a basic level of knowledge on this subject.

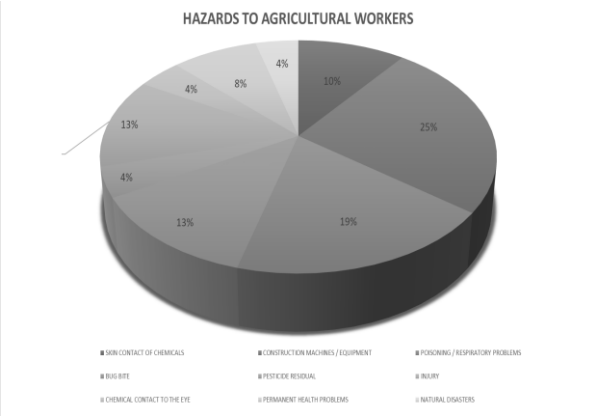

Figure 4. Hazards to agricultural workers.

The answers are given to the question "Measures to be taken in occupational health and safety", which is one of the most important questions in which training effectiveness is measured, satisfied our trainers. Personal protective equipment, which is an important issue to be considered in OHS, constitutes a large portion of the answers given. (Figure 5) The emphasis of future employers and workers in the response to employee training following PPE added value to training.

Figure 5. Measures to be taken in occupational health and safety.

After the importance of PPE was emphasized throughout the training, the answers to gloves, glasses, aprons, and masks written by most of the students who received vocational training (Figure 6) show that they understood the subject.

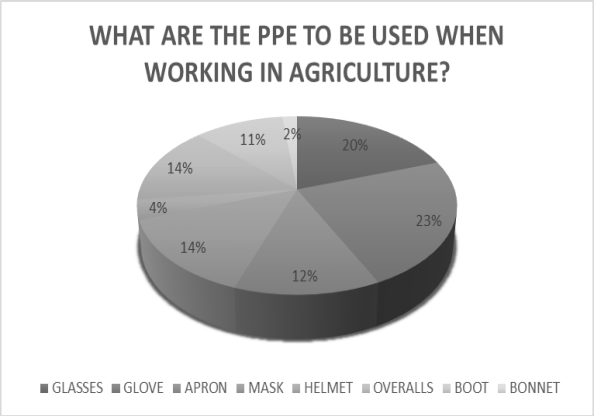

Figure 6. What is the PPE to be used when working in agriculture?

Based on this study, what needs to be done to raise awareness of occupational health and safety in agriculture can be summarized as follows.

1. To improve occupational health and safety services, the risks to which the employees in the field are exposed should be detailed and training modules and methods should be developed that will enable the employees to gain a safety culture specific to the workplace.

2. Vocational training modules specific to the agricultural sector should be developed, including occupational health and safety measures.

3. Since the employees in the sector are self-employed, or family-run, methods from different sectors should be developed to improve occupational health and safety.

4. Relevant training should be held in places where agricultural workers can easily reach, and the right and wrong examples from previous experiences should be visualized, especially in identifying risks and taking precautions.

5. Although it is not a result of the study, it can be interpreted that increasing the level of knowledge and awareness of the technical personnel who will work with agricultural workers on occupational health and safety can contribute to field studies.

6. Field research carried out in the sector should develop research and research projects like the studies presented in cooperation with relevant institutions, organizations, and social partners. It should be ensured that the gains to be addressed through these studies are disseminated.

7. More projects should be developed to increase awareness of occupational health and safety of trainers, researchers, and academicians working in different fields of agriculture and should be implemented with the candidates in this sector. Publications on the studies should be increased.

8. Exemplary risk assessment studies for sub-activity areas of agriculture should be increased and sample practices should be expanded together with those working in sub-activity areas.

9. Occupational health and safety awareness levels of all relevant occupational groups that are in one-to-one communication with those working in the field should be increased.

4. Conclusions

With this study, it has been observed that occupational health and safety in the agricultural sector is one of the areas in need of improvement and that the studies in this field should be continued within the framework of effective cooperation of all relevant stakeholders (Sert et al., 2018).

According to the NACE (Nomenclature des Activités Économiques dans la Communauté Européenne) coding system, it will be possible to ensure the health of young people who will work in the agricultural sector, which is in the dangerous class, when necessary, precautions are taken.

As a result, the consciousness level of vocational high school students should be maximized due to the health and safety risks in the working environment. For this reason, in addition to providing occupational health and safety training as semester courses, they should be given in detail within the titles of each course throughout the training process, and their awareness should be increased in their fields. Young people should also be encouraged to develop themselves by ensuring that the increased awareness remains constant. As a result of providing these, it will be ensured that agricultural and laboratory workers will take precautions by foreseeing the dangers and risks in the working environment.

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Research Article

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Determination of Agricultural Mechanization Level of Azerbaijan in Plant Production

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HIGHLIGHTS

- The situation of the agricultural mechanization in Azerbaijan was discussed.
- Change of agricultural mechanization status by years in Azerbaijan was determinated.

Abstract

Agricultural mechanization characteristics of Azerbaijan were investigated in this study. Based on the statistical data of Azerbaijan, number of tractors, number of agricultural tools and machines and agricultural mechanization level indicators were calculated and summarized. Respectively in the years 2010 and 2021, average tractor power was identified as 68.2 and 74.7 HP, tractor power per cultivated area as 916 and 1672.2 HP/ha, number of tractors per 1000 hectares as 13.4 and 22.2, number of combine harvesters per 1000 hectares as 1.2 and 2.1, cultivated area per tractor as 75 and 45 ha, cultivated area per combine harvester as 821.5 and 458.3 ha, agricultural field per capita as 0.52 and 0.47 ha and finally number of people per unit area as 1910 and 2120.

Keywords: Azerbaijan, Mechanization level, Tractor, Combine harvester

1. Introduction

Increasing world population and decreasing natural resources threaten all countries. Besides all these, negative factors such as pandemic and wars that have emerged in recent years have once again revealed the importance of food in human life. Food products are obtained from animal and plant sources. In this sense, it has become necessary to increase productivity in plant production activities, especially in declining agricultural areas. Efficiency can be analyzed in two parts as product efficiency (product quantity per unit area) and improvements to be made in input costs. Agricultural mechanization provides significant time savings at every stage of production, reduces human labor and energy costs in agricultural activities. Mechanization also plays an important role in yield and quality. Therefore, within the scope of agricultural activities, increasing the level of agricultural mechanization should be among the priority strategic objectives of all countries.

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Agricultural mechanization with a great role in increasing productivity in agricultural activities is an indispensable factor for the sustainability of agriculture. Increasing agricultural mechanization allows farmers to do agriculture over larger areas and contributes to social, cultural and economic development of the population engaged in agriculture (Özpınar, 2001; Demir and Çelen, 2006).

Mechanization also plays an important role in improving production, productivity and quality in agriculture, facilitating agricultural activities, minimizing existing costs, modernizing enterprises, opening new business areas, and developing the agricultural sector socio-economically (Altay and Turhal, 2011). Agricultural mechanization, which is an indispensable input of modern agricultural techniques, requires good planning because it is expensive and long-term investment. Therefore, agricultural mechanization status and problems should be adequately revealed on a national and regional basis (Baydar and Yumak, 2000).

Within the scope of this study, tools and machinery used in plant production, especially tractor and harvester inventory of Azerbaijan were investigated and mechanization level indicators were calculated and evaluated in Tables and charts.

2. Materials and Methods

Azerbaijan is a Eurasian country located in the South Caucasus. Its location is Eastern Europe and Southwest Asia. It is located between 38° and 42° north latitudes and 44° and 51° east longitudes. The length of its borders is 2648 kilometers of which 1007 kilometers with Armenia, 756 kilometers with Iran, 480 kilometers with Georgia, 390 kilometers with Russia and 17 kilometers with Turkey. Azerbaijan has a coastline of 800 kilometers and the widest border length of the Azerbaijani part of the Caspian Sea is 456 kilometers. The country's territory stretches for 400 kilometers from north to south and 500 kilometers from east to west.

Azerbaijan harbors a wide natural diversity. Although it is surrounded by mountains and high hills, most of Azerbaijan is plain and the most fertile parts of its land are the delta where the Kura and Aras rivers mix. There is a temperate climate in Azerbaijan, but a harsh climate is encountered toward inward from the Caspian Sea, in the high mountains and other high parts. In higher elevations, winters are long, cold and snowy and summers are cool. On the plains, winters are cool and rainy and sometimes snowy and summers are hot and dry.

The plains of Azerbaijan are mostly steppes and 25% are covered with forests, some of which are mountains. Forests are seen in the northern and southern parts of the mountains up to 2000 m altitudes (Anonymous, 2022a).

The annual average temperature of Azerbaijan is 14.5 °C. Average annual precipitation in Azerbaijan varies from region to region. The annual total average of precipitation varies between 110 kg/m² (Puta town) to 1750 kg/m² (Kekiran, Lenkeran). Atmospheric precipitation is one of the main factors of weather and climate, but it is also of great importance for agriculture (Mammadov, 2003).

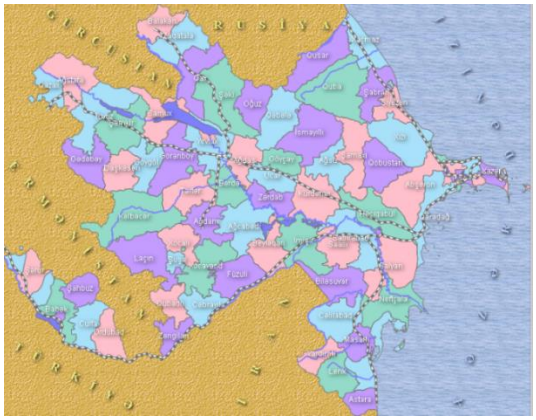

Figure 1. Azerbaijan map and terrestrial bordering countries (Anonymous, 2022b).

Figure 2. Location of Azerbaijan in the world (Anonymous, 2022c).

Various research methods are used to determine the mechanization level of a country or a region. The most widely used of these methods are tractor power per unit area (kW/ha), agricultural area per tractor (ha/tractor), number of tractors per unit agricultural area (tractor/1000 ha). The other criteria used in determining the level of mechanization include the mass of agricultural machinery per tractor, the energy variety used in the agricultural sector, the tractor usage time and the tractor purchasing power of the producers (Pınar et al., 1994; Ülger et al., 2002; Işık et al., 2003; Arıöz, 2007; Yıldız et al., 2007; Koçtürk and Avcıoğlu, 2007; Lüle et al., 2012).

Several studies have been conducted in Turkey to determine agricultural mechanization levels. In a study conducted to determine the agricultural mechanization level of Nevşehir province, it was determined that the number of tractors per 1000 ha in Nevşehir was 50.28 in 2003 and 48.39 in 2012 (Eryılmaz et al., 2013). In another study, the agricultural mechanization level of Kırıkkale province was investigated and it was concluded that the average tractor power was 40.41 kW in 2003 and 36.74 kW in 2012 (Yeşilyurt, 2013). In a study analyzing the agricultural mechanization status of Hakkari province, the cultivated area per tractor in Hakkari was determined as 61.84 ha in 2003 and 56.66 ha in 2012 (Gökdoğan, 2014).

Within the scope of this study, the data obtained from the Azerbaijan State Statistical Institute were used, evaluations were made and results were presented in tables and graphs. Changes in the number of combine harvesters and tractors for the last 12 years and mechanization level characteristics were determined.

3. Results and Discussion

Within the scope of the data obtained from the Azerbaijan State Statistics Institute, number of tractors and total tractor powers of the last 12 years are given in Table 1.

When the data shown in Table 1 is examined, it was seen that number of tractors was 21258 in 2010 and 36808 in 2021. Considering the statistical data in the last 12 years, there were increases in number of tractors.

The total tractor power was 1451000 HP in 2010 and 2750000 HP in 2021. During this period, it was determined that there was an increase of 15550 units or 73.1% in the number of tractors, an increase of 1299000 HP or 89.5% in the total tractor power and an increase of 6.5 HP or 9.5% in the average tractor power.

According to Table 1, the average tractor power of Azerbaijan was 68.2 HP in 2010 and 74.7 HP in 2021. Considering the increase in average tractor power, it was understood that tractors entering the country in recent years had greater horsepower.

The change in the number of combine harvesters in Azerbaijan by years is presented in Table 2. When Table 2 is examined, it was determined that the number of combine harvesters in Azerbaijan was 1928 in 2010. Although there were increases and decreases in the number of combine harvesters between 2010 and 2021, the number of combine harvesters increased by 1560 and reached to 3588 by 2021. In addition, the amount of change in the number of combine harvesters between the years 2010-2021 was calculated proportionally and provided in Table 3.

Looking at Table 3, there were increases and decreases in the number of machines in the agricultural equipment-machine park in the last 12 years. According to Table 3, there were increases in number of tractors (73.1%), plows (67.6%), cultivators (72.3%), seeders (107.1%), mowers (95.7%), balers (13%), combine-harvesters (86%), combine-harvester compatible corn harvesters (20%), self-propelled cotton harvesters (2254%), self-propelled potato harvesters (295%), self-propelled sugar beer harvesters (1577), solid manure spreaders (462.5%), liquid manure spreaders (266%), while there was a decrease in the number of self-propelled forage harvesters (-20%).

According to Anonymous (2022d), the information presented in Table 4 revealed that the total lands given to agricultural use by the Azerbaijan State was 4766800 ha in 2010 and 4780600 ha in 2021. Not all of the lands reserved for agriculture were cultivated, total size of cultivated lands was 1842700 ha in 2010 and 2049800 ha in 2021.

In Table 4, the area per capita from the lands allocated for agriculture (person/ha) and the number of people per unit area allocated for agriculture (1000 ha/person) were provided.

According to the information presented in Table 5, the number of tractors per 1000 ha area (tractor/1000 ha) in Azerbaijan was 13.4 in 2010 and this figure increased to 22.2 in 2021. The total power per 1000 ha area (HP/1000 ha) of 916 HP in 2010 increased to 1672.2 HP in 2021. The cultivated area per tractor (ha/tractor) was 75 ha in 2010 and this number decreased to 45 ha in 2021.

According to the data shown in Table 5, the number of combine harvesters per 1000 ha area (harvester/1000 ha) was 1.2 in 2010 and this figure increased to 2.1 in 2021. In addition, the area per harvester (ha/harvester) was 821.5 ha in 2010 and it was observed that this area decreased to 458.3 ha in 2021.

When the Charts prepared in the light of the information obtained from the Azerbaijan State Statistics Institute were examined, it was seen that there has been a serious progress in the level of agricultural mechanization after 2015. The main reason for this is to support the development of agriculture and accelerate its modernization, to provide a systematic and complex approach to solving existing deficiencies in the agricultural sector, based on the 32nd paragraph of Article 109 of the Constitution of the Azerbaijan Republic, as a result of the great initiative shown by the President of Azerbaijan Ilham Aliyev to agriculture and to use the administrative and financial resources of the state efficiently in the sector. For this purpose, 2015 was declared the "Year of Agriculture" of the Republic of Azerbaijan in order to publicize the agricultural potential of Azerbaijan widely (Anonymous, 2015).

Table 1. Number of tractors, total tractor power (HP) and average tractor power (HP) of Azerbaijan for the last 12 years (Anonymous, 2022d).

Years	Tractors		
	Number of Tractors	Total Tractor Power (HP)	Average Tractor Power (HP)
2010	21 258	1 451 000	68.2
2011	21 404	1 464 000	68.3
2012	21 073	1 434 000	68
2013	23 469	1 630 000	69.45
2014	23 090	1 605 000	69.5
2015	12 262	775 000	63.2
2016	17 043	1 415 000	83.02
2017	21 787	1 585 000	72.8
2018	34 829	2 090 000	60
2019	34 936	2 441 000	69.9
2020	34 954	2 558 000	73.2
2021	36 808	2 750 000	74.7

Table 2. Distribution of a number of combined harvesters of Azerbaijan in the last 12 years (Anonymous, 2022d).

Years	Combine Harvesters
	Number of Combine Harvesters
2010	1 928
2011	1 776
2012	1 724
2013	2 143
2014	2 218
2015	658
2016	1 285
2017	1 621
2018	3 671
2019	3 817
2020	3 642
2021	3 488

The total tractor power was 1 451 000 HP in 2010 and 2 750 000 HP in 2021. During this period, it was determined that there was an increase of 15 550 units or 73.1% in the number of tractors, an increase of 1 299 000 HP or 89.5% in the total tractor power and an increase of 6.5 HP or 9.5% in the average tractor power.

According to Table 1, the average tractor power of Azerbaijan was 68.2 HP in 2010 and 74.7 HP in 2021. Considering the increase in average tractor power, it was understood that tractors entering the country in recent years had greater horsepower.

The change in the number of combined harvesters in Azerbaijan by year is presented in Table 2. When Table 2 is examined, it was determined that the number of combine harvesters in Azerbaijan was 1 928 in 2010. Although there were increases and decreases in the number of combine harvesters between 2010 and 2021, the number of combine harvesters increased by 1 560 and reached 3 488 by 2021. In addition, the amount of change in the number of combine harvesters between the years 2010-2021 was calculated proportionally and provided in Table 3.

Table 3. Number of agricultural tools and machines of Azerbaijan in 2010 and 2021 (Anonymous, 2022e).

Agricultural Tools and Machines	**2010**	**2021**	**Change ratio (%)**
Tractors	21258	36808	+ 73.1%
Plows	3344	5602	+ 67.6%
Cultivators	939	1618	+ 72.3%
Seeders	1844	3819	+ 107.1%
Mowers	873	1703	+ 95.7%
Balers	1501	1697	+ 13%
Combine harvesters	1928	3588	+ 86%
Combine-harvester compatible corn harvesters	5	6	+ 20%
Self-propelled forage harvesters	661	109	- 83%
Self-propelled cotton harvesters	22	496	+ 2254%
Self-propelled potato harvesters	20	59	+ 295%
Self-propelled sugar beer harvesters	9	142	+ 1577%
Solid manure spreaders	112	518	+ 462.5%
Liquid manure spreaders	624	1665	+ 266%

Table 4. Change of total agricultural land (ha), number of people per unit area and total cultivated land (ha) recorded at the end of the year (Anonymous, 2022e).

Self-propelled forage harvesters	661	109	- 83%
Self-propelled cotton harvesters	22	496	+ 2254%
Self-propelled potato harvesters	20	59	+ 295%
Self-propelled sugar beer harvesters	9	142	+ 1577%
Solid manure spreaders	112	518	+ 462.5%
Liquid manure spreaders	624	1665	+ 266%

Table 5. Change of tractor/1000ha, HP/1000ha, combine harvester/1000ha, ha/tractor, ha/harvester parameters of Azerbaijan between 2010-2021 (Anonymous, 2022e).

Years	Number of tractors per 1000ha land	Tractor power per 1000ha land (HP)	Number of combine harvester per 1000ha land	Land area per tractor (ha)	Land area per combine harvester (ha)
2010	13.4	916	1.2	75	821.5
2011	13.3	910.3	1.1	75	905.5
2012	12.8	870.6	1	78	955.3
2013	13.9	967.8	1.3	72	785.9
2014	14.3	994.5	1.4	70	727.5
2015	7.7	488.8	0.5	129	2409.4
2016	10.5	869.0	0.8	96	1267.1
2017	13.1	951.5	1	76	1027.5
2018	20	1202.5	2.1	50	473.4
2019	20.4	1421.5	2.2	49	449.8
2020	21.3	1568.4	2.2	47	447.8
2021	22.2	1672.2	2.1	45	458.3

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The effects of Some Organic Compounds on Yield and Fruit Quality in Albion Strawberry (*Fragaria x ananassa* Duch) Cultivar

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HIGHLIGHTS

- Vinasse increases the yield of the strawberry.
- Molasse increases the fruit quality of the strawberry.
- Vinasse and molasse are advised to use together for strawberry growers.

Abstract

Strawberry is one of the most popular fruits in Türkiye, and its cultivation is increasing due to its high adaptability to different climatic and soil conditions. Greenhouses and conventional agriculture are preferred in strawberry cultivation in terms of both growing conditions and the applicability of good agriculture and organic agriculture. Good agriculture and organic agriculture have increased their importance in achieving reliable and quality food, according to the World Health Organization (WHO). For these reasons, the application compounds are increasing day by day. Accordingly, the types and varieties of organic compounds have increased. Albion strawberry cultivars were grown under calcareous soil conditions, and the effects of various organic component levels on yield and fruit quality were examined. In the experiment, vinasse, molasses, and vermicompost (liquid) were each employed at quantities of 2.5%, 5%, 7%, and 10%. Because of the treatments, a vinasse concentration of 2.5 % was shown to be more beneficial than the others on yield metrics such as yield per decare (1664.89 kg) and yield per plant (332.98 g) (332.98 g). There was a marked improvement in fruit quality between the molasses treatments and the other organic compound treatments. It was discovered that the treatment with molasses at a concentration of 2.5 % (15.94 %) had a greater TSS than the other treatments, whereas the treatment with molasses at a concentration of 5.0 % had to have a higher TAC of 1.058 %. Based on the results, strawberry farmers can be told that using vinas and molasses together is an effective way to increase strawberry yield and improve the quality of the fruit.

Keywords: Alkaline soil, fruit quality, organic compound, strawberry, yield

1. Introduction

In terms of complexity, fertility is the soil quality most analogous to the control of plant nutrients. The part of soil productivity that is concerned with the availability of nutrients and the soil's capacity to supply nutrients from its reserves. Nutrient dynamics and availability are influenced by of several soil variables (biological, chemical, and physical) that are combined here. To optimize crop nutrition in the short and long term and achieve sustainable crop output, it is crucial to control soil fertility, which is a soil property. About a

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quarter of the world's farmable soils are severely deficient in chemical health. Because of their widespread nature and the high expense of remediating the soils, these problems cannot be solved quickly (Vose 1983).

In addition, calcareous soils account for 30 percent of the world's land area. Due to their poor solubility at high pH and the development of relatively insoluble complexes like calcium (Ca)-phosphorus (P), these soils typically have low availability of plant nutrients including iron (Fe), manganese (Mn), copper (Cu), and zinc (Zn) (Marschner 1995). Chlorosis caused by a disruption in Fe metabolism on high Ca-containing soil is sometimes referred to as "lime-induced iron chlorosis" (Faust 1989). This ubiquitous and potentially severe nutritional issue affects several important horticulture crops (Webster et al. 2005). Horticultural crops such as peaches, pears, grapes, and strawberries are particularly susceptible to lime-induced chlorosis. Therefore, in calcareous soils, Fe chlorosis and P deficiency caused by the lime application can be particularly problematic.

Therefore, as much as 90% of the applied P is retained in an insoluble form, making it unavailable for plant uptake. Chlorosis is brought on by an excessive amount of lime, leading the farmer to spend more money on inputs by applying more fertilizer than necessary. Alternatives to chemical fertilizers and agrochemicals are desperately needed all over the world.

In sugar plants located in agricultural areas, studies on the viability of utilizing by-products other than sugar have been carried out throughout the course of the past few years. Molasses and vinas are two examples of these by-products that can be produced.

Molasses, a by-product of the sugar industry, is rich in organic matter and macro- and micro-components and are produced as a by-product of the processing of sugar beets into sugar. Ulusu and Yavuzaslanoğlu (2017) found that applying molasses to plants promoted their vegetative growth. Molasses provides the necessary nutrients for plant growth, and it plays a significant role in the rapid development of plants and the formation of fruits.

The production of sugar from sugar beets results in vinas as a byproduct. The by-product vinas are then treated in yeast factories to remove excess potassium and make it useful. Vinas is a complex organic material made up of several trace elements, macromolecules, and microorganisms. This is why it finds application in the production of fertilizer and animal feed. Vinas is used to creating both the gel and liquid organic fertilizers in the fertilizer industry (Türker et al. 2015).

In addition, it has been observed that the application of vermicompost in the process of agricultural production has been growing in popularity over the past several years. Applying vermicompost to your plants is simple, and it will improve your soil and provide essential nutrients to your plants at the same time. Many people believe that vermicompost has significant potential to improve organic farming in the future because of its involvement in plant nourishment.

This investigation's objective was to determine whether or not the addition of molasses, vinas, or vermicompost to the growing medium altered the production values or the fruit quality features of the "Albion" strawberry variety.

2. Materials and Methods

In the year 2022, this study was conducted at Selcuk University's Research and Application Orchard, which is located within the Department of Horticulture.

The "Albion" strawberry cultivar was studied in the field for a full year from the time it was a frigo seedling (*Fragaria* x *ananassa* Duch.). In 1999, the Albion variety was selected from a breeding program (Diamante x Cal 94.16-1.) at the University of California. The Albion is a day-neutral cultivar. According to research (Shaw and Larson 2006), its typical fruit is elongated, conical, and highly symmetrical.

The alkaline soil that was used in the experiment had a high lime content (29.6 %), as well as a pH level (7.80). The experiment soil preparation with river sand: alkaline soil (3:1) was used to cultivate strawberry plants in 5-liter plastic pots.

In the experiment, vinasse, molasses, and vermicompost (liquid) were each employed at quantities of 2.5%, 5%, 7%, and 10% to see what effect they had on strawberry yield and fruit quality.

The control group plants were watered to simulate a no-treatment situation. Following planting, irrigation water was used to apply all organic compounds employed in the study once each in the months of June, July, August, and September.

To evaluate the effect that organic compound treatments had on fruit production, we assessed the yield per strawberry plant (in grams), the yield per decare (in kilograms), the number of fruits produced by each plant, and the average weight of each fruit. To get a more complete picture of the quality of the fruit, further measurements such as its color (L, C, and H), total acidity content (TAC), total soluble solids (TSS), and fruit juice pH were carried out (Arıkan et al. 2020; Ipek et al. 2014).

Five plants were used in each replicate across all three treatments in a fully random order (13 treatments, 5 replicates, and 5 plants for a total of 325 plants). One-way analysis of variance (ANOVA) was used to examine all of the data, and Duncan's multiple range test was used to compare the means of groups when there was a statistically significant difference at the P = 0.05 level in SPSS 23.0. (SAS Inc., Cary, NC, USA).

3. Results and Discussion

In 2022, the yield value and fruit quality criteria were observed. At a concentration of 2.5 %, treatment of the vinasse was found to have the highest possible production value per plant (332.98 g) and the highest possible yield per decare (1664.89 kg). The highest fruit counts were found in the treatment of the molasses (7.5 %) and, the treatment of the vinasse (2.5 %) with the former producing 22.50 fruits per plant and the latter 21.92 fruits per plant. It was discovered that the treatments with a vinasse concentration of 2.5 percent (15.20 g) and 5.0 percent (15.15 g) had a fruit weight that was greater than that of the other treatments (Table 1). Compost, humic acid, amino acid, vermicompost, and salicylic acid were found in early investigations of strawberry yield to improve yield per square meter, yield per plant, average fruit weight, fruit length, and fruit diameter (Aghaeifard et al. 2016; Arancon et al. 2003; Mohamed et al. 2011; Sayğı 2022). According to the findings of Anil K Singh et al. (2015) and Rajbir Singh et al. (2008), the utilization of vermicompost resulted in an increase in the overall production of strawberries, as well as an increase in the yield per decare, yield per plant, and a number of fruits produced per plant. Researchers found that by applying molasses at varying concentrations to the soil and plant leaves three times throughout the vegetative season, sugar beet root yield may be improved by 20% (Şanlı et al. 2015). Elderberries were studied, and it was shown that applying vermicompost at a rate of 1.5 kg da^{-1} over the course of three separate periods improved both the number of shoots by 5% and the stem diameter by 2.5% (Şakar 2019).

Total soluble solids (TSS) levels varied depending on the treatment. Between 13.86% and 15.94 %, the TSS fluctuated. The TSS value found for the 2.5 % molasses treatment (15.94 %). was the highest among the tested other treatments (Table 2). There was a wide variation in acidity levels, from 0.562% to 1.0588%. The greatest amount of TAC was found in the sample that had been treated with molasses at a concentration of 5.0 % (1.058 %) (Table 2). It was discovered that strawberries had higher levels of TSS and TAC when compost, humic acid, and amino acids were present (Mohamed et al. 2011). The use of vermicompost contributed to an increase in both the TSS and TAC content of strawberries (Sayğı 2022; Anil K Singh et al. 2015; Rajbir Singh et al. 2008).

Table 1. Effect of organic compounds on yield parameters

Treatments	Yield (Plant g^{-1})	Yield (Decare kg^{-1})	Number of Fruit per Plant	Average Fruit Weight (g)
Control	198.45 m	992.24 m	15.24 g	13.04 def
Molasses 2.5%	230.05 j	1150.26 j	17.31 de	13.30 cde
Molasses 5.0%	238.35 g	1191.77 g	17.45 de	13.67 c
Molasses 7.5%	305.42 b	1527.09 b	22.50 a	13.59 cd
Molasses 10.0%	281.01 c	1405.04 c	19.74 b	14.24 b
Vermicompost 2.5%	206.14 l	1030.70 l	16.28 f	12.67 fg
Vermicompost 5.0%	251.61 e	1258.06 e	18.39 c	13.71 c
Vermicompost 7.5%	246.05 f	1230.23 f	19.31 b	12.75 efg
Vermicompost 10.0%	224.84 k	1124.17 k	17.18 e	13.11 cdef
Vinasse 2.5%	332.98 a	1664.89 a	21.92 a	15.20 a
Vinasse 5.0%	273.64 d	1368.20 d	18.07 cd	15.15 a
Vinasse 7.5%	233.96 i	1169.83 i	19.20 b	12.19 g
Vinasse 10.0%	236.96 h	1184.81 h	17.53 de	13.52 cd

Table 2. Effect of organic compounds on fruit quality parameters

Treatments	TSS (%)	TAC (%)
Control	13.69 k	0.676 gh
Molasses 2.5%	15,94 a	0,726 ef
Molasses 5.0%	14,92 d	1,058 a
Molasses 7.5%	15,17 c	0,906 b
Molasses 10.0%	15,64 b	0,844 c
Vermicompost 2.5%	14,53 g	0,562 k
Vermicompost 5.0%	14,71 ef	0,692 fgh
Vermicompost 7.5%	14,77 e	0,746 e
Vermicompost 10.0%	14,66 f	0,598 jk
Vinasse 2.5%	13,86 j	0,626 ij
Vinasse 5.0%	14,13 i	0,712 efg
Vinasse 7.5%	14,30 h	0,792 d
Vinasse 10.0%	14,04 i	0,658 hi

The L, C, and H color values of the fruit harvested in treatments of the Albion cultivar were shown in Table 3. The L, C, and H levels of the fruits from each treatment were significantly different from one another. Only the treatment with molasses at a concentration of 2.5% was capable of producing the highest L, C, and H values. The values of L, C, and H that were determined to be the greatest were 40.27, 49.68, and 40.83, respectively (Table 3). Rajbir Singh et al. (2008) and Sayğı (2022) found that when vermicompost was used, the strawberry's L, C, and H levels all went up, which led to an overall increase.

Table 3. Effect of organic compounds on fruit color

Treatments	L	C	H
Control	27.62 k	35.06 m	26.68 m
Molasses 2.5%	40.27 a	49.68 a	40.83 a
Molasses 5.0%	36.37 d	44.53 d	35.21 d
Molasses 7.5%	37.44 c	45.39 c	36.57 c
Molasses 10.0%	38.64 b	46.88 b	37.73 b
Vermicompost 2.5%	30.72 j	37.28 l	28.40 l
Vermicompost 5.0%	33.00 h	40.43 i	31.11 i
Vermicompost 7.5%	32.35 i	39.63 j	30.34 j
Vermicompost 10.0%	31.55 j	38.70 k	29.58 k
Vinasse 2.5%	33.50 h	43.71 e	34.37 e
Vinasse 5.0%	35.41 e	41.14 h	31.85 h
Vinasse 7.5%	34.79 f	42.21 g	32.60 g
Vinasse 10.0%	34.08 g	42.99 f	33.52 f

4. Conclusions

The purpose of this study was to examine the impact of various organic preparations on the growth, yield values, and fruit quality features of strawberry plants. All the treatments with the organic compounds resulted in an improvement in yield as well as the quality criterion for fruit, in comparison to the control groups. Vinasse's application at a concentration of 2.5 % yielded superior results in terms of value, but a dose of molasses applied at a concentration of 2.5 % yielded the best results in terms of quality criterion for fruit. Molasses and vinasse are both beneficial additions that might be advised to strawberry farmers as part of their cultivation practices.

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The Effects of Growth Regulatory Agents in Varying doses on *Lavandula angustifolia* and *Lavandula × intermedia* Species in Different Rooting Media

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HIGHLIGHTS

- Rooting *Lavandula* species in different media.

Abstract

Lavender is a valuable ornamental and aromatic plant species with several applications, including food additives, cosmetics, perfumes, medicine, and aromatherapy, owing to its antimicrobial, antibacterial, antiviral, and antioxidant properties, as well as its pleasant odor. The purpose of this study was to determine the rooting capability of lavender species (*Lavandula angustifolia* and *Lavandula × intermedia*) in different media (peat, perlite, peat+perlite) and different doses of indole-3-butyric acid (IBA) (1000, 1500, and 2000 ppm) on cuttings. After 5 seconds in the (IBA) solution, the cuttings were planted in various rooting media in the greenhouse environment. The highest rooting rate, 93%, was obtained from 2000 ppm IBA application in peat+perlite (1:1) medium, whereas the lowest rooting rate, 13%, was obtained from *Lavandula angustifolia* species from control application in peat media. In a peat+perlite (1:1) medium with 1500 ppm, the longest root length was 13.16 cm. IBA application *Lavandula angustifolia* species, the lowest root length in *Lavandula × intermedia* cuttings were 2.7 cm from control application in perlite medium. *Lavandula × intermedia* cuttings in peat medium produced the best results in terms of root number (3.36 pcs/cuttings), while *Lavandula × intermedia* cuttings in perlite medium produced the lowest root number in the control application. In terms of viability rate, both species received high values, with the lowest viability rate obtained from the control application in perlite medium with 80% in *Lavandula angustifolia* species.

Keywords: Indol-3-butyric acid (IBA); *Lavandula angustifolia*; *Lavandula X intermedia*; Peat; Perlite; Rooting

1. Introduction

Plants are extremely important in nutrition. Medicinal and fragrant plants have been utilized since the dawn of time for a variety of purposes including food, medicine, cosmetics, and spices. Essential oils derived from medicinal and aromatic plants are in great demand due to their antioxidant, antidepressant, antiseptic, antibacterial, analgesic, anti-inflammatory, antifungal, antispasmodic, and sedative characteristics, as well as their relaxing effects (Bousta and Farah 2020). Furthermore, medicinal, and aromatic plants have very powerful organic plant chemicals that, due to the scent molecules they contain, purify the surroundings of illnesses, bacteria, and fungi (Dapkevicius et al. 1998; Klaochanpong et al. 2015; Schippmann et al. 2006). It is

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known that the essential oil and aroma molecules in the lavender plant protect it from many kinds of bacteria. It is used to make medicines for headaches and to boost the immune system. It is also used in the pharmaceutical industry to give some medicines a smell and taste (Hay et al. 1998; Nikolaevskiĭ et al. 1990; Romine et al. 1999).

Lavender (*Lavandula angustifolia* Mill.), and lavender (*Lavandula* × *intermedia* Emeric ex Loisel.) a fragrant herb, has been used since antiquity for both medicinal and essential oil purposes (Jianu et al. 2013; Upson and Andrews 2004). Lavender includes anthocyanins, phytosterols, sugars, minerals, coumaric acid, glycolic acid, valeric acid and its esters, ursolic acid, heparin, coumarin, and tannins in addition to essential oils. In addition, lavender flowers are gathered and utilized in the dried flower industry, and in recent years, they have also been used as bouquet flowers. Lavender is a plant that can yield even in poor soil conditions, has the almost minimal disease and harmful factors in its agriculture, and requires less effort in terms of labor (Anonymous, 2020). The genus *Lavandula* contains 39 wild species (Arabaci et al. 2007). In Turkey, there are two prevalent species of lavender (*L.* × *intermedia* and *L. angustifolia*) (Korkunc 2018).

Today, it is grown in large amounts in Southern Europe, Australia, the USA, French and Bulgaria (Karakas and Scout 2021). According to 2021 statistics, our country produces 6.108 tons of lavender on an area of 35.386 decares. Isparta (1.436 tons) accounts for 23% of total output. This is followed by the provinces of Afyonkarahisar (1.110 tons), Antalya (438 tons), Ankara (403 tons), Denizli (349 tons), and Burdur (320 tons) (Tuik, 2022). Lavender has been traded for the last 40 years in the Lakes Region, where lavender cultivation is intense, and in this process, it has provided an important cultural and agricultural benefit and an additional source of income to the existing rose oil industry. In the region, lavender oil is produced on a small, medium, and large scale. In recent years, due to the interest in lavender flowers and lavender oil, it has become the product of choice for many producers (Anonymous, 2020).

Lavender is a semi-shrub and perennial herb in the *Lamiaceae* family. The lavender plant, which is commonly used for decorative and landscaping purposes, grows to a height of 40-60 cm. The lowest portion of the stem is woody, while the upper portion is green with lance-shaped leaves. Lavender flowers grow on spikes organized in circles at the top of the stalk (3-5 flowers per circle). Although white-flowered (Alba and Nana Alba) and pink-flowered (Rosea) cultivars have been developed, they are pale violet (Góra et al. 2005). The lavender plant can be propagated both vegetatively and generatively. Because the foreign-pollinated lavender plant will exhibit genetic expansion, it can be reproduced vegetatively for seedling production also, the seed germination rate is very low. Certain lavender species can only be propagated through seeds, while others can be grown through shoot cuttings vegetatively, and some lavender species and variants can be propagated more readily and swiftly using both methods. Some research on rooting in lavender cuttings has revealed that there are variances in the type of cuttings taken and the varied rooting media utilized to eliminate these difficulties (Bona et al. 2012).

Many experiments have been conducted to improve rooting, root length, and root number percentages in various rooting media and IBA concentrations, however, it is well-recognized that these studies are quite restricted to lavender. As a result, the goal of this study is to assess the rooting capability of cuttings of high-value *Lavandula* species (*Lavandula angustifolia* and *Lavandula* × *intermedia*) in different habitats (peat, perlite, and peat+perlite) and IBA concentrations (0, 1000, 1500 and 2000 ppm).

2. Materials and Methods

This study was carried out in the Research and Application Greenhouse of the Department of Horticulture, Faculty of Agriculture, Selcuk University, between the years 2021-2022. The lavender species *Lavandula angustifolia* and *Lavandula* × *intermedia* were employed in the experiment. *Lavandula angustifolia* and *Lavandula* × *intermedia* species were cut into 15-20 cm long cuttings. To reduce water loss in the cuttings, all the leaves

were cleaned so that 2-3 leaves remained on each cutting and the cuttings obtained from these varieties; practice, in the form of sheaves of cutting, 1-2 cm of the bottom parts were dipped in IBA solution (control, 1000 ppm, 1500 ppm, and 2000 ppm) for five seconds and we waited for the alcohol to release for a short period.

The cuttings were then planted in peat, perlite, and peat+perlite media in three replications, with 15 plants in each replication, using a randomized plot design. To prevent water loss in cuttings, the leaves that grew during the development stage were harvested. Bordeaux slurry was used to prevent the growth of fungal diseases caused by excessive moisture. The viability and rooting rates (%), average root number (pcs/cuttings), and root length (cm) of cuttings were determined in this study. The Duncan's multiple range test (DMTR) was Duncan's multiple range test (DMTR) was used to compare mean values at $p < 0.05$ by SPSS 23.0 software.

3. Results

The effects of various rooting media and IBA doses on rooting and several parameters of cuttings of two lavender species were studied in this study (Table 1-2). The effects of different rooting mediums and IBA doses on the rooting rate of cuttings of *Lavandula angustifolia* species are shown in Table 1, and the effects of *Lavandula* × *intermedia* on the viability rate, average root length, average root number, and rooting rate are shown in Table 2. Vitality levels: In both species, the effects of hormone doses and varied rooting media were statistically significant ($p<0.01$). The maximum viability rate (100%) was obtained in *Lavandula angustifolia* species from peat and perlite rooting media and 1000 to 1500 ppm IBA doses. Cuttings administered at 1500 and 2000 ppm in perlite media and 2000 ppm IBA in peat+perlite (1:1) media resulted in the maximum survival rate (100%) in *Lavandula* × *intermedia* species.

The effects of hormone doses and different rooting media on the root length of both species' cuttings were statistically significant ($p<0.01$). When hormone doses were tested, the peat/perlite (1:1) media produced the longest root length (13.16 cm). The control (3 cm) application in perlite media yielded the shortest root length. The longest root length (9.6 cm) was observed in *Lavandula* × *intermedia* species at 1500 ppm IBA dose from perlite media. The control application in perlite media yielded the shortest root length (2.7 cm). Among the species, peat+perlite (1:1) media (13.16 cm) and 1500 ppm IBA dosage produced the best root length findings. When the effects of three different rooting media on some rooting parameters of *Lavandula angustifolia* cultivars (Hemus, Sevtopolis and Drujba) and Super A cultivars of *Lavandula* × *intermedia*, with the lowest root length of 2.34 cm, was obtained from *Lavandula angustifolia* Hemus cultivar in soil (Karakas and Izci 2021). In a study on various aromatic plants, root lengths of 18.89 cm for oil rose, 14.32 cm for berberis, 25.58 cm for rosemary, and 17.26 cm for lavender were obtained in perlite rooting media and treatments of 4000 and 5000 ppm IBA doses, respectively. Perlite medium as a rooting medium has been reported to produce the greatest results (İzgi 2020).

When the root count values in *Lavandula* species were examined, the effect of IBA applications and different rooting media was statistically significantly affected in peat+perlite (1:1) media ($p<0.01$). It was statistically significantly affected in terms of root numbers in peat and perlite media ($p<0.05$). The best root count results were obtained in 2000 ppm IBA application with *Lavandula angustifolia* (3 pcs/cutting) and *Lavandula* × *intermedia* (3.36 pcs/cutting) in peat media the best root number was determined. *Lavandula* × *intermedia* was obtained in peat+perlite (1:1) media (2.5 pcs/cutting). Furthermore, the greatest results in *Lavandula angustifolia* species were achieved in 1500 IBA treatments (2.7 pcs/cutting) in perlite medium and both 1500 (2.76 pcs/cutting) and 2000 (2.46 pcs/cutting) ppm IBA applications in peat+perlite media. The lowest root numbers were found in *Lavandula angustifolia* perlite media (pcs/cutting) and *Lavandula* × *intermedia* peat+perlite media (1.5 pcs/cutting) from 1000 ppm IBA applications.

Table 1 The effect of different rooting media and IBA doses on the rooting of *Lavandula angustifolia* cuttings

IBA (ppm)	Rooting medium		
	Peat	**Perlite**	**Peat+Perlite**
Vitality Rate (%)			
0	83.0 e	80.0 e	90.1 c
1000	100.0 a	100.0 a	90.0 c
1500	100.0 a	100.0 a	95.2 c
2000	97.0 b	95.5 c	100.0 a
Average Root length (cm)			
0	3.50 c	3.0 e	4.83 d
1000	5.50 c	7.8 cd	8.90 c
1500	6.23 bc	9.4 a	13.16 a
2000	6.70 b	8.3 bc	9.50 c
Average Root number (pcs/cutting)			
0	3.0 A	2.0 BC	1.70 b
1000	2.5 AB	1.7 C	2.03 b
1500	2.4 AB	2.7 A	2.76 a
2000	3.0 A	2.2 ABC	2.46 a
Rooting Rate (%)			
0	13.00 e	20.0 f	47.0 d
1000	41.00 c	47.2 d	40.1 d
1500	33.50 b	47.0 d	40.0 d
2000	27.13 c	33.5 e	93.0 a

A, B P <0.05; a,b P<0.01. There is no difference between the averages indicated with the same letter. (p<0.05)

The influence of rooting material on the rooting rate is statistically significant (p<0.01) in terms of *Lavandula angustifolia* rooting rate. The perlite+peat (1:1) 2000 ppm IBA application resulted in the highest rooting rate of 93%, while in the peat, control application resulted in the lowest rooting rate of 13%. *Lavandula × intermedia* had the highest rooting rate in perlite media (80.1%), followed by control (27.06) and 1000 ppm (27.04) IBA in perlite (33.5%) and peat+perlite (1:1) media. The applications in peat medium yielded the lowest rooting rates. One study found that *L. angustifolia* var. Silver the number of roots, root length, and rooting rate of Silver variety cuttings were determined to be different, and the best rooting rate (95.13%) was determined at a 4000 ppm IBA dose (Kara and Baydar 2011). When lavender and rosemary cuttings were compared to control cuttings in terms of rooting rate, all of the cuttings (100%) were rooted at 6000 ppm, 2000, and 4000 ppm IBA doses in rosemary stem cuttings. The maximum rooting rate (98.33%) was seen in 2000 and 4000 ppm IBA treatments (Arslanoğlu and Albayrak 2011). In one study, the highest rooting rate was achieved from the *Lavandula × intermedia* Super A cultivar in cocopeat media (62%), whereas the lowest rooting rate was obtained from the *Lavandula angustifolia* Sevtopolis and Drujba cultivars in soil (60%). (Karakas and Izgi 2021). Izgi (2020), in the research that different media and in the study in which the effects of different IBA doses on some rooting parameters were investigated, the cuttings were treated with IBA Control-0, 1000, 2000, 3000, 4000 and 5000 ppm doses and then planted in peat, perlite, peat and perlite mixture (1:1) and cocopeat media. Rooting rates were 95.00% for oil rose, 81.67% for berberis, 88.33% for rosemary and 82.50% for lavender.

In terms of quality rooting and root cutting rate, different IBA doses can be used in rooting studies of lavender plants. Three different rooting media were used, including perlite, peat, and field soil, as well as 500, 1000, 2000, and 4000 ppm IBA doses on lavender (*Lavandula hybrida*) cuttings. Although there was no

significant difference in rooting rate between the media and the doses, 2000 and 4000 ppm IBA doses and commercial rooting rates in lavender were seen when compared to the control cuttings. The majority of the cuttings (76.25%, 87.50%, and 83.75%, respectively) were rooted in the rooting powders, according to the results.

Table 2 The effect of different rooting media and IBA doses on the rooting of *Lavandula × intermedia* cuttings

	Rooting medium		
IBA (ppm)	**Peat**	**Perlite**	**Peat +Perlite**
	Vitality Rate (%)		
0	87.0 d	90.5 d	87.1 d
1000	93.0 c	97.7 b	87.1 d
1500	93.3 c	100.0 a	90.0 b
2000	97.3 b	100.0 a	100.0 a
	Average Root length (cm)		
0	7.30 d	2.7 e	5.33 d
1000	9.00 ab	4.9 d	9.33 c
1500	8.43 bc	9.6 a	11.60 b
2000	8.20 c	7.3 b	11.30 b
	Average Root number (pcs/cutting)		
0	2.0 B	1.63 C	2.03 b
1000	2.0 B	2.13 ABC	1.50 c
1500	2.5 AB	2.00 BC	2.00 b
2000	3.4 A	2.53 AB	2.50 a
	Rooting Rate (%)		
0	20.00 d	33.5 e	27.06 e
1000	27.03 c	60.0 c	27.04 e
1500	27.30 c	73.3 b	40.33 d
2000	40.20 d	80.1 a	54.00 b

A,B P <0.05; a,b P<0.01. There is no difference between the averages indicated with the same letter. (p<0.05).

IBA doses were found to enhance rooting, with the maximum rooting (70%) attained with a 4000 ppm IBA treatment (Özcan et al. 2013). In their study titled determination of the appropriate cutting type and IBA dose for cuttings in lavender (*Lavandula angustifolia* Mill.), they obtained a rooting rate of 34.17%-56.67%, the highest rooting rate from 8000ppm IBA dose, and the lowest rooting rate in the control group reported that they obtained (Çiçek and Abdulhabip 2017).

When applied to cuttings of rosemary and sage, commercial preparations containing IBA promoted healthy root formation, the researchers found. Rosemary seedlings grew by a total of 22.68% in length, 18.95% in root length, 21.74% in fresh seedling weight, and 10.29% in dry seedling weight. Sage growth rates outpaced rosemary rates. The findings from experiments including rosemary corroborate our own (Parađiković et al. 2013).

4. Discussion

Based on the results of studies conducted with *Lavandula stoechas* (Ayanoğlu et al. 2000), *Lavandula officinalis* (Bhat et al. 2008; Kumar and Sreeja 1996), L. *Salvia indica* L. (Ayanoğlu et al. 2002), *Salvia officinalis* L. (Arslan

et al. 1995; Ayanoğlu and Özkan 2000; Nicola et al. 2003), *Sideritis ssp.* (Gümüşçü and Gümüşçü 2014), *Origanum onites*, (Sarıhan et al. 2003), *Thymus ssp*. (*T. capitatus, T. serpyllum, T. vulgaris* (Lapichino et al. 2006), *T. satureioides*, (Karimi et al. 2014), *Origanum vulgare* L., *Mentha piperita* L. and *Melissa officinalis* (Kuris et al. 1980) plant cuttings, it was determined that IBA applications improved the rooting rate and rooting related features compared to control applications, and that different doses had an effect, although this varied with the species. These broad conclusions corroborate the information we gathered during our study.

Previous research on different IBA doses and rooting media of plant cuttings in several lavender species, as well as the values obtained from lavender cuttings in this study, reveal that rooting values in parallel increase with increasing IBA doses (up to a maximum of 4000 ppm). All factors tested among the species differed according to the different habitats used. Lavender, which has been attempted to be produced primarily in small regions, has increased interest in lavender agriculture in recent years because of its increasing economic relevance.

5. Conclusions

One of the most significant constraints to the production of the lavender plant, which is not native to our nation but stands out in terms of essential oil quality, is a lack of saplings. Lavender sapling production from seed is not recommended because of germination problems and genetic expression. For this reason, sapling production is made by cutting, which is one of the vegetative propagation methods. However, the low rooting rate is one of the most important problems in the propagation of lavender by cuttings. In our study, we aimed to determine the effects of different doses of growth regulators on the rooting of *L. angustifola* and *L.* × *intermedia* cuttings in different media. According to these data, the best rooting parameters for *L. angustifolia* species were peat+perlite medium and 2000 ppm IBA dose, whereas the best rooting parameters for *L.* × *intermedia* species were perlite medium and 2000 ppm IBA dose.

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An Investigation on the Relationship Between Mineral Nutrition of Lemon and Rumple

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HIGHLIGHTS

- Fruit development stages are extremely important for Lemon and Rumple.
- The nutrient content of the fruit rind is also highly important for Lemon and Rumple.

Abstract

This study investigated the relationship between Rumple and tree crown parts regarding direction, fruit development stages and fruit rind nutrient content. A Lemon orchard on which Rumple disorders have shown severely were chosen among Erdemli and Silifke region where the majority of grown lemon cultivar is Kütdiken. In this orchard, from healthy and contaminated trees samples were taken from the South and West half parts of crown and the North and East parts of the crown separately. Also, fruit samples were taken at four fruit development stages which were hazelnut-sized fruit, end of fruit enlargement, the beginning of maturation and fully mature fruit stages. The rind of samples fruit was analyzed, and their content of N, P, K, Ca, Mg, S, Mn, Fe, Zn, B, Cl and Na was determined. PCA was used to analyze these data. Biplot scheme of the 2nd Sampling from the part one-half of the trees which includes the South and West directions, that is, from the Healthy (G2S) and Rumple signed trees (G2B) taken were examined. The increase in K, Zn, Fe, Ca, and Mg is associated with Na, P and Cl concentration reduction. Besides this, in this period, it was observed that fruit rind has higher N, S, Mn and B content which were taken from part one, that is, the South and West sides, of healthy plants. The relationship identified here is important because Rumple's symptoms become visible after this stage.

Keywords: Lemon, Citrus, Rumple, Mineral Nutrition

1. Introduction

This rind disorders damage the external layer of lemon fruit. It is given different names in different countries and by different researchers. For example, Russo and Klotz (1963) called "Wrinkle Rind", Knorr (1963) called "Rumple", Salerno (1963) called "Raggrinzimento Della Buccia", Özbek et al. (1974) Çöküntü, Benek and Çopur. Rumple does not affect fruit flesh and juice, but it causes fruit to lose its market quality and value. Rumple was described first in Florida in 1956 by Knorr (1958). Later, it is detected by Russo and Klotz (1963), by Salerno et al. (1968) in Italy, Florida, Korsika and Cyprus. Moreover, it is detected by Chapot and Bahcecioglu(1969) and by Chapot (1971) in Turkiye, Cyprus, Lebanon and Ethiopia, respectively. Chapot ve Bahçecioğlu (1969) reported that Rumple was found in Antalya, Mersin Adana and Hatay (Arsuz) in the years 1960-1961.

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Rumple damage rate has shown differences according to years and region. Knorr (1963) 10-14%, Salerno (1965) 30%, Knorr and Koo (1969) 38% have reported damages rates. Besides these, some extremely high damage rates, like 77% in Florida, 75% in Turkiye have been detected (Knorr 1963; Knorr and Koo1969; Chapot and Bahçecioğlu 1969; Chapot 1971; Klotz et al. 1972). In Spain, in Murcia and Alicante, citrus-grown regions, Rumple affected to Primofiori and Fino's lemon cultivar-grown orchards, where the damage rate was 20-80% (Pinilla 1991).

Rumple damage resembles *Oleocellosis* on fruit rinds. Fat sacs maintain their normal shape, but the surrounding tissues lose their normal appearance (Knorr 1963). The first symptoms of the collapse began in the early period when the color of the fruits begins to change. The change in lemon peel manifests itself as a slight color change. Subsequently, the affected areas gradually spread unevenly and increase in size. Gradually, their color starts from dark green on a yellow background darkens to chestnut-brown and finally turns into a dark brown-black color. Parallel to these macroscopic changes, essential oil glands undergo a series of similar discolorations and eventually collapse. The factors causing the collapse and the occurrence of damage to the fruits were investigated with numerous field trials, but no reliable results could be obtained.

The first scientific studies were carried out in Florida in 1958, on its relationship with genetic structure. (Knorr 1958,1963; Knorr and Koo 1969). The relationship of fungi, bacteria, aphids, worms, and pesticides with the sediment was investigated and negative results were obtained (Knorr 1963; Salerno et al. 1968; Knoor and Koo 1969). It was investigated assuming that it could be associated with virus disease or citrus petrification disease and negative results were obtained (Knorr 1963; Chapot and Bahçecioğlu 1969; Knorr and Koo 1969; Chapot 1971). Studies on the relationship between Rumple and water balance and irrigation were initially promising, but later satisfactory findings could not be obtained (Russo and Klotz 1963; Salerno 1968, 1965; Scaramuzzi 1965; Knorr 1965, 1966, 1967; Salerno and Continella 1967; Salerno et al. 1968; Knorr and Koo 1969). Knorr (1965), Knorr and Koo (1969). Considering that the collapse is a physiological disorder, they applied GA3 and anti-transpirant applications to prevent cracking and splitting of the bark and to preserve the fruits on the tree, but the results were not as they expected. Mechanical effects were also investigated, and reliable results could not be obtained (Knorr et al. 1963; Knorr and Oberbacher 1964; Knorr and Koo 1969).

Turkey produces around 1,188 thousand tons of lemon (TUIK 2020). The amount of production is more than 1.8 times the consumption of our country. In other words, the consumption of lemon should be increased, expanded, spread throughout the year, and more importantly, some of it should be exported. In addition, since lemon production is concentrated in certain months of the year, it is necessary to increase the supply time to the market and to store it to meet the demand of the market. In addition, to ensure price stability, it is necessary to supply enough products to the market regularly and stably. This is only possible if the product is of storable quality and can be stored. Kütdiken is the most widely grown lemon variety in our region due to its superior quality and long-term storage properties. Unfortunately, in our region, Kütdiken is the lemon variety that was the most affected by Rumple and the market value of the fruit in fresh consumption completely be destroyed too. This study investigated the relationship between Rumple and tree crown parts regarding direction, fruit development stages and fruit rind nutrient content.

2. Materials and Methods

As a result of the literature review and interviews with experienced producers, the gardens in Erdemli and Silifke districts of Mersin, where almost all the Kütdiken Limon variety is grown, have been scanned. A garden was selected on the eastern bank of the Göksu River, 600 m away from the river, in the Göksu Delta of the Silifke district, which was believed to have the most intense Rumple. As a result of the information received from the producer and depend in on observation, 6 infected lemon trees showed collapse in their fruits and 3 healthy lemon trees were selected and marked.

The tree crown is divided into two parts with a line length from northwestern to southeastern regarding sunlight exposure. Part, one included the east and west directions, and part two included the north and east direction. This was done to determine the direct effect on Rumple. (Figure.1)

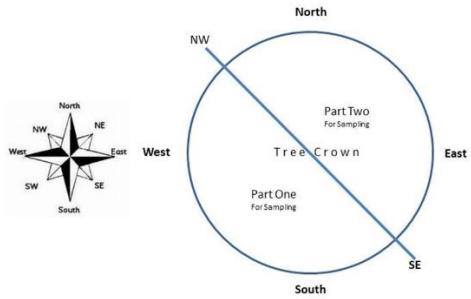

Figure 1. Tree Crown

In 2018 and 2019 years, fruit samples were taken from crown parts, at four fruit development stages which were hazelnut-sized fruit (1. Sampling stage), end of fruit enlargement (2. Sampling stage), the beginning of maturation (3. Sampling stage) and fully mature fruit stages (4. Sampling stage).

The fruit skins of the samples taken were peeled, dried, and prepared for analysis. The total N contents of the samples were determined by the Kjeldahl method. (Macz et al. 2001). To determine the P, K, Ca, Mg, S, Mn, Fe, Zn, B, Cl and Na amounts, the ground plant samples were burned in nitric acid: perchloric acid (HNO3:HClO4) (4:1) mixture, the final volume was made up to 100 ml with bi-distilled water, and the readings were made in ICP-OES (Hong et al., 2019).

3. Results and Discussion

As a result of the evaluation of these samples collected at the Gevne Valley (Alanya- Hadim-Taşkent) in 2019-2020, 11 species were identified belonging to the genera: *Adoxomyia*, *Pycnomalla* (Clitellariinae), *Lasiopa* (Nemotelinae), *Chloromyia* (Sarginae) and *Oxycera*, *Oplodontha* and *Stratiomys* (Stratiomyinae). The list with all specimens and species found is presented below.

The parameters obtained from the samples taken at different growth and maturation periods of lemon were subjected to Principal Components Analysis (PCA) (Tablo 1). As a result of PCA, the study was explained as high as 86.6% in two components. Studies reported that the first two components must be explained in more than 25% of the study to use the PC analysis (Mohammadi and Prasanna 2003; Mozafari et al. 2019; Seymen et al. 2019). It is obvious that a strong explanation of PCA will yield important results regarding the usability of this analysis and the parameters looked at.

As a result of PCA, the first component (PC1) explained a very high rate of study at 75.7%. N, K, Ca, Mg, S, Mn, Fe, Zn and B parameters were explained high in the positive direction, while Cl, P and Na were the parameters explained in the negative direction.

The second component (PC2), on the other hand, explained 10.9% of the study. And parameters such as N, P, S, Mn, B and Cl were explained high in the positive direction and Zn was the parameter that was explained high in the negative direction. Especially Cl showed a very high positive value.

Table 1. PC1 and PC2 eigenvalues and eigenvectors

Components	**PC1**	**PC2**
Eigenvalue	9.0873	1.306
Varyans Ratio	75.727	10.883
Total Varyans	75.727	86.611
Eigenvectors		
N	0.28712	034319
P	-0.31312	0.21631
K	0.31365	-0.02166
Ca	0.31678	-0.09476
Mg	0.30604	0.00224
S	0.29132	0.33707
Mn	0.29538	0.30693
Fe	0.31042	-0.1061
Zn	0.27018	-0.29875
B	0.27054	0.34605
Cl	-0.19913	0.61154
Na	-0.26983	0.15464

Principal Components (PC): Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg), Sulfur (S), Manganese (Mn), Iron (Fe), Zinc (Zn), Boron (B), Chlorine (Cl), Sodium (Na)

Using PC1 and PC2 components, a Loading Plot Chart was created to examine the relationship between the nutrient content of fruit samples taken from different sides of the crown of healthy and infected trees at different developmental stages (Figure 1). It has been reported that if the angle between the vectors in the figure is <90°, there is a positive relationship, if it is >90°, there is a negative relationship, and if the angle between the vectors is 90°, there is no significant relationship (Yan and Kang 2003). When the figure is examined, it is seen that there is a high positive correlation between the fruit peel nutritional elements content parameters (N, K, Ca, Mg, S, Mn, Fe, Zn and B) explained in PC1. (Cl, P and Na) elements, on the other hand, showed a positive relationship with each other in a negative direction. The element group (Cl, P and Na) exhibited a highly negative relationship compared to the element group (N, K, Ca, Mg, S, Mn, Fe, Zn and B). The first signs of collapse disorder generally begin to appear at the beginning of ripening (3rd sampling period). In this respect, it can be said that at the end of fruit enlargement, which is the second sampling period, the mineral content of the fruit peel is very important in the emergence of Rumple. Therefore, it has been evaluated that Principal Components Analysis (PCA) can provide important information in the 2nd sampling period. According to PCI, in the 2nd sampling period, it was determined that the changes in the K, Mg, Ca and Fe contents of the fruits taken from part one and part two with Rumple and the trees without Rumple were different. While the contents of K, Mg, Ca, and Fe were higher in the peels of fruits taken from part two in the 2nd sampling period from healthy trees compared to those taken from Part one. These elements were found to be higher in the peels of the fruits taken from part one of the infected trees than those taken from part two. In addition, the contents of K, Mg, Ca, and Fe in the fruits taken from part one of the trees with Rumple were higher than those of the fruits taken from part one of the trees without Rumple. Again, in this period, it was determined that the N, S, Mn, and B elements were higher in the peel of the fruit samples taken from part one of the trees that did not show any Rumple symptoms. In addition, in the 2nd sampling period, it was determined that the peels of the fruits taken from part one of the trees without Rumple had higher P content than both the peels of the fruits from part two of the trees without Rumple and the peels of the fruits taken from the part one and part two of the trees with Rumple.

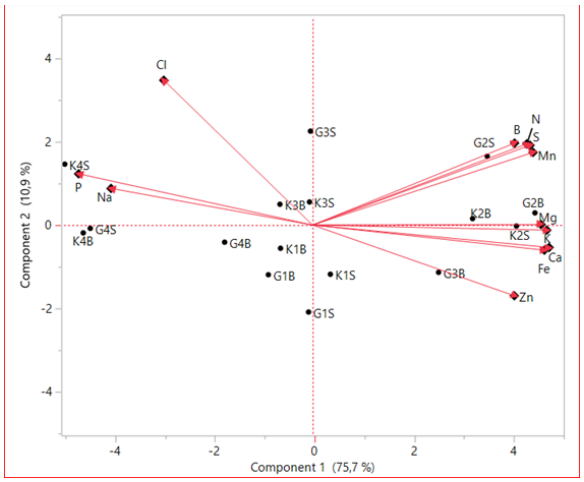

Figure 2. Biplot graph

Abbreviations K1S: First sample from part two, healthy trees, K1B: First sample from part two, infected trees, K2S: Second sample from part two, healthy trees, K2B: Second sample from part two, infected trees, K3S: Third sample from part two, healthy trees, K3B: Third sample from part two, infected trees, K4S: Fourth sample from part two, healthy trees, K4B: Fourth sample from part two, infected trees, G1S: First sample from part one, healthy trees, G1B: First sample from part one, infected trees, G2S: Second sample from part one, healthy trees, G2B: Second sample from part one, infected trees, G3S: Third sample from part one, healthy trees, G3B: Third sample from part one, infected trees, G4S: Fourth sample from part one, healthy trees, G4B: Fourth sample from part one, infected trees

4. Conclusions

When the figure drawn by the biplot method is examined (Figure 2). An increase in the concentrations of N, S, Mn and B elements in the fruit peel and a decrease in the concentrations of Na and P elements were observed in the sample taken from part one of the G2S tree at the end of the fruit enlargement period. Biplot also shows that the K2B, G2B and K2S samples are associated with the increase in Mg, Ca, Fe and Zn concentrations, and has negative relation with the decrease in the concentrations of Cl, Na and P elements. The relationship identified here is important. Because the Rumple symptoms seen on the peel of the fruits become visible symptoms for the first time after this stage. Biplot also showed the differentiation of healthy and defective fruits at the beginning of the maturation period of fruits, in part one of the tree crown (G3S and G3B). Comparing G3S and G3B, it was seen that G3B was associated with an increase in Zn, Fe, Ca and Mg and a decrease in Na, P and Cl concentration. According to the findings, it can be thought that the differences and irregularities in the distribution of minerals such as K, Mg, Ca, and Fe in the tree are effective factors in the formation of Rumple. We believe that promising results can be obtained if new studies are conducted on the negative correlations observed in the concentrations of K, Fe, Ca and Mg groups and Na, P and Cl groups occurring before the beginning of maturation in fruits with Rumple in part one.

In addition, it would be helpful to determine and correlate the mineral content of the leaf and the mineral content in the fruit peel to make a healthier evaluation.

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Stratiomyidae (Diptera) Fauna and Zoogeographic Evaluation of Gevne Valley (Konya-Hadim) in Turkey

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HIGHLIGHTS

- Stratiomyidae fauna have been determined in the Gevne Valley (Konya, Hadim-Taşkent), Turkey.
- 11 species from the family Stratiomyidae were identified.
- *Stratiomys ruficornis* (Macquart, 1838) is recorded for the first time from the Gevne Valley.
- The Gevne Valley was evaluated from a zoogeographical point of view.

Abstract

This study presents the fauna of Stratiomyidae from the Gevne Valley (Konya, Hadim-Taşkent), Turkey, collected between 2019-2020. *Chloromyia speciosa* (Macquart, 1834), *Oplodontha viridula* (Fabricius, 1775), *Oxycera meigenii* Staeger, 1844, *Oxycera quadrilineata* Üstüner and Hasbenli, 2007, *Pycnomalla splendens* (Fabricius, 1787), *Stratiomys cenisia* Meigen, 1822, *Stratiomys chamaeleon* (Linnaeus, 1758) and *Stratiomys ruficornis* (Macquart, 1838) are recorded for the first time from the Gevne Valley. The distribution of the species in the Palaearctic Region is discussed. Photographs of all species are presented.

Keywords: Gevne Valley, Stratiomyidae, Fauna, Zoogeography, Distribution, Türkiye

1. Introduction

The Gevne Valley is in the transition zone of the Mediterranean Region and Central Anatolia Region, within the borders of Alanya-Hadim districts. The Gevne Valley, which is within the scope of Important Natural Areas (KBA) criteria, contains Juniper communities, maquis and pioneer scrub communities, riverside plant communities, rocky plant communities, black pine (*Pinus nigra* ssp. *pallasiana*), red pine (*Pinus brutia*) and Taurus fir (*Abies cilicica* ssp. *isaurica*) forests, deciduous and mixed coniferous consists of forests, high alpine meadows, steppes and agricultural lands.

Stratiomyidae is a medium- to large-sized fly family, with around 2,800 species in the world and around 450 in the Palearctic Region (Woodley 2001). So far, 71 species belonging to 18 genera in seven subfamilies have been identified from Turkey. Until now, only five species (*Adoxomyia aureovittata* (Bigot 1879), *A. begreliensis* (Üstüner 2012), *A. cinerascens* (Loew 1873), *A. palaestinensis* (Lindner 1937), *A. sarudnyi* (Pleske 1903)) known from the Gevne Valley (Üstüner and Hasbenli 2011; Üstüner 2012). Until today, a detailed

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faunistic study of the family has not been conducted in Gevne Valley. In addition, the fact that it is in the transition zone between the Mediterranean climate and the continental climate, it acts as a refugium (shelter), which makes the valley very interesting in terms of biological diversity.

2. Materials and Methods

A total of 53 stratiomyids, 21 males and 32 females, were collected from Gevne Valley between the years of 2019 and 2020 (Fig.1). Stratiomyide specimens were captured with an entomological net, then sacrificed in jars containing ethyl acetate and pinned. Their diagnosis was made based on relevant literature. Photographs of each species were taken. The material is now housed at the Selçuk University, Faculty of Science, Department of Biology.

Figure 1. Different habitats in the Gevne Valley

3. Results

As a result of the evaluation of these samples collected at the Gevne Valley (Alanya- Hadim-Taşkent) in 2019-2020, 11 species were identified belonging to the genera: *Adoxomyia*, *Pycnomalla* (Clitellariinae), *Lasiopa* (Nemotelinae), *Chloromyia* (Sarginae) and *Oxycera*, *Oplodontha* and *Stratiomys* (Stratiomyinae). The list with all specimens and species found is presented below.

This section may be divided into subheadings. It should provide a concise and precise description of the experimental results, their interpretation, as well as the experimental conclusions that can be drawn.

3.1.1. Stratiomyidae

3.1.1. Clitellariinae

3.1.1.1. Adoxomyia Kertész, 1907

3.1.1.1.1. Adoxomyia aureovittata (Bigot 1879)

Material Examined: Turkey: 1 ♂, Konya, Hadim, Beyreli Village, Gevne Valley, elev. 1450 m, 19.V 2019 (Fig.2.1; Fig.3.15).

Distribution in Turkey: Konya (Hadim and Taskent districts) (Üstüner and Hasbenli 2011).

General Distribution: Palearctic Region: Greece, Turkey (Alexiou et al. 2020; Üstüner and Hasbenli 2011).

3.1.1.1.2. Adoxomyia obscuripennis (Loew 1873)

Material Examined: Turkey: 1♂, 1♀, Konya, Hadim, Beyreli Village, Gevne Valley, elev. 1450 m, elev. 20.VI 2019 (Fig.2.2,3; Fig.3.16,17).

Distribution in Turkey: Konya-Hadim district (Üstüner and Hasbenli 2011).

General Distribution: Palearctic Region: Kazakhstan, Russia, Tajikistan, Turkey, Uzbekistan (Kertész 1908; Kertész 1923; Pleske 1925a; Lindner 1938; Rozkošný 1983; Nartshuk 1988; Rozkošný and Nartshuk 1988; Üstüner and Hasbenli 2011; Woodley 2001).

3.1.1.2. Pycnomalla Gerstaecker, 1857

3.1.1.2.1. Pycnomalla splendens (Fabricius, 1787)

Material Examined: Turkey: 1♂, Konya, Hadim, Beyreli Village, Gevne Valley, elev. 1450 m, 06.VI 2020 (Fig.2.4; Fig.3.18).

Distribution in Turkey: Adana, Bitlis, Erzurum, Karaman, Kars, (Kemal and Koçak 2013; Demirözer et al. 2017; Üstüner et al. 2002).

General Distribution: Palearctic Region: Algeria, Armenia, Morocco, Israel, Portugal, Spain, Tunisia, Turkey (Kertesz 1908; Pleske 1925a; Séguy 1926; Lindner 1931, Lindner, 1938; Lindner 1974; Rozkošný 1983; Rozkošný and Nartshuk 1988; Woodley 2001; Üstüner et al. 2002).

3.1.2. Sarginae

3.1.2.1. Chloromyia Duncan, 1837

3.1.2.1.1. Chloromyia speciosa (Macquart, 1834)

Material Examined: Turkey: 2♀♀, Konya, Hadim, Beyreli Village, Gevne valley, elev. 1450 m, 02.VII 2019. 1♀, Konya, Hadim, Beyreli Village, Gevne Valley, elev. 1450 m, 08.VI 2020 (Fig.2.5; Fig.3.19).

Distribution in Turkey: Artvin, Bursa, Erzurum, Hatay, Ordu, Rize (Demirel and Üstüner 2019; Demirözer et al. 2017; Rozkošný 1982; Hurkmans et al. 1997).

General Distribution: Palearctic Region: Algeria, Austria, England, Bulgaria, Czech Republic, France, Greece, Germany, Italy, Morocco, Poland, Portugal, Russia, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Tunisia, Turkey, Yugoslavia (Lindner, 1938; Rozkošný 1982; Rozkošný and Nartshuk 1988; Woodley 2001).

3.1.3. Stratiomyinae

3.1.3.1. Oxycera Meigen, 1803

3.1.3.1.1. Oxycera meigenii Staeger, 1844

Material Examined: Turkey: 1♀, Konya, Taskent, Beyreli Village, Gevne Valley, elev. 1450 m, 06.VII 2019 (Fig.2.6; Fig.3.20).

Distribution in Turkey: Ankara, Alanya, Bayburt, Erzurum, Isparta, Kayseri, Konya, Sivas (Demirözer et al. 2017; Üstüner et al. 2002; Üstüner 2005; Üstüner andHasbenli 2013).

General Distribution: Palearctic Region: Afghanistan, Austria, Azerbaijan, Belgium, Bulgaria, Czech Republic, China, Denmark, France, Greece, Georgia, Germany, Hungary, Iran, Italy, Kazakhstan, Mongolia, Poland, Romania, Russia, Slovakia, Sweden, Switzerland, Tajikistan, Turkey, Turkmenistan, Ukraine, Uzbekistan, Yugoslavia (Kertész 1908; Pleske 1925b; Séguy 1926; Lindner 1938; Rozkošný 1973; Dušek & Rozkošný 1974; Nartshuk 1976; Rozkošný 1983; Nartshuk 1988; Rozkošný and Nartshuk 1988; Woodley 2001; Üstüner et al. 2002).

3.1.3.1.1. Oxycera quadrilineata Üstüner and Hasbenli, 2007

Material Examined: Turkey: 3♀♀, Konya, Taskent, Beyreli Village, Gevne Valley, elev.1450 m, 06: VII 2019 (Fig.2.7; Fig.3.21).

Distribution in Turkey: Bayburt, Sivas (Demirözer et al. 2017; Üstüner and Hasbenli 2007; Üstüner et al. 2014).

General Distribution: Palearctic Region: Turkey (Üstüner and Hasbenli 2007).

3.1.3.2. Oplodontha Rondani, 1863

3.1.3.2.1. Oplodontha viridula (Fabricius 1775)

Material Examined: Turkey: 6♀♀, Konya, Taskent, Avsar Village, Gevne Valley, elev. 1750 m, 06.VII 2020. 2♂♂, 1♀♀, Konya, Hadim, Tosmur Plateau, Gevne Valley, elev. 1970 m, 07.VII 2020. 2♂♂, 7♀♀, Konya, Taskent, Avsar Village, Gevne Valley, elev. 1730 m, 08.VII 2020 (Fig.2.8,9; Fig.3.22,23).

Distribution in Turkey: Adana, Antalya, Bayburt, Burdur, Erzincan, Erzurum, Hatay, Isparta, Kayseri, Konya, Sivas, Trabzon (Demirözer et al. 2017; Rozkošný and Nartshuk 1988; Woodley, 2001; Üstüner and Hasbenli 2002; Üstüner 2005; Üstüner and Hasbenli 2013).

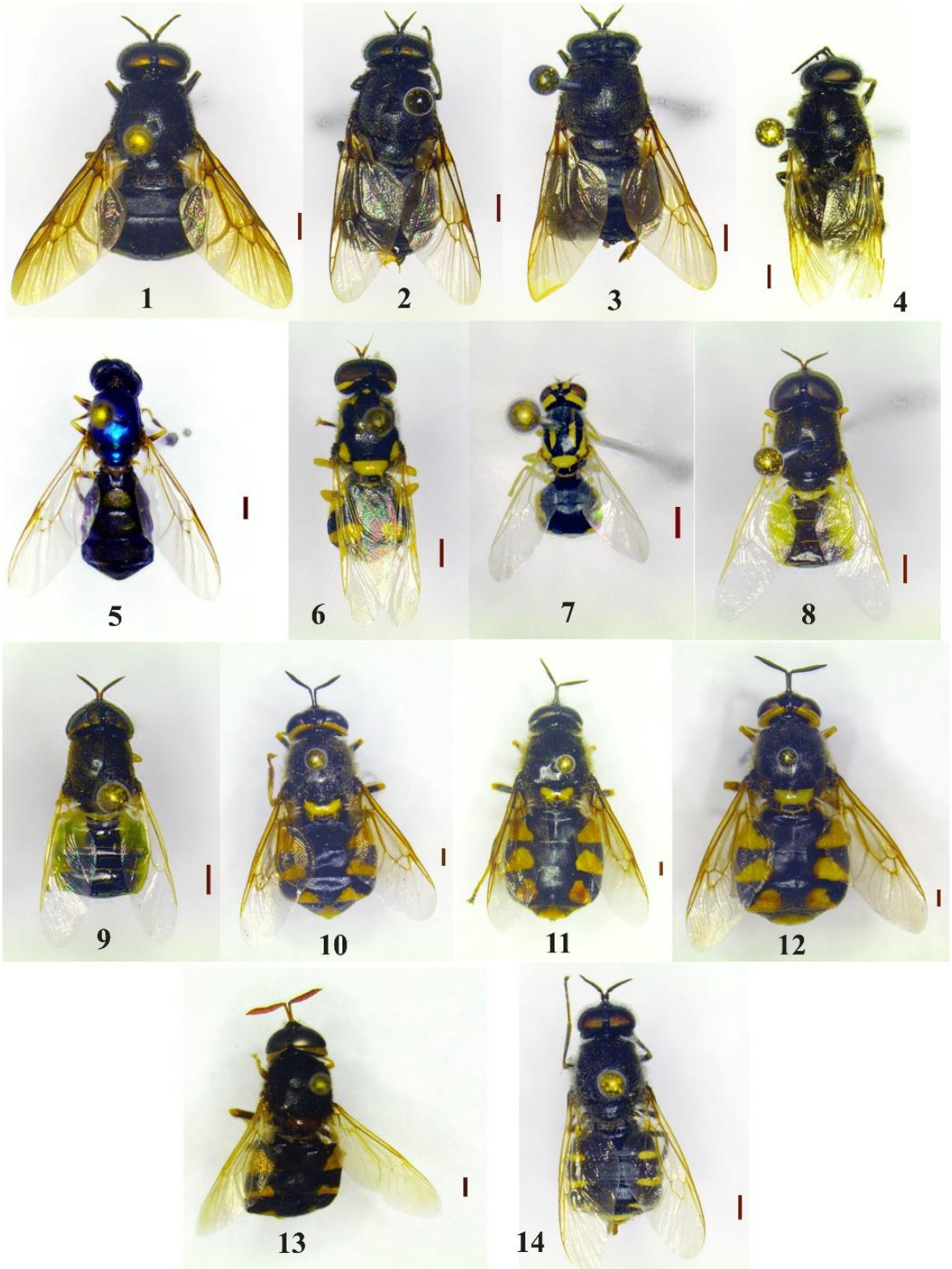
General Distribution: Palearctic Region: Albania, Algeria, Austria, Belgium, Bulgaria, Czech Republic, China, Denmark, England, Finland, France, Greece, Germany, Hungary, Iraq, Ireland, Israel, Italy, Kazakhstan, Kyrgyzstan, Netherlands, Mongolia, Morocco, Norway, Poland, Romania, Russia, Sardinia, Slovakia, Spain, Sweden, Switzerland, Turkey, (Kertész 1908; Pleske 1925c; Séguy 1926; Lindner 1938; Mason et al. 2009; Rozkošný 1973; Lindner, 1974; Nartshuk 1976; Rozkošný 1982; Nartshuk 1988; Rozkošný and Nartshuk 1988; Fleck and Greve 1990; Yimlahi et al. 2017; Woodley 2001).

3.1.3.3. Stratiomys Geoffroy, 1762

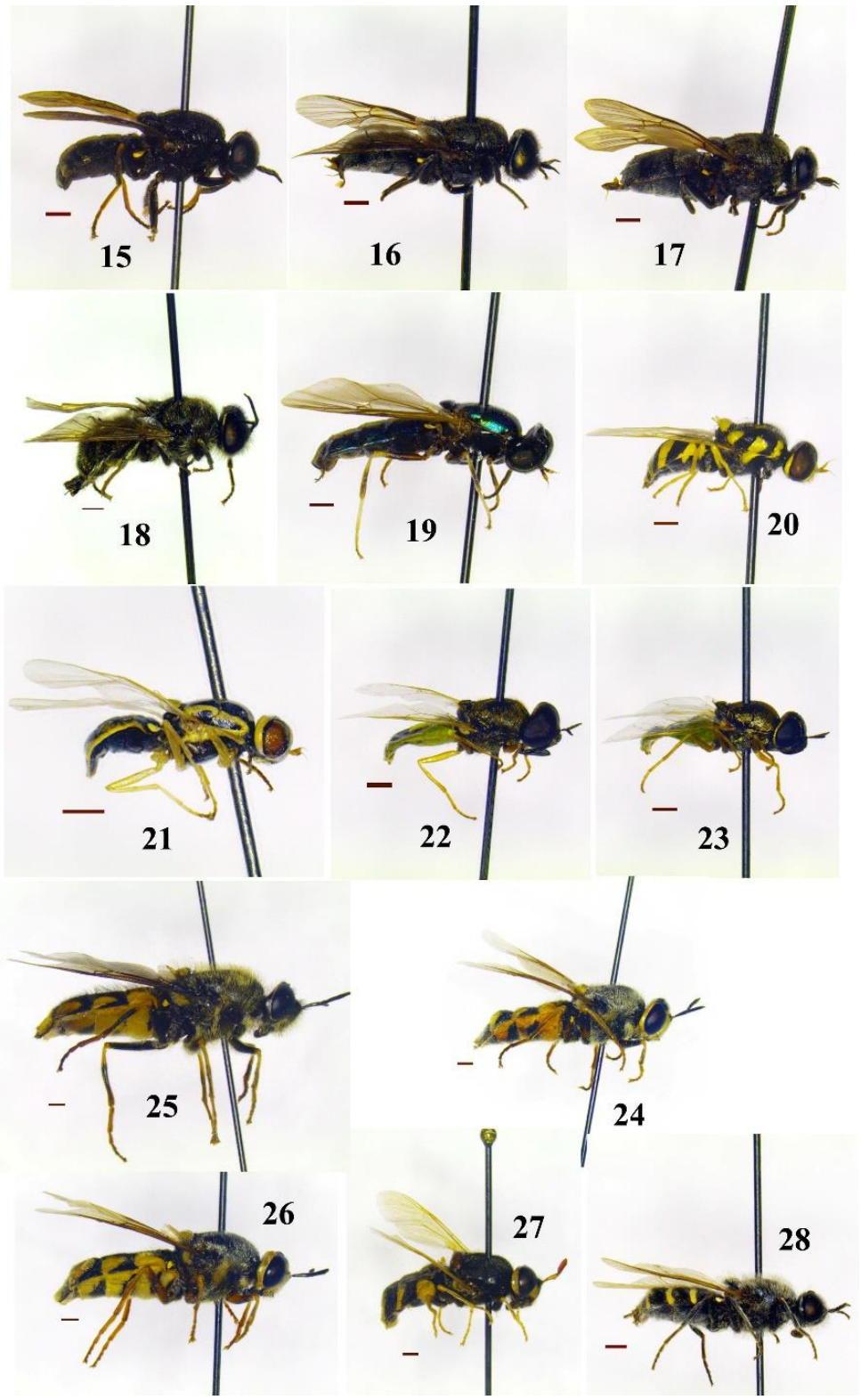
3.1.3.3.1. Stratiomys cenisia Meigen, 1822

Material Examined: Turkey: 1♀, Konya, Taskent, Avsar Village, Gevne Valley, elev. 1750 m, 06.VII 2020 (Fig.2.10; Fig.3.24).

Distribution in Turkey: Antalya, Bayburt, Burdur, Erzurum, İzmir, Mugla, Mersin (Demirözer et al. 2017; Rozkošný 1982; Üstüner and Hasbenli 2002).



Figures 2. 1. *Adoxomyia aureovittata*; 2–3. *Adoxomyia obscuripennis;* 4. *Pycnomalla splendens*; 5. *Chloromyia speciosa*; 6. *Oxycera meigenii*; 7. *Oxycera quadrilineata*; 8,9. *Oplodontha viridula*; 10. *Stratiomys cenisia*; 11–12. *Stratiomys chamaeleon*; 13. *Stratiomys ruficornis*; 14. *Lasiopa pseudovillosa*.



Figures 3. 15. *Adoxomyia aureovittata*; 16,17. *Adoxomyia obscuripennis;* 18. *Pycnomalla splendens*; 19. *Chloromyia speciosa*; 20. *Oxycera meigenii*; 21. *Oxycera quadrilineata*; 22,23. *Oplodontha viridula*; 24. *Stratiomys cenisia*; 25,26. *Stratiomys chamaeleon*; 27. *Stratiomys ruficornis*; 28. *Lasiopa pseudovillosa*.

General Distribution: Palaearctic Region: Algeria, Armenia, Austria, Bulgaria, Czech Republic, Cyprus, Egypt, France, Germany, Hungary, Iran, Israel, Italy, Kazakhstan, Morocco, Poland, Romania, Russia, Slovakia, Spain, Syria, Tunisia, Turkey, Turkmenistan, Ukraine, Yugoslavia (Pleske 1889; Kertész 1908; Pleske 1924; Séguy 1926; Lindner 1938; Rozkošný 1982; Nartshuk 1988; Rozkošný and Nartshuk 1988; Woodley 2001).

3.1.3.3.2. Stratiomys chamaeleon (Linnaeus, 1758)

Material Examined: Turkey: 2♂♂, 1♀, Konya, Taşkent, Avşar Village, Gevne Valley, elev. 1750 m, 06.VII 2020. 3♂♂, 3♀♀, Konya, Taşkent, Avşar Village, Gevne Valley, elev. 1730 m, 08.VII 2020 (Fig.3.11,12; Fig.3.25,26).

Distribution in Turkey: Artvin, Antalya, Burdur, Erzurum, Kayseri, Konya, Sivas (Demirözer et al., 2017; Rozkošný 1982; Rozkošný and Nartshuk 1988; Üstüner and Hasbenli 2002; Üstüner 2005; Üstüner and Hasbenli 2013).

General Distribution: Palearctic Region: Armenia, Austria, Azerbaijan, Belgium, Bulgaria, Czech Republic, China, Denmark, England, France, Georgia, Germany, Greece, Hungary, Italy, Kazakhstan, Lithuania, Netherlands, Poland, Romania, Russia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Yugoslavia (Pleske 1889; Kertész 1908; Séguy 1926; Lindner 1938; Nartshuk 1968; Rozkošný 1973; Rozkošný 1982; Nartshuk 1988; Rozkošný and Nartshuk 1988; Woodley 2001).

3.1.3.3.3. Stratiomys ruficornis (Macquart, 1838)

Material Examined: Turkey: 1♂, Konya, Taskent, Beyreli Village, Gevne Valley, elev. 1450 m, 20.VI 2019 (Fig.3.13; Fig.4.27).

Distribution in Turkey: Agri, Ankara, Artvin, Burdur, Bursa, Erzincan, Erzurum, Isparta, Kars, Konya (Aksehir), Malatya, Mersin, Sultan Mountains (Demirözer et al. 2017; Lindner 1938; Rozkošný 1982; Rozkošný and Nartshuk 1988; Woodley 2001; Üstüner and Hasbenli 2002; Üstüner 2005; Üstüner and Hasbenli 2013).

General Distribution: Palaearctic Region: Albania, Armenia, Austria, Azerbaijan, Bulgaria, Croatia, Czech Republic, France, Greece, Hungary, Iran, Iraq, Lebanon, Poland, Romania, Russia, Slovakia, Syria, Turkey, Yugoslavia (Kertész 1908; Séguy 1926; Lindner 1938; Nartshuk 1988; Rozkošný 1982; Rozkošný and Nartshuk 1988; Woodley 2001).

3.1.4. Nemotelinae

3.1.4.1. Lasiopa Brullé, 1833

3.1.4.1.1. Lasiopa pseudovillosa Rozkošný, 1983

Material Examined: Turkey: 2♂♂, Konya, Taskent, Beyreli Village, Gevne Valley, 1450 m, 19.VI 2019 (Fig.2.14; Fig.3.28).

Distribution in Turkey: Alanya, Burdur, Isparta, Konya (Demirözer, et al., 2017; Üstüner and Hasbenli, 2014).

General Distribution: Palaearctic Region: Iran, Italy, Switzerland, Turkey (Rozkošný 1983; Woodley 2001; Rozkošný 2012, Mason 2013; Üstüner and Hasbenli 2014).

4. Discussion

Turkey is located at an important crossroads of the confluence of Europe, Asia and Africa Continents. The species herein presented can be observed both in Africa, Asia and in Europe, including Turkey. In the country, there are transition corridors that act as a bridge through which living species cross between these three continents, generally high mountain ranges act as barriers that restrict the distribution of species, and isolated areas serve as refugium. At the same time, the country is also rich in biodiversity because it has different climatic zones. Gevne Valley is one of the Important Natural Areas (INA) in Turkey.

The Gevne Valley is an isolated area in the Mediterranean region in Turkey. As a result of the research, it has been shown that the Gevne Valley is an important zoogeographic region where Stratiomyidae species originating from Europe, Asia and Africa can be distributed, although it is an isolated the area.

Adoxomyia aureovittata and *Adoxomyia obscuripennis* previously detected in Gevne Valley are examples of the species that have been found again in this study. Until now, *Adoxomyia aureovittata* is only known from Turkey and Greece. According to its zoogeographical distribution, the species is a Mediterranean element. The presence of *A. aureovittata* in Valley Gevne in the south of Turkey is a possible outcome. Nartshuk's study (2009) on the zoogeographical range of Stratiomyidae species in Eastern Europe, specified the *A. obscuripennis* known from Kazakhstan, Uzbekistan, Russia and Tajikistan as the Caucasian-Central Asian species. *A. obscuripennis* from Gevne Valley in the south of Turkey was detected by Üstüner in 2011. In this study, the existence of *A. obscuripennis* in the same area has been once again determined. Thus, according to the results of this study, it is certain that *A. obscuripennis* has been distributed in Anatolia. According to the map designed by Rozkosny (1980) where the zoogeographic distribution areas of the European Stratiomyidae species, *A. obscuripennis* is a truly Turan zoogeographic element. However, according to the finding we obtained from the research, it can can also be characterized as an eastern Mediterranean zoogeographic element. Until now, *A. aureovittata* and *A. obscuripennis* species have been found only in Gevne Valley in the south of Turkey.

In Turkey, *Pycnomalla splendens* has been distributed from south to northeast, bordering the Caucasus. When the entire distribution area is examined, the species have been distributed in countries with a coastline to the Mediterranean, even up to Transcaucasia (known from a record in Armenia). In this study, the distribution of *P. splendens* is expanded and reaches southwestern Turkey.

Chloromyia speciosa found in Gevne Valley is widely distributed in most areas of Europe, and within the borders of the Palaearctic Region of Asia and Africa. The species is a Palaearctic zoogeographic element. Considering distribution in the palearctic, it is a possibility that *C. speciosa* is found in the Gevne Valley. Until now, *C. speciosa* have been known to show the distribution in the north of Turkey. Accordingly, its presence in the Gevne Valley in the south of Turkey is a very interesting result.

Species belonging to the genera *Oxycera*, *Oplodontha*, *Stratiomys* have been found in Gevne Valley. *Oxycera meigenii* is known in Europe and Asia. Regarding the range of the species in the Palaearctic Region, the westernmost border is in France, in Europe, the easternmost borders are Afghanistan, China and Mongolia in Asia, the northernmost borders are Germany and Sweden, in Europe and also Kazakhstan in Asia, and the southernmost borders are in the Mediterranean countries Italy, Greece, and Turkey. *O. meigenii* is a Palaearctic element. The species have been known for distribution from the south of Turkey (Alanya, Isparta) to Central Anatolia and Eastern Anatolia. It is a possible result that the species have been discovered for the first time in Gevne Valley.

Oxycera quadrilineata is only known in Turkey. Up to now, the species has been reported from the Central and the Eastern Anatolia parts of Turkey. As a result of this research, it has been found for the first time in the Gevne Valley. These findings have expanded the known distribution limits of the species to southern Turkey as well. Regarding to what we know about *O. quadrilineata*, it can be considered an Eastern Mediterranean element, since it has been found only in Anatolia.

Oplodontha viridula, Stratiomys cenisia and *Stratiomys chamaeleon* in Gevne Valley can be found in meadows, on the edge of still water in the higher parts of the valley. *Oplodontha viridula* is well distributed in Europe, Asia and North Africa. The species is also widely distributed in Turkey, but it is only now recorded in Gevne Valley. *Stratiomys cenisia*, also a Palaearctic element, is distributed in Europe, Asia (its eastern borders extend to Siberia and Mongolia) and North Africa. In Turkey, the species is distributed in western (Izmir), south (Antalya, Burdur, Bursa, Mersin) and eastern areas (Bayburt, Erzurum), and it is recorded for the first time from the Gevne Valley.

Stratiomys chamaeleon is widely distributed in Europe and it is also found in Siberia and China. Now, Turkey is the southernmost border where this species is distributed in the Palaearctic Region. The species has been distributed in southern Turkey, and in parts of central and northeast Anatolia. *S. chamaeleon* is recorded from Gevne Valley for the first time.

Stratiomys ruficornis is distributed in Asia from the Caucasus to the Middle East and also in Central Europe. Therefore, the species is present throughout the Palaearctic area, except in North Africa, and it can be then characterized as a Palearctic element. The species is widely distributed in Turkey as well, being also found in the Gevne Valley.

Lasiopa pseudovillosa is known in Italy and Switzerland in Europe. So, the species can be characterized as a sub-Mediterranean element. The species is also found in Turkey and Iran. Therefore, the species can also be characterized as an Iranian-Anatolian element. The species can be characterized as a Mediterranean element since it is within the limits of the distribution of Mediterranean elements.

5. Conclusions

In this study, the Gevne Valley's Stratiomyidae fauna have been determined in the Gevne Valley, which is a very isolated area. It is important to conduct similar faunistic studies at certain intervals in the future to monitor these species.

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Effects of Potassium Doses on Yield and Important Agricultural Properties of Mung Bean [*Vigna radiata* (L.) Wilczek] Genotypes

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HIGHLIGHTS

- Potassium is a macro element with important metabolic effects in plants.
- Mung bean is an uncommon but important legume.
- Potassium fertilizer had significant effects on some agronomic properties of the mung bean.

Abstract

The present study was conducted to determine the effects of potassium doses applied to mung bean [*Vigna radiata* (L.) Wilczek] genotypes on seed yield and important yield components. A field trial was carried out in 2020 in the Prof. Dr. Abdülkadir AKÇİN experimental fields belonging to Faculty of Agriculture located in Alaaddin Keykubat Campus. The study consisted of a total of 45 plots with 3 replications by applying 5 potassium doses (0, 10, 20, 30, 40 kg/da K_2SO_4) on 3 mung bean genotypes (Ermenek, Turkmenistan, Aşağıçağlar) and was planned according to the Factorial Trial Design in Random Blocks. According to the results of the analysis of variance, the difference between genotypes was statistically significant in terms of seed yield, while the difference between potassium doses was statistically significant in terms of protein content. According to the results of the research, the highest seed yield was obtained from the Aşağıçağlar genotype with 20.57 g/plant as the average of the potassium doses, and the plots that were applied 20 kg/da of potassium (18.16 g/plant) as the average of the genotypes. Similarly, the highest protein content was obtained from the Ermenek genotype (25.18%) and the plots (25.47%) treated with 10 kg da^{-1} potassium. As an average of potassium doses, the Aşağıçağlar genotype came to the forefront in terms of important yield factors such as thousand seed weight (69.13 g), plant height (54.52 cm) and first pod height (26.09 cm).

Keywords: Mung bean genotypes, Potassium doses, Protein yield, Seed yield

1. Introduction

Turkiye has rich ecological and biological diversity due to its location. This rich ecology, in which almost every climate type is observed, allows many crops to be grown. From this point of view, it is necessary to emphasize the importance of mung beans, which are grown in different parts of the world and locally grown in small areas in our country, in addition to known edible legumes.

Plants provide an important part of human nutrition and, depending on the plant species, the roots, tubers, stems, leaves, flowers, fruits and seeds of the plant are used. Legumes are one of the largest families in terms

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of the number of species (Ülker and Ceyhan 2008; Varankaya and Ceyhan 2012; Harmankaya et al. 2009; Harmankaya et al. 2010; Harmankaya et al. 2016; Kahraman 2022a). The availability of protein and starch in sufficient proportions, together with fiber, vitamins and microelements, has made legumes an important source of nutrients and the focus of attention. The added value of legumes can be increased by physically breaking them down into essential components such as protein, starch and fiber and using these products as additives to increase the nutritional value of the food (Ceyhan 2004; Ceyhan et al. 2014; Doruk Kahraman and Kahraman 2023). Therefore, legumes are important for the sustainability of food safety (Onder et al., 2011; Kahraman 2022b; Küçük and Ceyhan 2022; Tamüksek and Ceyhan 2022; Tekin and Ceyhan 2022).

Vigna radiata is called mung bean, green gram, golden gram, Oregon pea in English and mung in Turkiye. Its synonym is *V. aureus* Roxb (Bozoğlu and Topal 2005). Mung bean [*Vigna radiata* (L.) Wilczek] is one of the most important edible legumes in the genus *Vigna* (Toker et al. 2002; Kahraman et al. 2015).

Mung bean [*Vigna radiata* (L.) Wilczek] has been cultivated in India since ancient times. It is still widely cultivated in Southeast Asia, Africa, South America and Australia. Some sources even say that it was grown as a "Chickasaw pea" in America in the 1835s. It is also named after green gram, golden gram and chop suey bean. Mung beans are generally grown for human consumption, but their green residues are also used as animal feed (Oplinger et al. 1990).

The mung bean, which shows temperate climate characteristics, is locally called "Meş" in the Karaman Region, is grown in places with approximately 335 mm of precipitation and an altitude of 550-600 meters, and mostly in the villages near the Göksu River in the Ermenek district of Karaman, but not in the highland areas, usually soup, rice, börek. It is known that the above-ground parts are other than seeds are used in animal nutrition (Dalkılıç 2010).

In terms of its plant characteristics, the mung bean is a small, branched, hairy, herbaceous, annual, up right and semi-upright growing plant that can reach 25-125 cm in length. The leaves are broad, opposite on the plant and in the form of three leaves, generally oval and have a narrow leaf in the emergence period. Petiole is long and oval.

Its flowers are large, yellow and brown in color. The flower stalks are 2-10 cm long on the main stem and branches, and there are 5-15 flowers in bunches on each hill. The flowers are largely self-pollinated. The pods are long, narrow and turn gray, brown or black in the ripening period. Each pod contains 10-15 spherical and elliptical seeds. The pods may be widely hairy or glabrous. Seed testa is usually green or yellow, sometimes brown or blackish, flat, shiny or dull. 100 seeds weigh 2-8 grams (Anonymous 1981; 1982; 1983).

According to Jomduang (1985), mung beans contain 23.67% protein, 1.44% fat and 71.82% carbohydrates. On a dry weight basis, mung beans contain 25.0-28.0% protein, 1.0-1.5% fat, 3.5-4.5% cellulose, 4.5-5.5% ash and 62.0-65.0% carbohydrates. However, the protein content varies between 19.0-29.0% depending on the genotype and environmental conditions. In addition to being nutritious as a legume, it is obvious that a more balanced diet will be provided if consumed with grains (Doruk Kahraman and Gokmen 2021).

Mung bean is produced for reasons such as the use of green vegetables and sprouts as a salad in human nutrition, the high protein content of its seeds and its easy digestibility. Its wide adaptability, drought tolerance, high lysine content and ability to prevent gas collection in the stomach are other important features. It is widely grown commercially in Asia, Australia, West India, South America, and tropical and subtropical Africa (Anonymous 1988). In addition, mung bean can fix 58-109 kg/ha nitrogen in the soil thanks to its symbiotic relationship with the *Bradyrhizobium japonicum* bacterium (Singh and Singh 2011).

The newly developed varieties are cultivated on an area of approximately 3 million ha in Bangladesh, Bhutan, China, India, Myanmar, Nepal, Pakistan, Sri Lanka and Thailand. The Philippines and Indonesia are the main producing countries (Mogotsi 2006).

Numerous studies have been conducted on mung beans in the world and our country. Akdağ (1995) determined the seed yield per plant as 4.99-5.16 g, the plant height as 28-45 cm, the number of pods per two as 12-35 and the weight of one thousand seeds as 35-38 g. In different studies, the seed yield was 109 kg da^{-1} (Sharar et al. 1999), 89.7 kg da^{-1} (Ahmad 2001), 72-92 kg da^{-1} (Ihsanullah et al. 2002) and 24.06 g/plant (Dalkılıç 2010) differ. In the ecology of Konya, where the research was conducted, in previous years (Dalkılıç 2010), the protein ratio as the medium of varieties and applications is 27.32%, the weight of a thousand seeds is 47.42 g, the number of pods is 14.45, the number of leaves is 21.99, the number of main branches is 6.98, the plant height is 40.92 cm, the first pod height 8.09 cm, flowering period 58.97 days, pod binding time 61.61 days and vegetation period 133.44 days. In the same study, the relationships between seed yield and yield components were also examined and important results were obtained. In another study conducted in Konya ecology (Baydemir 2013), the average seed yield was 71.00 kg da^{-1}, the protein rate was 21.59%, the protein yield was 15.44 kg da^{-1}, the weight of a thousand seeds was 51.66 g, the number of pods was 17.51, the number of leaves was 17.49, the number of main branches was 7.15, the plant height was 40.39 cm, the first pod height was 10.39 cm, the flowering period was 73.35 days, the pod binding period was 77.58 days and the vegetation period was 110.48 days.

In Konya, which has the largest agricultural area in Turkey, the chance of different plants to alternate in irrigated areas gradually increases with the gradual introduction of Konya Plain Projects (KOP) and reveals an important production potential (Doruk Kahraman and Gokmen 2022). This research was carried out to determine the effects of potassium doses applied to 3 mung bean genotypes on yield and important yield factors in Konya ecological conditions.

2. Materials and Methods

The mung bean used as a material in the research is an annual, herbaceous, upright or semi-upright small structured, 25-125 cm tall, branched hot climate plant. Their pods are long and narrow and may be brown, bronze, gray or black in maturity. The pods may be pubescent or drooping, pubescent or glabrous. It has small seeds and there are 10-15 round seeds in each pod. Seeds are usually green or yellow, rarely brown or blackish. The leaves are broad, usually oval in the form of 3 leaflets and have a narrow leaf in the emergence period. The flowers are yellow and brown in color and emerge from the seat. Its stems are 2-10 cm long on the main stem and branches, and there are 5-15 flowers in bunches on each hill. Flowers are largely autogamy (Anonymous 1981; Şehirali 1988; Oplinger et al. 1990).

The climate values of the vegetation period of the region where the research was carried out show parallelism with the values of the long years and the values of the year of the research. According to the results of the soil analysis, the pH of the soil of the trial field is 7.48, the organic matter is at a medium level (2.34%), it has a calcareous, clay-loamy texture, poor in iron, and sufficient in terms of other elements.

In the field experiment, 3 different mung bean genotypes (Ermenek, Turkmenistan, Aşağıçağlar) were used and 5 different potassium doses (0, 10, 20, 30, 40 kg/da K2SO4) were applied in Selcuk University Faculty of Agriculture, located in Alaeddin Keykubat Campus, Prof. Dr. Abdülkadir AKÇİN Trial Field with 3 replications. A sufficient amount of base fertilizer was first applied to the seedbed prepared in accordance with the technique, and after the parceling process, the required amount of potassium fertilizer was given with planting. The experiment was formed from 45 plots (3 genotypes x 5 potassium doses x 3 replications). These plots are 2m x 3m = 6m2 in size and the total trial area is 425 m2. Seed sowing was done by hand on April 29, 2020 and 5 rows were planted in each plot. Row spacing in planting is 40 cm. By following the field controls carefully, 4 times of sprinkler irrigation and 3 times hoeing were carried out. Harvesting was done by hand carefully between 23-27 September. In the study, the protein ratio was determined over 2 replications.

In the experiment, seed yield per plant (g/plant), protein ratio (%), protein yield (g/plant), thousand seed weight (g), number of pods (number/plant), number of leaves (number/plant), main branch number (pieces/plant), plant height (cm), first pod height (cm), flowering time (days), pod setting time (days) and vegetation period (days).

3. Results and Discussion

Seed yield varied between 11.06-26.87 g/plant. In the experiment, the difference between genotypes was found to be significant in terms of seed yield per plant (Table 1). As the average of potassium doses, the highest seed yield was obtained from the Aşağıçağlar genotype with 20.57 g/plant, and it entered the "a" group according to the Lsd test. In terms of the average of genotypes, the highest seed yield was obtained from 18.16 g/plant and 20 kg da^{-1} potassium dose (Table 2). When the researchers' findings on seed yield were examined, the results showed parallelism with the findings of Dalkılıç (2010) at 16.13-29.25 g/plant.

Dülgerbaki (2011) found the plant seed yield as 3.37 g/plant, while the seed yield per decare was 78-115.2 kg da^{-1}, Mondal et al. (2012) plant seed yield 7.46-11.57 g/plant, Begum et al. (2013) determined as 21.87-45.35 g/plant. Ecological conditions and different methods applied can be shown among the reasons for this difference between the findings.

The difference between potassium doses in terms of protein ratio was found to be significant (Table 1). The protein ratio varied between 22.53-25.82%. As the average of the genotypes, the highest protein ratio was obtained from the potassium dose of 25.47% and 10 kg/da. When the average of the potassium doses was taken into account, the highest protein ratio was obtained in the Ermenek genotype at 25.18% (Table 2). When the findings of the researchers about the protein ratio were examined; Jomduang (1985) 22% to 25%, Ahmad et al. (2016) reported 23.98% to 25.61%, and Karaman (2019) reported that it varied between 17.34% and 18.69% in the first year of his two-year study, and between 20.93% and 22.99% in the second year.

As can be seen in the examination of Table 1, the difference between the genotypes was found to be significant in terms of protein yield and it varied between 2.77-6.56 g/plant. As an average of potassium doses, the highest protein yield was obtained from the Aşağıçağlar genotype with 5.06 g/plant, and the average of the genotypes was obtained from a potassium dose of 4.52 g/plant and 20 kg/da (Table 2). When the researchers' studies on protein yield are examined; Karaman (2019) reported that the protein yield varied between 15.13 kg da^{-1} and 25.83 kg da^{-1} in the first year of his study conducted in 2017 and 2018, and between 37.33 kg da^{-1} and 55.11 kg da^{-1} in the second year. He stated that genetic structure and especially environmental factors were effective in the difference observed between these years.

Thousand seed weights varied between 52.07-74.78 g and the difference between genotypes was significant (Table 1). As the average of the potassium doses, the highest thousand seed weight was obtained from the Aşağıçağlar genotype with 69.13 g, and the average of the genotypes was obtained from the potassium dose of 64.57 g and 10 kg da^{-1}. As can be seen in Table 2, lower values were determined for the Turkmenistan genotype compared to other genotypes. When the researchers' studies on thousand seed weight are examined; Gebeloğlu and Yazgan (1992) 54.23-82.30 g, Sohail et al. (2016) 42.6-55.6 g, Gül (2019) 35.72-70.64 g, Karaman (2019) reported that it varied between 34.13-50.90 g in the first year of his two-year study, and between 52.65-69.55 g in the second year.

Table 1. Variance analysis summary of investigated traits in the trial

		Mean of Squares			
Sources of Variation	**DF**	**Seed yield**	**Thousand seed weight**	**Number of pods**	**Number of leaves**
Total	44	53,71	74,58	307,60	36,48
Replication	2	145,00	88,71	1471,95	169,99
Genotype (G)	2	178,92*	945,11**	737,85	14,27
Potassium doses (K)	4	15,74	20,54	90,63	9,83
(GxK) int.	8	28,24	22,41	290,45	68,74*
Error	28	50,95	34,01	229,59	23,12
Sources of Variation	**DF**	**Number of branches**	**Plant height**	**First pod height**	**Days to flowering**
Total	44	2,53	115,80	68,69	7,60
Replication	2	12,14	655,09	50,77	3,62
Genotype (G)	2	3,38	467,08**	1080,69**	17,15
Potassium doses (K)	4	1,54	4,91	6,31	1,22
(GxK) int.	8	3,16	92,32	11,01	6,99
Error	28	1,74	74,73	23,09	8,29
Sources of Variation	**DF**	**Days to pod**	**Vegetation length**	**Protein ratio**	**Protein yield**
Total	29	21,44	10,21	1,37	31101,28
Replication	1	35,08	26,29	2,44	44788,40
Genotype (G)	2	157,22**	1,09	2,01	129735,20*
Potassium doses (K)	4	10,74	2,64	2,50*	13600,83
(GxK) int.	8	12,02	8,06	1,68	21373,72
Error	14	14,99	11,41	0,70	26591,81

*%5, **%1 statistically significance level

Table 2. Mean Values and Lsd Groups of the Investigated Characteristics in the Trial

Genotypes	Potassium Doses						Potassium Doses					
	0	**10**	**20**	**30**	**40**	**Mean**	**0**	**10**	**20**	**30**	**40**	**Mean**
	Seed Yield (kg/da)						**Protein Ratio (%)**					
Ermenek	11.06	12.04	13.32	17.90	16.22	**14.11b**	25.11	25.35	25.29	25.20	24.94	**25.18**
Türkmenistan	16.36	14.29	14.30	15.23	15.95	**15.23b**	24.97	25.82	25.56	22.53	22.60	**24.29**
Aşağıçağlar	16.92	21.38	26.87	19.09	18.58	**20.57a**	24.25	25.24	24.44	25.16	23.97	**24.61**
Mean	**14.78**	**15.90**	**18.16**	**17.41**	**16.91**	**16.63**	**24.78abc**	**25.47a**	**25.09ab**	**24.29bc**	**23.84c**	**24.69**
	Protein Yield (kg/da)						**Thousand Seed Weight (g)**					
Ermenek	2.77	3.05	3.36	4.51	4.04	**3.55b**	62.05	66.84	63.43	66.41	62.58	**64.26b**
Türkmenistan	4.08	3.68	3.65	3.43	3.60	**3.69b**	55.62	52.07	53.27	52.35	54.73	**53.61c**
Aşağıçağlar	4.10	5.39	6.56	4.80	4.45	**5.06a**	70.95	74.78	66.18	68.26	65.47	**69.13a**
Mean	**3.65**	**4.04**	**4.52**	**4.24**	**4.03**	**4.10**	**62.87**	**64.57**	**60.96**	**62.34**	**60.93**	**62.33**
	Number of Pods (Piece/Plant)						**Number of Leaf (Piece/Plant)**					
Ermenek	38.20	39.06	39.80	37.47	42.60	**39.43**	13.90bcd	14.50bcd	13.73bcd	15.63bcd	19.40abc	**15.43**
Türkmenistan	54.00	48.05	45.80	57.80	60.77	**53.28**	15.53bcd	16.83a-d	13.10cd	19.33abc	21.67ab	**17.29**
Aşağıçağlar	52.20	38.27	63.53	38.93	29.40	**44.47**	19.67abc	11.87cd	23.87a	14.67bcd	9.70d	**15.85**
Mean	**48.13**	**41.79**	**49.71**	**44.73**	**44.25**	**45.72**	**16.20**	**14.40**	**16.90**	**16.54**	**16.92**	**16.19**

* Separately according to the subjects and applications; There is no statistical difference between the averages denoted by the same letter

Table 2 Continues…

Genotypes	Potassium Doses						Potassium Doses					
	0	**10**	**20**	**30**	**40**	**Mean**	**0**	**10**	**20**	**30**	**40**	**Mean**
	Number of Branches (piece/plant)						**Plant Height (cm)**					
Ermenek	7.80	8.47	7.07	8.00	7.80	**7.83**	45.00	50.65	43.29	49.57	45.79	**46.86b**
Türkmenistan	7.40	6.16	5.93	8.27	6.87	**6.93**	48.35	38.66	39.69	41.58	50.00	**43.66b**
Aşağıçağlar	7.07	6.93	9.53	8.13	6.53	**7.64**	53.87	52.41	63.42	52.76	50.13	**54.52a**
Mean	**7.42**	**7.19**	**7.51**	**8.13**	**7.06**	**7.46**	**49.07**	**47.24**	**48.80**	**47.97**	**48.64**	**48.34**
	Height of First Pod (cm)						**Days to Flowering (day)**					
Ermenek	28.52	32.24	27.67	28.79	26.23	**28.69a**	103.33	100.00	101.00	103.33	101.67	**101.87**
Türkmenistan	14.64	11.01	12.23	12.80	13.64	**12.87b**	102.67	101.67	104.00	102.67	103.00	**102.80**
Aşağıçağlar	26.97	24.82	26.60	28.02	24.06	**26.09a**	102.33	106.00	105.00	103.67	103.00	**104.00**
Mean	**23.37**	**22.69**	**22.17**	**23.20**	**21.31**	**22.55**	**102.78**	**102.55**	**103.33**	**103.22**	**102.55**	**102.89**
	Days to Pod Setting (day)						**Vegetation Length (day)**					
Ermenek	102.67	106.67	107.00	102.67	103.33	**104.47a**	138.00	142.33	139.00	142.00	140.33	**140.33**
Türkmenistan	98.33	99.33	95.67	95.67	101.67	**98.13b**	140.67	139.00	140.67	139.00	142.33	**140.33**
Aşağıçağlar	100.00	100.33	101.00	99.67	99.67	**100.13b**	140.33	142.00	141.33	140.67	139.67	**140.80**
Mean	100.33	102.11	101.22	99.34	101.56	**100.91**	139.67	141.11	140.33	140.56	140.78	**140.49**

* Separately according to the subjects and applications; There is no statistical difference between the averages denoted by the same letter

The differences between genotypes and potassium doses were found to be insignificant in terms of the number of pods (Table 1). The number of pods varied between 29.40-63.53 pieces/plant. The highest number of pods as an average of potassium doses was obtained from the Turkmenistan genotype with 53.28 units/plant, and the average of genotypes was obtained from a potassium dose of 20 kg/da with 49.71 units/plant (Table 2). When the researchers' studies on the number of pods are examined; Gebeloğlu and Yazgan (1992) 11.93-35.20 units/plant, Gul et al. (2007) 32.66-58.66 units, Akgündüz (2016) 31.51-33.29 units, Karaman (2019) 18.70-42.06 units in its first year, 36.88-48.62 units in its second year, Akbay et al. (2020) reported that it varies between 9.43-23.98 units/plant. The reason for the differences between the findings is thought to be the result of the differences in the number of pods caused by different ecologies and cultivars/genotypes.

The number of leaves varied between 9.70-23.87 pieces/plant. Differences between potassium doses x genotype interaction were found to be significant (Table 1). The highest number of leaves (23.87 pieces/plant) was obtained with the Turkmenistan genotype from the potassium dose of 40 kg/da, and the lowest number of leaves (9.70 pieces/plant) was obtained from the potassium dose of 40 kg/da with the Aşağıçağlar genotype (Table 2). As it can be understood from here, it is thought that the genetic structure causes the high number of leaves in the Turkmenistan genotype even though the same potassium dose is applied. When the researchers' studies on the number of leaves are examined; Toker et al. (2002) 12-25 units/plant, Dalkılıç (2010) 21.99 units/plant, Baydemir (2013) 17.49 units/plant, Akbay et al. (2020) reported that it varies between 47.30-73.77 units/plant.

According to the results of the research, the number of main branches varied between 5.93-9.53 pieces/plant. Differences between genotypes and potassium doses were found to be insignificant (Table 1). As the average of potassium doses, the highest number of main branches was obtained from the Ermenek genotype with 7.83 units/plant, and the average of genotypes was obtained from a potassium dose of 30 kg/da with 8.13 units/plant (Table 2). When the researchers' studies on the number of majors are examined; Toker et al. (2002) 3-5 units/plant, Mondal et al. (2012) reported that it varies between 0.69-2.77 units, Dülgerbaki (2011) 10.2-12.0 units/plant, Gölgül (2019) 1.0-2.77 units/plant. The reason why these results differ from our findings is thought to be ecological differences. As a matter of fact, our research results are similar to those of Dalkılıç (2010) and Baydemir (2013), who conducted their research in Konya ecological conditions.

As a result of the measurements, the plant height varied between 38.66-63.42 cm. The difference between genotypes was found to be significant (Table 1). As the average of potassium doses, the highest plant height was obtained from the Aşağıçağlar genotype with 54.52 cm, and the highest plant height was obtained from the control (0 kg da^{-1}) dose with 49.07 cm as the average of the genotypes (Table 2). It is seen that different potassium doses do not have a significant effect on plant height. When the researchers' studies on plant height are examined; Gebeloğlu and Yazgan (1992) 28-44.67 cm, Ihsanullah et al. (2002) 44-47 cm, Begum et al. (2013) 55.50-73.50 cm, Pekşen et al. (2015) 39.95-82.53 cm, Akgündüz (2016) 46.44-93.75, Gölgül (2019) 43.3 cm, Akbay et al. (2020) reported that it varies between 36.43-41.70 cm. Present research results are similar to the literature.

The difference between genotypes was found to be significant in terms of first pod height (Table 1). The height of the first pod varied between 11.01-32.24 cm. As the average of the potassium doses, the highest first pod height was obtained from the Ermenek genotype with 28.69 cm, and the highest 23.37 cm as the average of the genotypes was obtained from the control (0 kg da^{-1}) dose (Table 2). As can be seen in the examination of Table 2, the first pod height of the Turkmenistan genotype was found to be quite low compared to the other genotypes. This is thought to be due to the difference in genetic structure. When the researchers' studies on the height of the first pod are examined; Dülgerbaki (2011) 21.8-23.5 cm, Pekşen et al. (2015) 15.75-49.33 cm, Akgündüz (2016) 17.19-52.38 cm, Gölgül (2019) 17.4-29.3 cm, Gül (2019) 22.77 cm, Akbay et al. (2020) reported that it varies between 11.82-21.70 cm. Our research results are partially similar to the literature. It can be said that this is due to the difference in environment and genotype.

As can be seen in the examination of Table 1, the differences between the genotypes and potassium doses in the flowering period were not significant and varied between 100-106 days. The highest flowering period was obtained from the Aşağıçağlar genotype with 104 days as the average of the potassium doses, and the average of the genotypes was obtained from the 20 kg da^{-1} potassium dose of 103.33 days (Table 2). When the researchers' studies on the flowering period are examined; Gebeloğlu and Yazgan (1992) 54.33-64.33 days, Çancı and Toker (2005) 20-76 days, Dalkılıç (2010) 43-73 days, Baydemir (2013) 73.35 days, Begum et al. (2013) 42-67.30 days, Akgündüz (2016) 52.67-55.57 days, Akbay et al. (2020) reported that it varies between 50-67.33 days. The information obtained as a result of the experiment was quite higher than these results. These differences reveal the effect of ecological conditions on the flowering period.

The pod binding time varied between 95.67-107 days. The difference between genotypes was found to be significant (Table 1). As an average of potassium doses, the highest pod setting time was obtained from the Ermenek genotype with 104.47 days, while the highest 102.11 days as an average of genotypes were obtained from a potassium dose of 10 kg da^{-1} (Table 2). When the researchers' studies on pod setting time were examined; Dalkılıç (2010) 46.30-74 days, Baydemir (2013) 75.33-80.67 days, Pekşen et al. (2015) reported that it varies between 47.25-68.25 days, Akgündüz (2016) 55.26-56.48 days in areas that depend on precipitation, and 58.60-59.20 days in plants grown under well-irrigated conditions. It is thought that genotypic and climatic factors may be among the reasons why the pod setting time is higher than in previous studies.

According to the results of the research, the vegetation period varied between 138-142.33 days, and the differences between genotypes and potassium doses were not significant (Table 1). As can be seen from the examination of Table 2, no differences were observed between vegetation periods. When the researchers' studies on vegetation period are examined; Dalkılıç (2010) 133.44 days, Baydemir (2013) 110.48 days, Mondal et al. (2012) 60.0-74.7 days, Begum et al. (2013) 78.25-105.50 days, Akgündüz (2016) 127.31-131.51 days, Akbay et al. (2020) reported that it varied between 73.67-99 days. The fact that the vegetation period is higher than the previous years is thought to be due to the effect of environmental and climatic factors on the vegetation period.

4. Conclusions

According to the research results, while the differences between the genotypes were statistically significant in terms of seed yield, protein yield, thousand-seed weight, plant height, first pod height and pod setting time, the differences between potassium doses were not statistically significant in terms of all other investigated properties except protein ratio. In terms of seed yield, protein yield and some characteristics, Aşağıçağlar genotype and 20 kg da^{-1} potassium dose were seen to come to the fore. Plant height and first pod height values decreased in all the potassium-treated plots compared to the control plots. Potassium application in mung beans had a positive effect on yield.

Mung bean is a very healthy and nutritious vegetable protein source that consumers can choose. Necessary importance should be given to the promotion of this legume species, especially in the Konya region, and its cultivation in more areas.

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Determination of Some Quality Characteristics of Durum Wheat under Dry Conditions in Konya

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HIGHLIGHTS

- Wheat is an indispensable product.
- It is necessary to increase the grain yield of wheat.
- Quality is a quantitative character and is influenced by many factors.

Abstract

This study was carried out to determine the quality characteristics of some durum wheat varieties grown in different regions of Turkey under Konya ecological conditions. Altıntaş-95, Burgos, Ç-1252, Dumlupınar, Eminbey, Imren, Kızıltan-91, Kunduru-1149, Leonardo, Levent, Kümbet-2000, Mimmo, Mirzabey-2000, Sırçalı, Soylu, Svevo, Traubadur, Türköz, Vehbibey, Yelken-2000 varieties were used as plant material. In the research, the field trial was established in a randomized block design with three replications. Within the scope of the research; hectoliter weight, glassiness, semolina color and protein characteristics were examined. In the study, significant differences were found between the varieties in terms of hectoliter weight and protein ratio, while semolina color and glassiness were found insignificant. The highest hectoliter weight was found in the Yelken-2000 variety and the highest protein ratio was found in the Burgos variety.

Keywords: Drought, Durum wheat, Glassiness, Semolina color

1. Introduction

Turkey, the homeland of durum wheat as well as many other plants, is ecologically suitable for producing high-quality durum wheat (Bozkurt 2012). Currently, Turkey is an important producer of durum wheat in the Southeastern and Central Anatolia regions and is expected to become even more important in durum wheat production in the coming years. This requires increasing production and the quality of the products produced. In this context, the first thing to be done is to identify the varieties that can be successfully grown in the regions and provinces of Turkey where durum wheat is widely produced. It is known that wheat yield and quality can be increased by 20-30% with the use of appropriate varieties (Geçit 2016).

The quality of durum wheat is closely related to genetic structure, ecological conditions, cultivation technique, and especially the amount of nitrogen fertilizer used and other cultural practices. For this reason, in Konya province, which ranks second after Şanlıurfa in terms of durum wheat cultivation area in Turkey (Geçit 2016), it will be important for both producers, industrialists, and consumers to identify varieties with high yield and quality and to encourage their production. In durum wheat, hectoliter weight is one of the

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important quality traits that gives information about many characteristics of the product such as starch content, spelled content and grain shape (Kandemir 2004). Although hectoliter weight, which is determined by the structure, size, fullness, and homogeneity of the grain, varies mostly according to the variety, it can also be affected by growing conditions (Elgün 2008; Ünal 1991).

One of the important quality characteristics of durum wheat is color (Aydoğan et al. 2012). Banach et al. (2021) stated that durum wheat varieties with high yellow pigment content are of higher quality and the color value is very important in the commercial, nutritional and technological quality evaluation of durum wheat, and that yellow color value is considered an important nutritional resource and is little affected by the environment, but this value increases in years with low rainfall.

The hard, firm, and glassy structure of durum wheat grains is the most important indicator indicating that the protein content of the product is high. For this reason, glassiness is used as an important quality factor in durum wheat in our country and all over the world (Geçit 2016). Hard and glassy grain and durum wheat are often mentioned together, and the glassiness ratio is a physical quality element that can be determined quickly and practically used in the classification of durum wheat in many countries (Türköz 2016). Studies on the subject have shown that the Southeastern Anatolia Region is the most suitable in terms of physical characteristics of the grain, protein content, and glassiness rate (Atlı 1999; Kılıç 2020). Borghi et al. (1997) stated that while hot and dry conditions caused a decrease in yield, they created an advantage in terms of glassiness.

The grain protein content is one of the most important quality criteria in durum wheat (Gooding and Davies 1997) and has a positive effect on glassiness (Borghi et al. 1975). Researchers state that protein content varies partly depending on species and cultivar, but mostly on environmental factors, and generally the protein content of glassy grains is higher than non-glassy grains (Budak et al. 1997; Mut et al. 2007; Yazar and Karadoğan 2008). Kartal et al. (2011) also stated that environmental and growing conditions and soil structure play an important role in determining the protein content of grain.

This study was carried out to determine some quality characteristics of some durum wheat varieties grown in different regions of Turkey under Konya ecological conditions.

2. Materials and Methods

A total of 53 stratiomyids, 21 males and 32 females, were collected from Gevne Valley between the years of 2019 and 2020 (Fig.1). Stratiomyide specimens were captured with an entomological net, then sacrificed in jars containing ethyl acetate and pinned. Their diagnosis was made based on relevant literature. Photographs of each species were taken. The material is now housed at the Selçuk University, Faculty of Science, Department of Biology.

This research was conducted in the experimental field of Konya Bahri Dağdaş International Agricultural Research Institute Directorate during the vegetation period of 2020-2021. Some climatic characteristics of the vegetation period are given in Table 1.

As can be seen from Table 1, the total rainfall for nine months in the experimental year was 181.4 mm, which is 149.4 mm less than the total rainfall of the long years (330.8 mm). In the study, the amount of rainfall in April, May, and June, which coincided with the stalk emergence, flowering, fertilization, and grain-filling periods, known as critical periods in terms of grain yield, was much lower than expected. Similarly, the rainfall regime in the experimental year was more irregular than the long-term average.

Table 1. Climatic values of the vegetation period

Months	2020-2021 *Vegetation Period*					(1929-2020) *Long years*				
	Temp. (°C)			Precip.	Rel. hum.	Temp. (C°)			Precip.	Rel. hum.
	Mean	Max.	Min.	(mm)	(%)	Mean	Max.	Min.	(mm)	(%)
October	16,3	28,7	3,6	13	56	12,6	31,6	-7,6	29,9	58
November	5.8	17.9	-8.1	25	78	6,5	25,2	-20,0	32,2	69
December	4.5	14.6	-7.5	12.6	88	1,6	20,0	-22,4	42,8	77
January	2.5	20.2	-11.2	51.8	85	-0,1	17,6	-25,8	37,9	76
February	2.9	20	-16,5	1.6	67	1,4	21,2	-25,0	28,5	70
March	5.2	31.3	-7.8	31.6	66	5,5	28,9	-15,8	28,7	62
April	12.1	30.2	-1.2	17.4	53	11	31,5	-8,6	31,9	58
May	19.1	33.7	1.7	2.4	38	15,8	33,4	-1,2	43,3	55
June	19.5	32.5	4.3	26	51	20,1	37,2	3,2	25,7	47
Mean /Total	9.7	26.9	-4.7	181.4	60.8	10.4	34.4	-16.7	330.8	61

Source: Bahri Dağdaş International Agricultural Research Institute

The soil of the test area has a clayey texture, a high lime level, and is alkaline. The potassium (K) and phosphorus (P) content of the soil are high and it is poor in organic matter.

In the study, 20 varieties obtained from some private and public institutions were used as plant material. These are Altıntaş-95, Burgos, Ç-1252, Dumlupınar, İmren, Kızıltan-91, Kunduru-1149, Kümbet-2000, Mimmo, Mirzabey-2000, Sırçalı, Svevo, Traubodur, Türköz, Vehbibey, Yelken-2000, Soylu, Eminbey, Leonardo and Levent.

The research was established in a randomized block design with three replications. Each plot was 4 m long, 20 cm between rows, and consisted of six rows. Sowing was done with a seeder on November 12, 2020, and the sowing norm was adjusted to 550 plants per m2. Weeds were controlled with a herbicide containing 2,4-D. 6 kg phosphorus (P2O5) and 15 kg nitrogen (N) were given per decare. In this context, 14 kg of DAP fertilizer (18% nitrogen and 46% phosphorus) was applied before planting. The remaining part of nitrogen was applied in the form of urea (46% nitrogen) before the emergence of stalks. Plants were stressed due to drought during emergence and for this reason, water was given to the plants once on May 10 by flood irrigation. Harvesting was carried out with a plot combine harvester after all varieties matured.

This article was an oral presentation at the "Turkey 13. National - II. International Field Crops Conference (TABKON-2022)" and published as an abstract in the proceedings book (Doruk Kahraman and Gökmen 2022).

The data obtained as a result of the research were subjected to statistical analyses with the computer-based package program named "MSTAT-C" according to the Coincidence Blocks Experimental Design. Accordingly, the comparison of the mean values, which were found to be significant in the F test, was carried out according to the Duncan multiple tests.

3. Results and Discussion

The mean values and Duncan grouping of some durum wheat cultivars grown in different regions of Turkey in Konya ecological conditions are given in Table 2.

3.1. Hectoliter weight

As seen in Table 2, the difference between the varieties in terms of hectoliter weight was statistically significant at a 5% level. The highest hectoliter weight was obtained from the Yelken variety with 82.1 kg and the lowest hectoliter weight was obtained from the Kümbet-2000 variety with 75.9 kg. The hectoliter weights of the other varieties used in the experiment varied between these two values.

Hectoliter weight, which is accepted as a physical quality criterion and used as the easiest measure to determine quality, is especially important in milling (Ünal 2002). It is known that as the hectoliter weight increases, flour yield also increases (Atlı 1999). Hectoliter weight should be 80 kg and above for first-class durum wheat, 78 kg and above for second-class durum wheat, and 76 kg and above for third-class durum wheat (Yürür 1998). When the results obtained from the experiment are examined, it is seen that most of the varieties are in the third class in terms of hectoliter weight. This situation is thought to be caused by drought. Türköz (2016), in his study conducted with durum wheat under Konya conditions, determined that the hectoliter weights of most of the varieties were lower than the third-class durum wheat class and reported that the reason for this decrease in hectoliter weights was insufficient and irregular rainfall during the experiment. Similarly, Guttieri et al. (2001), in a study conducted by applying two different drought stresses to 16 different durum wheat cultivars, observed that the hectoliter weights of the cultivars decreased significantly under stress conditions.

Table 2. Mean values of investigated characteristics and Duncan grouping

Cultivars	Test weight	Semolina color	Vitreousness	Protein content
Altıntaş-95	78.8 bcd*	30.2	97.0	14.1 ıj**
Burgos	78.8 bcd	29.7	97.2	16.9 a
Ç-1252	77.8 cdefg	27.8	98.2	14.2 hı
Dumlupınar	76.8 efgh	28.8	97.6	14.3 gh
İmren	76.4 gh	29.5	97.9	15.3 cd
Kızıltan-91	76.5 fgh	27.2	97.6	15.3 c
Kunduru-1149	76.9 efgh	28.9	96.6	14.4 fg
Kümbet-2000	75.9 h	27.3	96.3	12.7 l
Mimmo	77.3 defgh	28.0	95.0	14.4 fg
Mirzabey-2000	78.4 bcde	28.2	97.5	15.3 c
Sırçalı	76.2 gh	29.0	98.3	13.8 k
Svevo	78.1 cdef	29.2	96.3	12.7 l
Traubodur	77.5 defgh	29.2	97.4	14.8 e
Türköz	79.3 bc	28.8	96.6	15.1d
Vehbibey	76.1 gh	30.1	96.1	14.1 hı
Yelken-2000	82.1 a	27.7	95.6	14.1 ıj
Soylu	77.4 defgh	27.8	98.7	13.9 jk
Eminbey	77.8 cdefg	27.9	97.6	15.6 b
Leonardo	79.9 b	28.8	97.6	14.5 f
Levent	79.3 bc	28.1	95.9	15.2 cd
LSD	1.441	-	-	0.1715

*: 0.05 significance level, **: 0.01 significance level

3.2. Semolina color

The difference between the varieties in terms of semolina color was found statistically insignificant. The highest semolina color was observed in the Altıntaş-95 variety, while the lowest value was obtained from the Kızıltan-91 variety (Table 2). In another study conducted under Konya conditions, it was determined that the Altıntaş-95 variety gave the highest semolina color value (Aydoğan et al. 2012). In another study conducted for two years under dry conditions in Konya and Çumra locations, the researchers found that semolina color varied between 17.11-22.40 (Aydoğan et al. 2012). Although the study was conducted in the same region, it

can be said that the fact that the values obtained in the related study were considerably lower than the values found in our study may be because both studies were conducted in different years, places, and varieties.

In their studies on the subject, Kendal et al. (2012) determined semolina color as 19.7-28.4 and Kaplan Evlice and Özkaya (2019) as 20.56-26.87. It was observed that the semolina color values of the varieties in the experiment were higher than the results of other studies. It is thought that this may be due to climatic characteristics, especially insufficient rainfall. Banach et al. (2021) also reported that although the color value is a trait that is little affected by environmental conditions, this value increases in years with low rainfall. In their study in which they determined grain yellowness (b value), which is an indicator of the content of carotenoid pigments, the researchers stated that the values varied between 26.72-28.84. The results obtained from the study and the values obtained from this study are similar.

3.3. Glassiness

The difference between the varieties in terms of the glassiness ratio was found statistically insignificant. The glassiness rates of durum wheat varieties used in the experiment varied between 95.0-98.7% and the highest glassiness rate was observed in the Soylu variety, while the lowest value was determined in the Mimmo variety. It was observed that all of the varieties used in the experiment had a high glassiness ratio (Table 2). It can be said that the high glassiness rate in the study is due to the high temperature and low rainfall during the grain-filling period (Table 1). In this regard, Borghi et al. (1997) also stated that hot and dry conditions increase the rate of glassiness, although they cause irregularities in yield.

Kılıç (2020), in a study conducted with some durum wheat varieties under Kızıltepe and Diyarbakır conditions, reported that the glassiness rates varied between 74.1- 99.9% and both locations were suitable for durum wheat production. However, the Kızıltepe location is expected to have a high glassiness rate because it is warmer and rainfall is lower than the Diyarbakır location.

3.4. Protein rate

In the study, the difference between the varieties in terms of protein ratio was statistically significant at a 1% level. The highest protein rate was determined in the Burgos variety with 16,9% and the lowest was determined in the Kümbet-2000 variety with 12,7%. The protein rate of the other varieties in the experiment was between these values.

The variation in the protein ratio of varieties grown under the same conditions is due to the different genetic structures of the varieties and their responses to ecological conditions. Similarly, Gökmen (1989) reported that protein ratio varies primarily depending on a variety of characteristics. On the other hand, Çölkesen et al. (1993) reported that the protein ratio in wheat varies partly depending on the species and variety, but

mostly on environmental factors; generally, the protein ratio of glassy grains is higher than non-glassy grains. In this study, the fact that the varieties with a high glassy grain ratio also had a high protein ratio is by the findings of Çölkesen et al. (1993). Campbell et al. (1981) stated that the highest protein contents usually occur under unfavorable conditions. Although insufficient rainfall and hot weather in the year of the experiment (Table 1) negatively affected many traits, the fact that the protein contents of the varieties were within the desired limits confirms this information.

The hectoliter weight of the Kümbet-2000 variety with the lowest protein ratio was also found to be the lowest (Table 2). The high hectoliter weight is related to the hard structure of the grain and therefore the high protein content (Kün, 1988). Ateş Sönmezoğlu (2010) and Çevik (2018) stated that the protein ratio increased with decreasing thousand-grain weight. This information is confirmed by the fact that Ç-1252 and Sırçalı varieties showed low values in terms of protein ratio although their thousand-grain weights were high. There are other findings that the protein ratio increases with decreasing thousand-grain weight (Weston et al. 1993; Gürsoy, 2011; Kartal et al., 2011; Kon, 2019).

4. Conclusions

In this study, the Gevne Valley's Stratiomyidae fauna have been determined in the Gevne Valley, which is a very isolated area. It is important to conduct similar faunistic studies at certain intervals in the future to monitor these species.

The results obtained from this study, which was carried out to determine some quality characteristics of 20 durum wheat varieties grown in different regions of Turkey under Konya conditions and some suggestions that can be made on the subject are summarized below.

Due to the severe drought experienced during the growing period, the traits studied in this research were found to be different from most of the studies conducted in Turkey on the subject.

Drought caused by insufficient rainfall and high temperatures during the period starting from the emergence of stalks until the maturity of the plants affected glassiness, protein ratio, and semolina color, which are important quality traits of durum wheat, positively, and hectoliter weight negatively. Since the grain yield is very low, it seems possible to say that the increase in quality characteristics is an advantage in practice. Since there was an extreme drought during the growing period in which the research was conducted, it does not seem possible to make any variety of recommendations. For this reason, it would be better to carry out the study for at least a few years and make a variety of recommendations as a result.

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Investigation of the Effects of Potassium on Some Agronomic Traits in Dry Bean Genotypes

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HIGHLIGHTS

- Potassium is an essential mineral for plant growth and development.
- Dry beans are among the most consumed foods due to being satiating, giving plenty of energy and proteins in its content.
- Potassium has effects on the yield and quality of dry beans.

Abstract

This study was carried out to investigate the effects of 5 different doses of potassium (0, 15, 20, 25 and 30 kg da^{-1}) on some yield and important yield components on 6 different dry bean genotypes of bean [*Phaseolus vulgaris* L.] in Yunak Town – Konya City (TURKIYE) ecological conditions. was made in 2018. The aforementioned research was designed with 3 replications based on "Split Plots in Randomized Blocks Trial Design". According to the results of the research, it has been determined that potassium applications at different doses are statistically significant in terms of emergence time, flowering time, pod setting time, and vegetation period. As a result of the research; the emergence period was 6.33 – 15.67 days, the flowering period 32.00 – 71.67 days, the pod setting time 48.67 – 88.00 days, the vegetation period 84.67 – 118.00 days, the spad value 41.57 – 53.87 spad, number of main branches per plant 2.90 – 5.00, first pod height 9.40 – 18.40 cm, root neck diameter of 4.97 – 31.50 mm, the number of pods per plant varied between 13.30 – 42.00, the number of seeds per pod varied between 3.20 – 5.67 values. When evaluated in general, emergence time, flowering time, pod setting time increased with increasing potassium application, while vegetation time, and first pod height (maximum value at 15 kg da^{-1} dose) values decreased. In the study, all of the shortest duration values in terms of all phonological observations emerged in the Akkiraz genotype, which was applied at a fertilizer dose of 15 kg da^{-1}. The highest value for the first pod height was determined in the 25 kg da^{-1} fertilizer dose X Nirvana genotype, the highest pod number value in the 20 kg da^{-1} fertilizer dose X Nirvana genotype, the highest seed number value in 15 kg da^{-1} fertilizer dose X Nirvana genotype. For the consistency of the research findings, it can be said that longer-term studies and evaluation of different genotypes in different ecologies are required.

Keywords: Agronomy, Cultural practices, *Phaseolus vulgaris*, Fertilization

1. Introduction

If global population growth and current food consumption trends continue, 60% more food will be needed by 2050 than today. Increasing agricultural production is the most reasonable means to meet the need for more

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food and fight the problem of poverty. Since arable land is limited, increasing agricultural production can be achieved by increasing the productivity of existing areas under production or by improving and developing problem areas (Dibaba, 2015). However, the natural environments in which agricultural production is carried out are also under the influence of abiotic and biotic stress factors in a complex way. Plant responses to these stresses can be just as complex (Cramer, 2010; Kahraman, 2022). Turkiye has a great potential in terms of agricultural production, and besides seed production, it also has an important place in terms of ownership of processed product technology (Doruk Kahraman and Gokmen, 2021).

Legumes, which we use as food, have an important place in human nutrition both in our country and in the world. While cereals are in first place in the production of field crops, edible legumes are in second place (Gülümser, 2016). It has been reported that legumes, which have an important place in the human diet, have been found in tomb excavations and Egyptian pyramids in studies conducted from ancient times until today (Kızmaz and Gümüş, 2021). After cereals, they are the most produced field crops. In addition to nutrition, it maintains a symbiotic life with the symbiotic Rhizobium bacteria and plays a major role in converting the free elemental nitrogen in the air into a form that can be used by plants (Ceyhan et al., 2014).

While 7% in terms of carbohydrates and 22% in terms of vegetable protein are met in the human diet from legumes in the world; 5% of carbohydrates and 38% of proteins are met in the animal diet. The high protein content in legumes plays an active role in meeting nutritional deficiency. In addition, when compared to other protein groups, the reasons such as being easy to obtain, cheap, low-fat content and high fiber value increase the demand for these product groups (Gthb 2020). While 70% of the world's protein needs are provided from plant sources; 48.5% of vegetable proteins are met from legumes and 66% from cereals (Doğan et al., 2011). It contains an average of 18%-36% protein from edible legumes, as well as having plenty of vitamins A, B and D; it has an important place in nutrition because it contains elements such as calcium, iron, phosphorus and potassium (Yolci, 2020).

Bean is an annual herbaceous plant originating from the genus *Phaseolus* of the *Legumes* (*Fabaceae*) family, originating in Central America, and is one of the most important crops widely grown worldwide for both fresh bean and dried grain. Beans, with approximately 76 species, constitute 50% of the legumes consumed worldwide. Five different bean species are cultivated in the world (Celmeli et al., 2018), and two of them, *P. vulgaris* L. and *P. coccineus* L., are also grown in Turkiye (Smýkal et al., 2015).

Although Turkiye is not the homeland of dry beans, it is an important country for beans in terms of both genetic diversity and food culture, as it has micro gene centers (Kan et al., 2019). Beans, which can be grown in every region of our country, are most common in Central Anatolia. Bean, which has a very important place in the economy, is an important source of income for the farmer (Ulum et al., 2020; Doruk Kahraman and Kahraman, 2023).

Turkiye, which used to be an important bean exporter, has been trying to become a more self-sufficient country in recent years (FAOSTAT, 2018). Due to its geographical structure, Turkiye has a wide variety of bean genotypes. Dry beans can be grown in every region of Turkiye. According to the data of the Turkish Statistical Institute (Tuik, 2021), beans take third place after chickpeas and lentils among grain legumes in terms of cultivation area and production amount. The total amount of dry bean production in an area of approximately 103 thousand hectares in Turkiye in 2020 is 280 thousand tons, and the yield is approximately 2.71 tons ha^{-1}. Dry bean consumption per capita in Turkiye is around 3.5 kg per year, and the adequacy ratio is 75%. The provinces with the most common dry bean cultivation are Konya, Karaman, Erzincan, Niğde, Nevşehir, Samsun and Kahramanmaraş, respectively. In Konya, where this research was conducted, the dry bean cultivation area is 14788 ha, production is 49604 tons and yield is 335 kg da^{-1} (Tuik, 2021).

Potassium plays an important role in plant water relations, growth of new tissues, photosynthesis, water balance, transport of carbohydrates and sugars and activation of enzymes required in various plant metabolic

events. (Coker et al., 2003). Potassium deficiency causes increased susceptibility to drought, and diseases, decreased nitrogen use efficiency, fiber quality and low yield.

Potassium, one of the important macronutrients, is one of the main factors in protein synthesis, synthesis of glycolytic enzymes and photosynthesis (Marschner, 1995). Since drought occurs in plants under both drought and salt stress, K+ has the same importance in both stress conditions. As the amount of water in the soil decreases, the amount of K in the plant also decreases. Kuchenbuch et al. (1986), in their study, they stated that low soil moisture reduces root development and K uptake of onion plants. Plants growing under arid conditions are likely to show K deficiency (Beringer and Trolldenier, 1978). Many studies have shown that K fertilization has eliminated the negative effects of drought (Sangakkara et al., 2001). Potassium increases the resistance of plants to drought stress by regulating of stomata, osmoregulation, energy status, protein synthesis and internal balance (homeostasis) (Beringer and Trolldenier, 1978; Marschner, 1995). At the same time, the continuation of K turgor pressure (Mengel and Arneke, 1982) and reducing transpiration in dry conditions can prevent the plant from being damaged by drought (Andersen et al., 1992).

Cassman et al. (1989), in a 2-year field study in which they evaluated the variability in terms of potassium use efficiency related to potassium uptake, distribution and critical potassium requirements, it was determined that the yield was 29% higher in the first year and 35% higher in the second year in the potassium-use effective cultivars in the plots where potassium was not applied; they stated that the differences in variety yield were due to the higher cocoon set at the later fruit formation points, but this was not related to the differences in potassium distribution between vegetative and generative structures. In addition, if the supply of potassium is not limited, variety yields are similar; yields of two cultivars are closely related to leaf potassium concentration and potassium availability in the soil; it was determined that potassium uptake and total potassium accumulation were higher during the boll development period, especially at low soil potassium levels.

Researcher Yenigün (2021) stated that the potassium content of most of Turkiye's soils is high, but there are great debates regarding the use of potassium. The researcher also stated that the climate has an important effect on potassium availability, that new studies should be established in different soil conditions by using the up-to-date climatic data on potassium for each product, and that the most appropriate potassium dose should be determined in this context.

Considering the above-mentioned basic reasons and numerous literature reviews, it was concluded that the realization of this research, taking into account the needs of the region and the country, is of great importance to contribute to the production of functional food, especially for sustainable agricultural systems and healthy human nutrition. It was carried out in Yunak – Konya (TURKIYE) ecological conditions.

2. Materials and Methods

The field studies of this research were carried out in 2018 in the Sarayköy location of Yunak District of Konya province - Türkiye. In this experiment, which was carried out in 3 replications according to the Split Plots in Randomized Blocks Experiment Design, 5 potassium doses (0, 15, 20, 25 and 30 kg da^{-1} potassium sulfate) were placed on the main plots and dry bean genotypes were placed on the subplots.

The soil layers of 0-30 cm and 30-60 cm, which do not have salinity problems, have a clayey loam texture, are very calcareous, have a moderate amount of organic matter, sufficient in phosphorus, insufficient in potassium, and have normal alkaline character. In this research, as a source of potassium due to the high pH of the soil in the Konya Closed Basin where field trials were established; solid form fertilizer containing Potassium Sulphate (K_2SO_4) containing approximately 50% potassium and 46% sulfur as water-soluble mass was used. Considering that the recommended fertilizer dose is 20 – 25 kg da^{-1}, the application should be done

once before planting; 5 different doses of 0, 15, 20, 25 and 30 kg da^{-1} were applied to the plots before sowing and mixed with a harrow. Climatic features were similar to the long-term average.

In the research, 5 of the registered varieties (Akman-98, Red Kidney Bean type - Akkiraz, Karacaşehir-90, Nirvana and Zirve) supplied by the Department of Field Crops of the Faculty of Agriculture of Selcuk University, which was cultivated in large areas in Konya, were studied for many years. A total of 6 dry bean genotypes, including 1 (Alberto), among the foreign-origin dwarf dry bean populations, which stand out especially due to their high protein yield, were used as material. All registered cultivars and local populations used for integrity are designated as "genotype" in this study.

Considering the factors discussed in the research; a field trial consisting of 6 dry bean genotypes x 5 potassium doses x 3 replications, a total of 90 plots, was established. While the soil prepared by the technique was annealed, the seeds were planted on 19 May 2018, taking into account the regional conditions. Each parcel has a total area of 7.5 m^2, 2.5 m wide x 3.0 m long. A gap of 0.5 m was left between the plots and 2.0 m between the blocks. At harvest, the entire 1 row on the sides of the parcel and the 0.5 m long sections from both ends of the other rows will have an edge effect. According to the results of the soil analysis, suitable base fertilizer was given to the seedbed prepared by the technique before planting and mixed with the soil with a rake. In each plot, 5 rows were planted by hand, which will be opened at a distance of 50 cm with the marker, and it was diluted by hand so that the spacing between the rows was 15 cm after emergence.

During the growing period, cultural treatments (irrigation, fertilization, disease and pest control, hoeing) were carried out by the procedure throughout the experiment. During the vegetation period, irrigation was done according to the need and the plants were not put under water stress. The water needs of the plants were met by the drip irrigation system. After all the plants in the plots have matured, the parts except for the edge effect are harvested by hand, and important agronomic characteristics (emergence time, flowering time, pod setting time, vegetation period, spad value, number of main branches per plant, first pod height, root neck diameter, pod per plant) are harvested by hand. The number of seeds per pod) was determined.

The properties examined within the scope of the research were subjected to statistical analysis with the JUMP 5.0.1 program. As a result of the analysis of variance, the groupings for the features whose "F" value is significant; It was carried out at the 5% level with the "Student's test-test".

3. Results and Discussion

Tables of variance analysis and mean values are given below (From Table 1 to Table 20). As a result of the analysis of variance for the exit time; potassium dose, genotype, and interaction; it was significant at the 1% level. When the potassium dose is examined, the exit time; was detected between 9.44 days (15 kg da^{-1} dose) and 11.28 days (30 kg da^{-1} dose). The emergence times of the genotypes used in the study; while it had the shortest emergence period in the Population genotype with 8.13 days, the longest emergence period was determined in the Karacaşehir genotype at 12.73 days. When the interaction was examined, it was determined that the emergence period varied between 6.33 days and 15.67 days. In another study conducted in Konya ecology, the emergence period in dry bean genotypes was determined in the range of 5.67-19.0 days (Kahraman, 2014). In other studies, on the subject, emergence time in dry bean genotypes; 10-23 days (Yılmaz, 2008), 10.0-15.6 days (Güneş, 2011), 13-25 days (Atıcı, 2013), 6-9 days (Öztürk, 2018). It is thought that the variation in the emergence period may be due to genetic factors, as well as the effects of many factors such as climate, soil structure, and planting depth on the emergence period. A similar situation was observed in other studies conducted in the region (Doruk Kahraman and Gokmen, 2022).

When we look at the flowering period, the effect of potassium dose, genotype and interaction factors was significant at the 1% level. When the fertilizer doses were examined, the flowering period was between 44.39 days (15 kg da^{-1}) and 50.28 days (30 kg da^{-1}). Flowering time values were between 35.47 days (Akkiraz

genotype) and 60.27 days (Karacaşehir genotype). Flowering times for the interaction were determined between 32.00 and 71.67 days. In another study conducted by Kahraman (2014) in Konya ecology, the flowering period in dry bean genotypes was determined in the range of 43.33-63.17 days. According to the results of the studies on beans, the flowering period was 42-50 days (Madakbaş et al., 2004), 42.33-77.00 days (Erdinç, 2012), and 63.72 days (Ekincialp, 2012). The mentioned findings are similar to this study.

As a result of the variance analysis of the pod setting time; the effect of all 3 factors that were the subject of this research was significant at the 1% level. When examined in terms of potassium doses, the said period; was determined between 61.11 days (15 kg da^{-1}) – 64.44 days (30 kg da^{-1}). While the shortest pod tying time was 50.13 days (Akkiraz genotype), the longest time was determined as 77.07 days (Karacaşehir genotype). In terms of interactive effect, the pod setting time varied between 47.33 days and 88.00 days. In another study carried out, it was stated that the eating period of kidney bean and bean genotypes varied between 55-98 days (Öztürk, 2018). In another study carried out on beans, it was reported that genotypes reached eating death in the range of 88.67-128.33 days and the average duration of genotypes was 108.81 days (Loko et al., 2018).

According to the analysis of the variance of the vegetation period, the effect of each of the 3 factors discussed in this study was found to be statistically significant at the 1% level. The values in question in terms of fertilizer dose; it was found that it varied between 95.67 days (30 kg da^{-1}) and 97.22 days (0 kg da^{-1}). Accordingly, the shortest time was 87.67 days (Zirve genotype), while the longest was 111.80 days (Akman). When the values of the interaction were examined, the vegetation period was determined between 84.67 days and 118.00 days. Çirka (2012) conducted a study with 61 poles of 27 dwarf green beans; reported that the dwarf types reached the harvest in 61-83 days. In addition, Erdin (2012) explained in his study that the average harvest time was 92.71 days, and that the genotypes reached the average harvest time of the lowest at 68 days and the highest at 127 days. The researcher's results were found to be quite similar to our results.

Considering the results of the analysis of variance in terms of spad values; differences between genotypes were found to be significant at the 5% level, and significant at the 1% level in terms of interaction. The Nirvana genotype had the lowest spad value with 44.21 spad, and the Akkiraz genotype had the highest value with 47.35 spad. In terms of interaction, the values in question differed between 41.57 spad – 53.87 spad. In another study conducted in Konya ecology, the spad value in dry bean genotypes was determined between 36.82-49.95 days. It is known that chlorophyll content has a significant effect on yield in plant production and varies according to plant and leaf size (Erickson and Wedding, 1956). Similar to the results of this study, Luqueno et al. (2010) examined the effects of different nitrogen sources on yield in beans and determined that the chlorophyll value varied in the range of 10-45 spads. In a study, with chlorophyll content in dry beans; It has been stated that there is a direct and positive interaction with other growth characteristics due to the vegetative growth of the plant (Sara et al., 2013). In another study conducted in the Konya region (Kahraman, 2014), chlorophyll value in dry bean genotypes was determined in the range of 36.82 – 49.95 spads.

Table 1. Variance analysis summary of investigated traits in the trial

		Mean of Squares				
Sources of Variation	**DF**	**Emergence Time**	**Flowering Time**	**Pod Setting Time**	**Vegetation Time**	**Spad**
Replication	2	0,077	1,078	0,533	0,133	49,086
Potassium dose (A)	4	8,600**	88,222**	28,539**	6,961**	7,9603
Error$_1$	8	0,383	0,481	0,339	0,078	4,592
Genotype (B)	5	65,531**	1659,420**	2318,640**	1597,550**	28,611*
(A X B) Int.	20	3,887**	29,002**	45,079**	35,574**	25,8884**
Error$_2$	50	0,296	0,467	0,618	0,089	8,5792
Sources of Variation	**DF**	**Number of Main Branches per Plant**	**First Pod Height**	**Root Neck Diameter**	**Number of Pods per Plant**	**Number of Seeds per Pod**
Replication	2	0,026	0,264	61,668	11,977	3,224
Potassium dose (A)	4	0,436	0,906	73,886	46,092	0,556
Error$_1$	8	0,401	5,549	72,806	24,515	0,652
Genotype (B)	5	2,164**	38,401**	79,442	790,280**	2,054**
(A X B) Int.	20	0,594	23,122**	55,314	117,251**	1,294**
Error$_2$	50	0,375	6,642	56,429	15,571	0,469

*%5, **%1 statistically significance level

Table 2. Table of mean values of emergence time, "flowering time, pod setting time, vegetation time and spad in the bean genotypes

Potassium Dose (kg da^{-1})	Genotypes						Mean
	Akman	**Akkiraz**	**Karacaşehir**	**Nirvana**	**Population**	**Zirve**	
Emergence Time (days)							
0	12,67bcd	7,33mn	13,00bc	11,33ef	7,33mn	9,00jk	**10.11c**
15	12,33cd	6,33o	11,33ef	12,00de	6,67no	8,00lm	**9.44d**
20	11,33ef	9,00jk	13,33b	12,00de	9,00jk	10,00hı	**10.78b**
25	13,00bc	8,33kl	10,33gh	12,67bcd	8,33kl	10,00hı	**10.44bc**
30	11,33ef	9,00jk	15,67a	11,00fg	9,33ıj	11,33ef	**11.28a**
Mean	**12.13b**	**8.00d**	**12.73a**	**11.80b**	**8.13d**	**9.67c**	10.41
Flowering Time (days)							
0	54,67de	33,67o	58,67b	53,00f	36,00mn	39,00ıj	**45,83c**
15	55,33de	32,00p	55,67cd	51,67g	35,00n	36,67lm	**44,39d**
20	51,33g	37,33kl	59,67b	53,00f	38,00jk	41,00h	**46,72b**
25	55,67cd	32,67op	55,67cd	54,33e	37,33kl	39,33ı	**45,83c**
30	51,67g	41,67h	71,67a	56,67c	42,00h	38,00jk	**50,28a**
Mean	**53,73b**	**35,47e**	**60,27a**	**53,73b**	**37,67d**	**38,80c**	46,61
Pod Setting Time (days)							
0	73,33hı	49,33tu	75,00ef	77,33c	50,67rs	52,67pq	**63,06c**
15	72,33ı	47,33v	70,67j	73,67gh	50,33st	52,33pq	**61,11d**
20	68,67k	52,33pq	79,33b	76,00de	52,33pq	54,33no	**63,83b**
25	74,67fg	48,67u	72,33ı	76,67cd	53,33op	51,67qr	**62,89c**
30	64,33l	53,00p	88,00a	71,00j	55,67m	54,67mn	**64,44a**
Mean	**70,67c**	**50,13f**	**77,07a**	**74,93b**	**52,47e**	**53,13d**	63,07
Vegetation Time (days)							
0	118,00a	88,00n	104,00g	98,00j	88,00n	87,33o	**97,22a**
15	115,00c	84,67q	110,00d	96,00k	88,00n	88,00n	**96,94b**
20	108,00e	90,00l	105,00f	96,00k	90,00l	89,00m	**96,33c**
25	116,00b	86,00p	103,00h	96,00k	90,00l	86,00p	**96,17c**
30	102,00ı	90,00l	108,00e	96,00k	90,00l	88,00n	**95,67d**
Mean	**111,80a**	**87,73e**	**106,00b**	**96,40c**	**89,20d**	**87,67e**	96,47
Spad (spad)							
0	43,93e-ı	48,23b-e	41,60ı	46,37b-ı	43,23f-ı	46,27b-ı	**44,94a**
15	46,57b-h	46,77b-h	45,30c-ı	45,97b-ı	44,90d-ı	43,07f-ı	**45,43a**
20	47,63b-f	46,60b-h	42,70ghı	41,57ı	46,70b-h	53,87a	**46,51a**
25	45,97b-ı	45,27c-ı	48,43b-e	44,90d-ı	48,93bcd	42,70ghı	**46,03a**
30	47,20b-g	49,90abc	43,83e-ı	42,27h-ı	44,37d-ı	50,77ab	**46,39a**
Mean	**46,26ab**	**47,35a**	**44,37b**	**44,21b**	**45,63ab**	**47,33a**	45,86

Table 3. Table of mean values of main branches per plant, first pod height, root neck diameter, pods per plant and number of seeds per pod in the bean genotypes

Potassium Dose (kg da^{-1})	Genotypes						Mean
	Akman	Akkiraz	Karacaşehir	Nirvana	Population	Zirve	
Main Branches per Plant" (number/plant)							
0	3,57	3,27	3,50	4,63	4,00	4,37	**3,89**
15	4,03	3,33	2,90	4,03	4,33	3,93	**3,76**
20	3,40	3,40	3,53	4,33	4,63	4,33	**3,94**
25	3,17	3,57	4,33	3,30	4,00	3,67	**3,67**
30	3,13	3,53	4,37	4,37	4,03	5,00	**4,07**
Mean	**3,46c**	**3,42c**	**3,73bc**	**4,13ab**	**4,20a**	**4,26a**	3,87
First pod Height (cm)							
0	14,33a-h	14,00b-h	12,60e-j	15,33a-h	12,67e-j	13,13d-j	**13,68a**
15	11,20hıj	18,13ab	16,27a-e	17,80abc	11,70f-j	9,57ıj	**14,11a**
20	13,67c-ı	17,80abc	9,73ıj	14,73a-h	11,63f-j	14,37a-h	**13,66a**
25	9,40j	12,00f-j	17,07a-d	18,40a	12,77e-j	12,17e-j	**13,63a**
30	15,47a-g	17,40abc	15,57a-f	9,47ıj	12,00f-j	11,30g-j	**13,53a**
Mean	**12,81bc**	**15,87a**	**14,25ab**	**15,15a**	**12,15c**	**12,11c**	13,72
Root Neck Diameter (mm)							
0	9,18b	7,11b	7,96b	8,83b	8,90b	7,73b	**8,29a**
15	12,79b	7,67b	7,24b	9,27b	8,33b	5,37b	**8,45a**
20	8,15b	7,92b	7,64b	7,43b	8,40b	6,57b	**7,69a**
25	7,14b	6,55b	9,12b	7,33b	7,17b	4,97b	**7,05a**
30	10,87b	7,58b	7,47b	31,50a	8,93b	7,00b	**12,23a**
Mean	**9,63ab**	**7,37ab**	**7,89ab**	**12,87a**	**8,35ab**	**6,33b**	8,74
Pods per Plant (number/plant)							
0	21,73j-m	29,47f-ı	25,33h-l	37,73abc	20,60k-n	35,50b-f	**28,39a**
15	17,70mno	19,00l-o	14,73no	41,93ab	33,20c-g	31,03d-ı	**26,27a**
20	15,13no	27,80g-j	31,60c-h	42,00a	24,90ı-l	32,90c-g	**29,06a**
25	14,00 o	22,07j-m	16,33mno	30,73d-ı	36,00a-e	32,40c-g	**25,26a**
30	26,73g-k	16,60mno	13,30 o	29,60e-ı	36,93a-d	34,57c-f	**26,29a**
Mean	**19,06e**	**22,99d**	**20,26de**	**36,40a**	**30,33c**	**33,28b**	27,05
Seeds per Pod (number/pod)							
0	4,33c-f	5,33abc	3,67fg	5,13a-d	4,67a-f	3,20g	**4,39a**
15	4,30c-g	4,53b-f	5,27abc	5,67a	4,80a-e	4,23c-g	**4,80a**
20	5,60ab	4,13d-g	5,27abc	3,67fg	3,60fg	4,63a-f	**4,48a**
25	4,67a-f	5,13a-d	4,67a-f	5,27abc	3,97efg	4,30c-g	**4,67a**
30	5,07a-e	5,67a	4,13d-g	5,27abc	3,97efg	4,40c-f	**4,75a**
Mean	**4,79a**	**4,96a**	**4,60ab**	**5,00a**	**4,20b**	**4,15b**	4,62

In terms of the number of main branches in the plant, only the differences between genotypes were found to be statistically significant ($p<0.01$). Accordingly, the lowest value was determined in the Akkiraz genotype with 3.42 units/plant, and the highest value was determined in Zirve genotype with 4.26 units/plant. Singh et al. (1976) stated that the number of major branches in the plant is an important factor affecting the grain yield in dry beans. Similar to our study results, in various studies in which the number of main branches in a bean

was determined, this value was determined to be between 1.27-12.04 per plant (Anlarsal et al., 2000; Pekşen, 2005; Ülker and Ceyhan, 2008; Kahraman and Önder, 2009; Varankaya and Ceyhan 2012; Önder et al., 2013).

As a result of the analysis of variance for first pod height, genotype and interaction factors were found to be statistically significant ($p<0.01$). The said value differed between 12.11 cm (Zirve) and 15.87cm. In terms of interaction, it was determined that the values in question varied between 9.40 – 18.40 cm. The height of the first pod of beans is important in that the harvest can be done by machine. In various studies, it has been determined that the height of the first pod varies between 3.56-42.60 cm in bean, and it covers the values obtained as a result of our study (Bozoğlu, 1995; Anlarsal et al., 2000; Ceyhan 2004; Düzdemir and Akdağ, 2001; Pekşen, 2005; Pekşen and Gülümser, 2005; Kahraman and Önder, 2009; Önder et al., 2013).

As a result of the analysis of variance in terms of root neck diameter, the effects of the factors that were the subject of this study were found to be statistically insignificant. However, it has been revealed that the values of the root neck diameter show a wide variation in the range of 4.97 mm (25 kg da^{-1} X Zirve genotype) – 31.50 mm (30 kg da^{-1} X Nirvana genotype). It has been stated that there is a statistically significant and positive correlation between root neck diameter and pod filling (Knopkiewicz and Swiecicki, 2013) and the amount of photosynthesis (Stoffella et al., 1981). Researcher Ellal et al. (1982), 3.80-7.20 mm of the diameter of the root neck of dry beans, while Abubaker (2008) determined between 3.54-6.17 mm. In another study conducted in Konya ecology (Kahraman, 2014), the root neck diameter of dry bean genotypes was determined in the range of 5.63 – 20.87 mm.

In terms of the number of pods in the plant, the genotype and interaction effect of the factors that are the subject of the research was found to be significant at the level of 1%. The said value differed between 19.06 (Akman genotype) and 36.40 (Nirvana genotype). When the interactive effect was examined, the number of pods per plant was found to range from 13.30 to 42.00. Ergün (2005) reported that the number of pods per plant of the genotypes ranged from 22.85 to 201.9 units and the average number of pods per plant of the genotypes was 36. Zeytun (1987) found the number of pods per plant between 16.32 and 86.28 in his study. Similar results to our research results were also reported by Ceyhan and Şimşek (2021), Kepildek and Ceyhan (2021), Küçük and Ceyhan (2022), Tamüksek and Ceyhan (2022) and Tekin and Ceyhan (20022).

The effect of genotype and interaction factors, which are the subject of this study, were statistically significant at the 1% significance level in terms of the number of seeds in the broad bean. Accordingly, when the genotypes were examined, this value emerged in the range of 4.15 (Summit) – 5.00 (Nirvana). Considering the interactive effect, it was seen that this value was in the range of 3.20 – 5.67 items. Akbulut (2011) reported that the number of seeds in the pod varied between 5 and 8, and the genotype average was 6.42. Seymen (2010) reported in his research that the number of seeds per pod of genotypes is between 6.7 and 7.5. Zeytun (1987) reported that the number of seeds per pod of 33 bean genotypes grown in the Çarşamba plain was between 3.14 and 5.87. Another researcher reported that the average number of seeds in a fresh pod of 125 genotypes was 5.01, however, the number of seeds in a pod varied between 2.85 and 7.90 (Erdinç, 2012). Similar results to our research results were also reported by Kavasoğlu and Ceyhan (2018), Özsoy Altunkaynak and Ceyhan (2018), Kepildek and Ceyhan (2021), Küçük and Ceyhan (2022), Tamüksek and Ceyhan (2022) and Tekin and Ceyhan (20022)

4. Conclusions

According to the results of this research, in terms of all the phonological observations covered in the study, the shortest time values were determined in the Akkiraz genotype, which was applied at a fertilizer dose of 15 kg da^{-1}. In terms of the first pod height examined in the study, the highest value was determined in the 25 kg da^{-1} fertilizer dose X Nirvana genotype, the highest pod number value in the 20 kg da^{-1} fertilizer dose X

Nirvana genotype, the highest seed number value in the 15 kg da^{-1} fertilizer dose occurred in the X Nirvana genotype.

The main reasons for both the decrease in legume production and the extinction of local varieties in Turkiye are the increase in costs, fluctuations in prices, unreasonable price policies and low yield due to problems in fertilization. Improvement of the economic conditions provided to bean producers, innovations in production practices, and the development of durable and productive bean plants create positive effects on the economy. Due to the increase in population every year, the amount of consumption due to being both a vegetable protein source and one of the basic foods of Turkish cuisine is higher than the previous year.

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Determination of Resistance Levels of Selected Tomato Genotypes to *Meloidogyne incognita, Tomato Yellow Leaf Curling Virus* (TYLCV) *Verticillium Wilt, Fusarium oxysporum radicis, Fusarium Wilt, Tomato Spotted Wilt Virus* (TSWV)

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HIGHLIGHTS

- In our study, C1-3, C1-13, C1-21, C1-23, C1-24, C1-25, C1-34, C1-35, C1-36, C1-37, C1-39, C1-40, C1 Genotypes -42, C1-43, C1-46, C1-48, C1-56, C1-57, C1-59, C1-66, C1-67 showed homozygous resistance to all diseases and pests mentioned. It has formed the most important output of our work.

Abstract

Tomato is one of the most cultivated vegetables in the world. In this context, intensive tomato breeding studies are carried out around the world and new cultivars are emerging every day, which leads to great competition. In particular, resistance or tolerance levelstolerance levels to some important diseases and pests are considered important in cultivar breeding and in determining the commercial value of cultivars. In this context, the determination of resistance levels to 70 tomatoes, *Meloidogyne incognita, Tomato Yellow leaf curling virus* (Tylcv), *Verticillium wilt, Fusarium oxysporum radicis, Tomato spotted wilt virus* (TSWV), *Fusarium Wilt*, which have the potential to become parent lines at S8 level due to their agro-morphological characteristics formed the subject of this study. When the results of the study are examined, tomato genotypes showed resistance/sensitive levels according to combinations of alleles as 58 genotypes of RR (homozygous resistant), 10 Rr (heterozygous), 2 rr(sensitive) to *Meloidogyne incognita*, 45 RR (homozygous resistant), 15 Rr (heterozygous),10 rr (sensitive)to *Verticillium dahliae*, 10 to, 52 RR (homozygous resistant), 13 Rr (heterozygous), 5 rr (sensitive) to *Tomato Spotted Wilt Virus*,46 RR (homozygous resistant) 18 Rr (heterozygous), 6 rr (sensitive) to *Tomato Yellow leaf Curl Virus*, *Fusarium oxysporum (Fusarium wilt)* 49 RR (homozygous resistant), 13 Rr (heterozygous), 8 rr (sensitive), *Fusarium oxysporum radicis* (Frl) 52 Their resistances were determined as RR (homozygous resistant), 12 Rr (heterozygous), 6 rr (sensitive).

Keywords: Domates, *Meloidogyne incognita*, *Verticillium dahlia*, *Tomato Spotted Wilt Virus*, *Tomato Yellow leaf Curl Virus*, *Fusarium oxysporum (Fusarium wilt)*

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1. Introduction

It is reported that tomato is susceptible to many pathogens that limit or completely eliminate their growth and development (Klee and Giovannoni 2011). While viral diseases cause 80-100% losses undercover in tomato cultivation (Ates et al. 2019)other biotic stress factors are reported to cause 20-40% yield losses. While various methods such as the use of chemical pesticides and cultural practices are used in the fight against diseases and pests, especially the use of resistant varieties (Hull 2009), chemical control produces no results in the fight against viruses (Jones 2006). In the struggle to reduce the effects of biotic stress factors, as a result of unconscious and uncontrolled use of chemical pesticides, the resistance to diseases and pests can increase, and human health and the environment are adversely affected. The most effective, EcoReco-friendly economical method in the fight against the abovementioned diseases and pests is to use resistant varieties. The use of resistant varieties provides not only an increase in yield and quality but also a great decrease in the use of chemicals (Qi et al. 2022). Considering these reasons, it has become a necessity to use resistant varieties during the fight against viral diseases apart from other biotic stress factors (Erkan, 2020a). With this aspect, developing resistant varieties is among the important issues of plant breeding. In particular, adverse conditions such as viruses, bacteria, nematodes and fungi that cause biotic stresses limit tomato cultivation and cause significant yield losses (Grube et al. 2000). Root-knot nematodes (*Meloidogyne spp*.) are one of the main pests of tomatoes. Resistance to the strain *Meloidogyne incognita* was conferred by the Mi gene transferred from *Solanum peruvianum* (Smith 1944). Mi-1.1, Mi-1.2 and Mi-1.3 genes have been reported in the Mi locus (Milligan et al., 1998). *Tomato yellow leaf curling virus* (TYLCV) is a viral disease that does not have a chemical control method and causes high yield losses. Several resistant genes against TYLCV have been identified in wild species including *S. chilense* (Ty-1, Ty-3, Ty-4, and Ty-6), *S. habrochaites*(Ty-2), and *S. peruvianum* (ty-5). Ty1/Ty-3 and Ty-2 genes were successfully used for breeding new tomato varieties. Ty-1 and Ty-3 are mapped to chromosome 6 and Ty-2 is mapped to chromosome 11 and marker assisted selection procedures were implemented in breeding programs (Gill et al. 2019; Ji et al. 2007; Yang et al. 2014). Another viral disease that limits tomato cultivation is the *tomato spotted wilt virus* (TSWV). The presence of 8 TSWV resistance genes was determined in tomato. The Sw-5 gene, which is dominant against TSWV in the *S. peruvianum*genome, has been reported as a source of resistance to TSWV as it is not race-specific (Stevens et al., 1991). *Fusarium oxysporum f. sp. lycopersici* (FOL) and *Fusarium oxysporum f. sp.* the pathogen radicis lycopersici (FORL) is one of the root diseases that limit cultivation and cause yield losses in tomato-growing countries around the world, including Turkey (Cucu et al. 2020). Resistance to FORL in tomato is controlled by the Frl dominant gene (Roberts et al., 2000). *Verticillium wilt* (Ve) is one of the most important soil-borne fungal factors encountered in tomato cultivation (Song et al. 2017). Independent Ve1 and Ve2 genes providing pathogen resistance have been identified (Kawchuk et al. 2001). As in the whole world, intensive studies are carried out on tomato cultivation in Turkey, and many new varieties with commercial importance are coming to the market day by day, and it is a necessity to come up with new varieties in a competitive environment. In this study, the resistance of pure S8 level tomato lines against *Meloidogyne incognita, Tomato yellow leafroll virus* (TYLCV), *Verticillium wilt, Fusarium oxysporum radicis, Tomato spotted wilt virus* (TSWV), *Fusarium Wilt* was investigated by molecular methods. It is aimed to determine the use of these materials in breeding programs and to reveal the usability of these materials.

2. Materials and Methods

The study was carried out in cooperation with the private sector. 70 genetic materials obtained by the expansion of commercial varieties available in the market and reaching the S8 level by the preliminary selection, constituted the plant material of the study. The set of tomato genotypes was selected for resistance to *Meloidogyne incognita, Tomato Yellow leaf curling virus* (TYLCV), *Verticillium wilt, Fusarium oxysporum* radicis, *Tomato spotted wilt virus* (TSWV) and *Fusarium Wilt*. Two markers were used for the selection of *M. incognita*

resistance status (Table 1) (Garcia et al., 2007). TYLCV resistance was determined based on carrying either Ty-1/Ty-3 (Ji et al., 2007; Barbieri et al., 2010), or Ty-2 (Yang et al., 2014; Kim et al., 2020) resistance alleles. Selection for Verticillium wilt was performed using the CAPS marker described by Acciarri et al. (2007), *Fusarium oxysporum* f. sp. *radicis*resistance was determined according to Mutlu et al. (2015), TSWV resistance was monitored using the SCAR marker introduced by Dianese et al. (2010) and Fusarium wilt resistance was evaluated based on a CAPS (Staniaszek et al. 2007) and a SCAR marker (Zhang and Panthee, 2021) (Table 1). For molecular characterization, leaf samples were taken for DNA isolation from each genotype from healthy, young leaves of plants in the young seedling stage. Leaf tissue samples were stored at -20 °C. Tissue homogenization for DNA extraction was performed using a Qiagen Tissue Lyzer II device. SCAR and CAPS marker fragments (listed in Table 1) amplified from tomato leaf DNA samples. PCR mixtures of 20µL were prepared as follows: 0.5 unit Amplitaq Gold® polymerase, 1x AmplitaqGold® PCR Buffer, 2.5 mM $MgCl_2$, 200µM each dNTP, 300 nM each primer,1.0µL of template DNA (concentration adjusted to 50 ng/µL)and nuclease-free H_2O. PCR cycling conditions were as follows: 10 min/ at 95°C initial denaturation, 35 cycles of 30 sec/95°C denaturation; 30 sec/60°C annealing reaction, 30 sec/72°C extension, followed by a final extension step of 10 min/72°C Restriction reactions for CAPS markers; Restriction reactions were prepared in 20µl mixtures containing 10U restriction enzyme (NEB), 1X restriction buffer, 5µl PCR product and distilled, deionized water. SCAR and CAPs marker fragments were visualized with the Qiaxcel Fragment Analyzer (Qiagen Sample & Assay Technologies) capillary electrophoresis system and agarose gel electrophoresis.

3. Results

Since different genes provide resistance to diseases, different primer pairs were screened for each gene. Marker fragments were visualized with a capillary electrophoresis system. As a result, 58 (82%) homozygous, 10 (14%) heterozygous and 2 (2%) sensitive resistance to *Meloidogyne incognita* were determined.45 (64%) homozygous, 15 (21%) heterozygous and 10 (10%) sensitive resistance to Verticillium wilt were determined. 52 (74%) homozygous, 13 (18%) heterozygous and 5 (5%) sensitive resistance to Tomato Spotted Wilt Virus were determined. 46 (65%) homozygous, 18 (25%) heterozygous, 6 (8%) sensitive resistance to Tomato Yellow leaf Curl Virus were determined. To *Fusarium oxysporum* (*Fusarium wilt*) 49 (70%) homozygous, 13 (18%) Rr heterozygote, 8 (11%) sensitive resistance levels were determined. *Fusarium oxysporum radicis* (Frl) 52 (74%) homozygous resistance, 12 (17%) heterozygous resistance, and 6 (7%) sensitive resistance levels were determined. In Table 2, resistance to diseases and pests of *Meloidogyne incognita, Verticillium dahlia, Tomato Spotted Wilt Virus, Tomato Yellow leaf Curl Virus, Fusarium oxysporum (Fusarium wilt), Fusarium oxysporumradicis* are given.

Table 1. Primes used to determine the resistance levels of genotypes to the diseases mentioned.

Disease Name	Marker Name	Gen*	Primer Forward	Primer Reverse
Meloidogyne spp	CAPS	MI-REX	TCGGAGCCTTGGTCTGAATT	GCCAGAGATGATTCGTGAGA
	SCAR	MI23	TGG AAA AAT GTT GAA TTT CTTTTG	GCA TAC TAT ATG GCT TGT TTA CCC
Tomato Yellow Leaf Curling Virus (Tylcv)	CAPS	TY-1	GGTACTCCTGGAAGGGTTAAGG	CACGCTGGTTCTGTTGTATCTC
	SCAR	TY-3	GGTAGTGGAAATGATGCTGCTC	GCTCTGCCTATTGTCCCATATATAACC
	SCAR	TY-2	ACCCCAAAAACATTTCTGAAATCCT	TGGCTATTTTGTGAAAATTCTCACT
Tomato Spotted Wilt Virus	SCAR	Sw-5–2	AATTAGGTTCTTGAAGCCCATCT	TTCCGCATCAGCCAATAGTGT
Fusarium oxy. radicis	SCAR	Frl	CACATTCATCATCTGTTTTTAGTCTATTC	CACAATCGTTGGCCATTGAATGAAGAAC
Fusarium Wilt	CAPS	I-2	GGGCTCCTAATCCGTGCTTCA	GGTGGAGGATCGGGTTTGTTTC
	SCAR	I3	TTCCCTCAATCCAACAAAAGTT	ACTCTCGAGTTCCGGTGAAA
Verticillium Wilt	CAPS	V2LeO3	CAAACATAGCTGGAAGAATC	TAGGAGGAAAAGAATTGG

[1]Marker amplicon sizes are as follows: MI-REX, Resistant: TaqI digested bands of 570 and 160 bp, Susceptible: remains uncleaned (750 bp); MI23, Resistant: 380 bp, Susceptible: 420 bp; TY-1, Resistant: TaqI digested bands of 500, 300 and 160 bp, Susceptible: TaqI digested bands of 500, 300 and 200 bp; TY-2, Resistant: 120 bp, Susceptible: 213 bp; TY-3, Resistant: 630 bp, Susceptible: 320 bp; Sw-5-2, Resistant: 574 bp, Susceptible: 464 bp; Frl, Resistant: 950 bp, Susceptible: 1000 bp; I-2, Resistant: FokI digested fragments of 390 and 410 bp, Susceptible: remains uncleaned (800 bp); I3, Resistant: 673 bp, Susceptible: 480 bp; V2LeO3, Resistant: HincII digested fragments of 428 and 601 bp, Susceptible: remains uncleaned (1029 bp) Genetic distances of the markers with the disease resistance traits: TY-1: 0.2 cM, TY-3: 1.4 cM, Frl: 0.016 cM, I-2: 0.1cM. Markers located inside the genes of interest: MI-REX, MI23, TY-2, Sw-5–2, I3 and V2LeO3.

Table 2. Disease and pest resistance status of *Meloidogyne incognita, Verticillium dahlia, Tomato Spotted Wilt Virus, Tomato Yellow leaf Curl Virus, Fusarium oxysporum (Fusarium wilt), Fusarium oxysporum radicis*

Genotype	*Meloidogyne incognita*resistance status (MI-REX & MI23)*	Tomato Yellow leaf Curl Virus (Ty-1/Ty-3 or Ty-2)*	Tomato Spotted Wilt Virus resistance status (Sw 5-2)*	*Fusarium* oxy. *radicis* resistance status (Frl) *	Verticillium Wilt resistance status (V2LeO3)*	Fusarium Wilt resistance status (I-2 & I-3)*
C1-1	RR	RR	RR	RR	Rr	Rr
C1-2	RR	RR	RR	Rr	RR	Rr
C1-3	RR	RR	RR	RR	RR	RR
C1-4	RR	RR	Rr	RR	Rr	RR
C1-5	RR	RR	RR	RR	rr	RR
C1-7	RR	RR	RR	Rr	RR	RR
C1-8	RR	Rr	Rr	Rr	RR	RR
C1-9	RR	RR	RR	Rr	RR	RR
C1-10	RR	RR	Rr	Rr	RR	RR
C1-11	RR	RR	RR	Rr	RR	RR
C1-12	RR	RR	Rr	RR	RR	RR
C1-13	RR	RR	RR	RR	RR	RR
C1-14	Rr	rr	rr	RR	RR	RR
C1-15	RR	rr	rr	RR	Rr	Rr
C1-16	RR	RR	Rr	RR	Rr	Rr
C1-17	RR	RR	RR	RR	Rr	Rr
C1-18	RR	RR	RR	RR	rr	rr
C1-19	Rr	rr	rr	rr	rr	rr
C1-20	RR	Rr	Rr	RR	rr	rr
C1-21	RR	RR	RR	RR	RR	RR
C1-22	RR	Rr	RR	RR	RR	RR
C1-23	RR	RR	RR	RR	RR	RR
C1-24	RR	RR	RR	RR	RR	RR
C1-25	RR	RR	RR	RR	RR	RR
C1-26	RR	rr	Rr	Rr	Rr	Rr
C1-27	Rr	RR	RR	RR	Rr	Rr
C1-28	RR	RR	RR	RR	Rr	Rr
C1-30	RR	Rr	Rr	Rr	Rr	Rr
C1-31	RR	RR	RR	RR	Rr	RR
C1-32	RR	RR	RR	RR	Rr	RR
C1-33	Rr	Rr	RR	RR	Rr	RR
C1-34	RR	RR	RR	RR	RR	RR
C1-35	RR	RR	RR	RR	RR	RR
C1-36	RR	RR	RR	RR	RR	RR
C1-37	RR	RR	RR	RR	RR	RR
C1-38	Rr	RR	RR	RR	RR	RR
C1-39	RR	RR	RR	RR	RR	RR

Table 2. Continue

Genotype	*Meloidogyne incognita*resistance status (MI-REX & MI23)*	Tomato Yellow leaf Curl Virus (Ty-1/Ty-3 or Ty-2)*	Tomato Spotted Wilt Virus resistance status (Sw 5-2)*	*Fusarium* oxy. *radicis* resistance status (Frl) *	Verticillium Wilt resistance status (V2LeO3)*	Fusarium Wilt resistance status (I-2 & I-3)*
C1-40	RR	RR	RR	RR	RR	RR
C1-41	Rr	RR	RR	RR	RR	RR
C1-42	RR	RR	RR	RR	RR	RR
C1-43	RR	RR	RR	RR	RR	RR
C1-44	RR	Rr	RR	rr	rr	rr
C1-45	rr	rr	Rr	Rr	rr	Rr
C1-46	RR	RR	RR	RR	RR	RR
C1-47	RR	RR	RR	rr	rr	rr
C1-48	RR	RR	RR	RR	RR	RR
C1-49	rr	Rr	RR	RR	RR	RR
C1-50	RR	Rr	RR	RR	RR	RR
C1-51	RR	Rr	Rr	Rr	Rr	Rr
C1-52	RR	Rr	RR	rr	rr	rr
C1-54	RR	Rr	RR	RR	RR	RR
C1-55	Rr	Rr	Rr	RR	RR	RR
C1-56	RR	RR	RR	RR	RR	RR
C1-57	RR	RR	RR	RR	RR	RR
C1-59	RR	RR	RR	RR	RR	RR
C1-60	Rr	RR	RR	RR	RR	RR
C1-61	RR	RR	Rr	Rr	Rr	Rr
C1-62	RR	Rr	RR	RR	RR	RR
C1-63	Rr	RR	RR	RR	RR	RR
C1-64	RR	rr	rr	rr	rr	rr
C1-66	RR	RR	RR	RR	RR	RR
C1-67	RR	RR	RR	RR	RR	RR
C1-68	RR	RR	RR	RR	rr	RR
C1-69	RR	RR	Rr	Rr	Rr	Rr
C1-70	RR	Rr	RR	RR	RR	RR
C1-72	RR	Rr	RR	RR	RR	RR
C1-73	RR	Rr	rr	RR	RR	RR
C1-74	RR	Rr	RR	RR	RR	RR
C1-90	RR	Rr	RR	RR	RR	rr
C1-160-4	Rr	RR	RR	rr	RR	RR

4. Discussion

Lizardo et al.(2022) reported that 8 cultivars gave a sensitive band at 430 bp as a result of the use of the Mi23 molecular marker against *M. incognita*, and that these cultivars have no resistance to *M. incognita* and the sources of resistance need to be determined. Bozbuga et al. (2020) In a study examining the levels of resistance against *Meloidogyne incognita*, it was reported that three genotypes were resistant and 96 genotypes were susceptible. Kabas et al. (2021), it was reported that 7 genotypes were heterozygous resistant (464-575 bp and 510-575), 23 were homozygous resistant (575 bp) and 10 genotypes were susceptible (464 bp) as a result of molecular investigations against TSWV. Erkan (2020b) reported that, as a result of molecular investigations against TYLCV in commercial tomato varieties, 8 varieties of TYLCV gave a sensitive band at 269 bp, and two resistant bands of 519 bp and 269 bp in 12 varieties. Basım et al.(2022) in his study examining the levels of resistance against *Tomato spotted wilt virus, Tomato yellow leaf curl virus, Meloidogyne incognita*; 34 susceptible to TYLCV, 56 heterozygous resistant, 4 homozygous resistant, 57 susceptible to T SWV, 27 heterozygous resistant, 4 homozygous resistant and 2 genotypes in which Sw5-2 marker did not work, against *Meloidogyne spp*. As a result of the use of Mi23 molecular marker, 44 sensitive, 35 homozygous resistant and 11 heterozygous resistant were determined. Mutlu et al. (2015) designed a marker for the Frl gene. Homozygous resistant at 950 bp, susceptible at 1000 bp, and heterozygous resistant individuals have been reported to give bands at 950-1000. While 14 homozygous resistant, 80 heterozygous resistant and 63 susceptible genotypes were detected against *Fusarium oxysporum* in *S. lycopersicum* genotypes, 47 homozygous resistant, 66 heterozygous resistant and 45 sensitive genotypes were determined against *Verticillium wilt* (Aydın and Aktaş 2022).

5. Conclusions

The presence of genotypes with resistance genes against diseases and pests, which cause significant problems in tomato cultivation, which has a large production area and production amount in the world, is a valuable situation in terms of breeding. As a result of the study, more than one genotype with resistance gene against the aforementioned diseases and pests was determined. C1-3, C1-13, C1-21, C1-23, C1-24, C1-25, C1-34, C1-35, C1-36, C1-37, C1-39, C1-40, C1-42, C1-43, C1-46, C1-48, C1-56, C1-57, C1-59, C1-66, C1-67 genotypes which showed homozygous resistance against all the diseases and pests mentioned in our study are the most important output of the study. At the same time, 54 of the genotypes are homozygous resistant to 5 factors (RR), heterozygous to another factor (Rr), 64 of the genotypes are homozygous resistant to 4 different disease factors (RR), heterozygous resistance to the other two factors (Rr), gene determined to be carried. Considering these data obtained, a valuable gene pool with resistance to disease factors has been created for future breeding studies.

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Survey of Herd Management on Conventional Dairy Farms in North Algeria

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HIGHLIGHTS

- Most dairy farmers in Mostaganem province, Algeria feed their cows a basic ration of oat hay and straw, while only 32% use corn silage.
- Mastitis was the most common disease reported by farmers, with a culling rate of 23%, highlighting the need for improved herd health management practices.

Abstract

A survey was conducted to evaluate husbandry practices and herd health management in dairy farms in Mostaganem province, located in north Algeria. Data was collected through face-to-face interviews with 56 farmers, followed by a visit to the production environment of the dairy cows. The results showed that 64% of farmers feed their cows a basic ration of oat hay and straw, while 32% use corn silage. On average, 9.85 ±0.32 kg of concentrate was distributed per dairy cow. Most farms didn't have efficient forage production, while only 21% of them produced all the necessary forage. The average milk production per cow on the surveyed farms was 18.19 ±0.45 L, with a lactation length of 293.5 ±1.65 days. The cows were milked using a portable milking machine in poor hygienic conditions. Estrus detection was performed occasionally by farmers, and natural breeding was the main method of insemination, occurring at a rate of 63%. The voluntary waiting period was on average 76.6 ±3.56 days, and the average calving interval was 14.35 ±0.2 months. The culling rate in dairy farms was 23% on average, with the most common reasons for culling being mastitis and age at a rate of 23% and 21% respectively. The main diseases reported by the farmers were mastitis (82%), followed by lameness (57%). All surveyed farmers vaccinated their herds against only rabies and foot-and-mouth disease. This survey can help to identify the challenges and potential opportunities for improving dairy farm productivity and welfare in the Mostaganem province. The agricultural and economic sectors should work with farmers towards improving dairy farming techniques and practices, using efficient feeding systems and enhanced technology of dairy herd management, providing training and education to farmers, and resolving herd health issues to increase the economic efficiency of the dairy industry.

Keywords: Algeria, Cow, Dairy, Farms, Management, Survey

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1. Introduction

Dairy cow farming plays a vital role in the development of Algeria's dairy sector, agriculture, and food safety. Proper management of feeding, reproduction, production, and herd health has a significant impact on a dairy farm's economy and performance. To run a successful dairy farm, trained employees with husbandry knowledge are necessary, as farmers must be able to identify estrus, predict calving times, diagnose health and metabolic issues, and maintain milk quality and herd welfare. Despite the Algerian government's efforts to increase milk production through subsidies and support for breeders, milk collectors, processors, calf births, veterinary care, vaccination against foot-and-mouth disease, and the production of fodder and irrigation, the country's milk production remains low. Algeria has a cow population of 932,875 (MADR 2021), but only produces 2.5 billion liters of fluid milk per year, while demand is estimated at 4.5 billion liters (USDA 2022). In comparison, Canada, with a cow population of 977,800, produces 9.51 billion liters of milk (CDIC, 2021). and Austria, with a smaller cow population of 524,000, produces 3.82 billion liters (SA 2021). The low economic benefit and productivity in Algeria's dairy cattle industry can be attributed to several factors, such as a lack of forage, both in quantity and quality, prevalent diseases, inadequate herd health programs, and a lack of technological support. Poor heat detection, ineffective management practices and policies, and seasonality of production, as identified by Kaouche-Adjlane (2015), can also hinder productivity. Improved management skills and precision technology, which can reduce labor needs and enhance herd management, may help address these issues. The use of advanced technology in dairy farming is increasing as it enables farmers to better monitor and manage their cows, reduce labor needs, and improve herd management. These technologies provide farmers with advanced capabilities for managing their herds more efficiently. Research has shown that precision technology can help to improve the efficiency and productivity of dairy farms (Bewley 2010; Eastwood et al. 2012; Eastwood et al. 2015). As the complexity of cow management continues to increase, the use of these technologies is becoming increasingly important for improving management skills (Edwards et al. 2014; Bewley 2016). However, there is a lack of data on dairy farm management and performance in Algeria, specifically in the Mostaganem province, as well as limited research on the production systems in place. This may make it difficult to gain insight into the specific challenges and opportunities facing the dairy industry in Mostaganem. Surveys can help identify the major problems limiting the productivity and welfare of dairy cattle and identify potential avenues for improvement, which can guide Algeria's agricultural and economic sectors in setting priorities.

In this study, we present the findings of a survey of dairy farms in the Mostaganem province of northern Algeria. The study aimed to evaluate husbandry management practices that impact animal productivity and welfare, such as feeding and reproductive management, milk production, elements of herd health management, and primary herd health issues.

2. Materials and Methods

2.1. Study region

The province of Mostaganem is situated in the north of Algeria and is made up of two regions: the plateau and the Dahra highlands. These regions are further divided into four distinct morphological divisions: the low valleys in the west, the Dahra Mountains, the Mostaganem plateau, and the valleys in the east.

The province has a total agricultural area of 177,310 ha, with 132,268 ha being usable agricultural land, 42,870 ha being irrigated agricultural land, and 15,970 ha being designated for the growth of fodder crops such

as vetch, oats, corn, sorghum, barley, and oats. The province is home to a total of 31,900 cattle, including 21,100 dairy cows (DSA, 2021).

2.2. Data collection

A survey of dairy cattle farms in the Mostaganem province was conducted from January 2020 to March 2021 using a stratified random sampling method to select the farms (Thrusfield 2018). A total of 56 farms with 1,141 cattle, including 641 dairy cows, participated in the survey. The survey aimed to gather data on dairy farm management and performance by conducting interviews with the farmers and visiting the barns to observe and discuss the various practices used in the dairy herds. The questionnaire was divided into sections on feeding management, reproduction management, the milking system and production, treatment during the drying off period and dry period treatment; culling rate; and herd health management. This work did not involve the use of animals for laboratory studies. There is no violation of animal rights.

2.3. Statistics analysis

The data collected from the survey was analyzed using XLSTAT (2019) software. In the study, each farm was considered the experimental unit, and the variables in the questionnaire were coded and their frequencies determined. Descriptive statistics and the chi-square ($\chi 2$) were the statistical methods employed for data analyses. Mean, standard deviation, standard error and frequency was calculated.

3. Results

3.1. Feeding management

The majority of farmers in the study (64%) provided a basic ration of oat hay and straw for their dairy cows, while only 32% of farms distributed corn silage (Table 1).

Table 1. Main fodder in the feed ration of farms.

Feed ration composition	Farms (%)
Oat hay and/or wheat straw	64
Oat hay, wheat straw, and corn silage	32
Oat hay, wheat straw, sorghum	4

Many farmers did not use nutritional formulations specifically tailored to cattle performance; 52% of farmers had no crop production and purchased all of their cattle's forage, while 27% of farmers had partially effective crop production and purchased some of their forage. Only 21% of farmers had efficient forage production, with oats, sorghum, barley and alfalfa being the most common forage crops. Analysis of the results by chi-square test indicates a statistically significant effect ($P<0.05$) between the origin of roughage (purchased or self-produced) and the ration distributed to the herds. To adjust the basic rations distributed, the farmers resort to concentrates depending on the availability and market prices of feed.

In terms of grazing, less than half of the farmers surveyed (45%) practiced seasonal grazing, which typically occurred in the spring when green grass was abundant.

The average amount of daily concentrate feed provided to cows on the farms studied was 9.85 ±0.32 kg per cow, and only 5.3% of farmers supplemented their cows' diets with salt licks and multivitamins. The timing of feed distribution varied, with 32% of farms distributing feed before milking, 64% during milking, and 4% after milking.

3.2. Reproduction management

Natural breeding was the most commonly used method of inseminating cows on the surveyed farms, with 63% of farmers using this method exclusively and the vast majority of these farmers (87.5%) used bulls from their farms for reproduction. Artificial insemination was used by a small percentage of farms (14%) and was performed only by veterinarians. Some farmers (23%) used a combination of artificial and natural insemination methods. Nearly 89% of surveyed farmers used a voluntary waiting period (VWP) after calving and before cow insemination, with an average VWP of 76.6 ±3.56 days.

Direct observation was used by 95% of farmers to detect cows in estrus, with 96% of these farmers occasionally observing cows without a specific program and 4% having a daily detection program at least once a day for an average of 15 minutes. However, bulls were allowed to roam freely among the cows on 5% of the farms studied. None of the surveyed farms used indirect estrus detection or pregnancy diagnosis methods excluding heat detection. The average calving interval on the farms was 14.35 ±0.2 months, and the majority of farms (98%) had a non-seasonal calving period. Only a small number of farmers (9) had a calving pen and isolated pregnant cows for 1-2 weeks before calving.

3.3. Milk production

The milking method used on the farms studied was mechanical in 93% of cases and manual in 7% of cases. None of the farms featured a milking parlor or an automatic milking system. Dairy cows were milked twice a day, early in the morning and late in the afternoon, using portable milking machines under non-hygienic conditions. The Montbéliarde was the main breed raised in surveyed dairy farms. The average daily milk yield per cow on the surveyed farms was 18.19 ±0.45 L, and the average lactation length was 293.5 ±1.65 days. Figure 1 shows that 29% of the dairy cows on the studied farms were in their third lactation.

In terms of milking hygiene, 54% of farmers cleaned the cow udders before milking, while 46% only cleaned the udder teats. The main liquid used for udder hygiene was water. Teat dipping was practiced on only 1 farm before and after milking, and the fore-stripping technique was used by a small number of farmers (5%) before milking. However, most farmers did not follow any milking hygiene practices and did not use gloves or milking clothes.

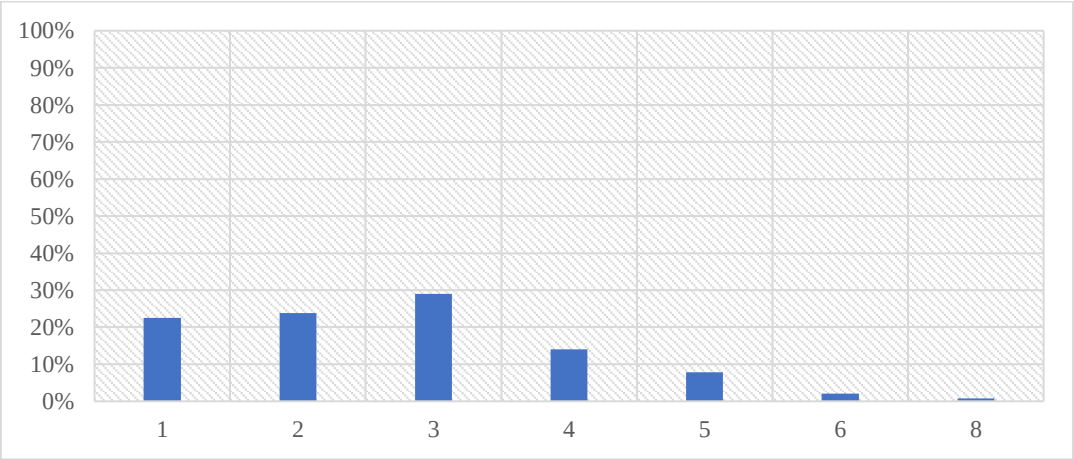

Figure1. Distribution of dairy cows according to their number of lactations.

3.4. Drying off and calf weaning

Dairy cows on the surveyed farms were gradually dried off, with an average dry-off period of 62.1 ±0.55 days. The dry-off period was 60 days in 79% of farms and more than 60 days in 21% of the surveyed farms.

Newborn calves on all of the assessed farms received colostrum for an average of 5.92 ±1.7 days before being fed exclusively cow's milk; no farmer used a milk replacer. Calves were weaned at an average age of 5 months. A small minority of 5 farmers weaned their calves at or before 2 months of age, while 51 farmers weaned their calves after 2 months (8 weeks). In general, calves were fed a fattening diet of concentrated feed and wheat straw.

3.5. Culling rate

All of the surveyed farmers culled cows occasionally, without any annual objectives. The average culling rate for dairy cows was 23%. The main reasons for culling were mastitis (23%) and age (21%), followed by infertility (9%). The other reasons for culling included brucellosis, tuberculosis, dystocia, chronicle cachexia and traumatic reticuloperitonitis (Figure 2).

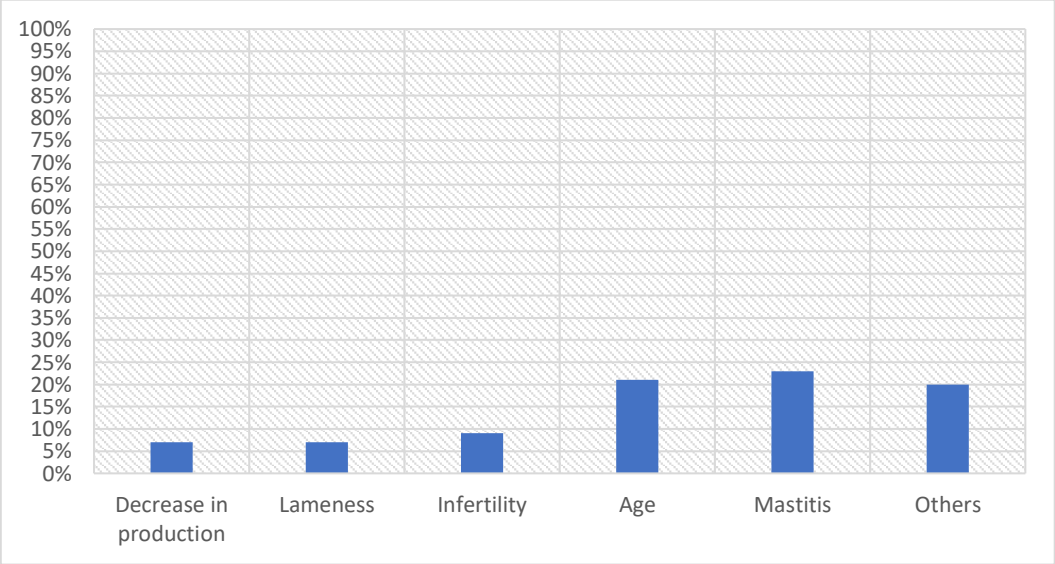

Figure 2. Culling reasons on surveyed farms in Mostaganem Province.

3.6. Dominant diseases in surveyed farms

The most frequently reported disease among the surveyed farmers was Mastitis, with a prevalence rate of 82%. Lameness was the second most common disease, affecting 57% of the surveyed herds, followed by placental retention (23%) and abortions (5%). The other diseases included abomasal displacement, traumatic reticuloperitonitis, dystocia and infertility (Figure 3).

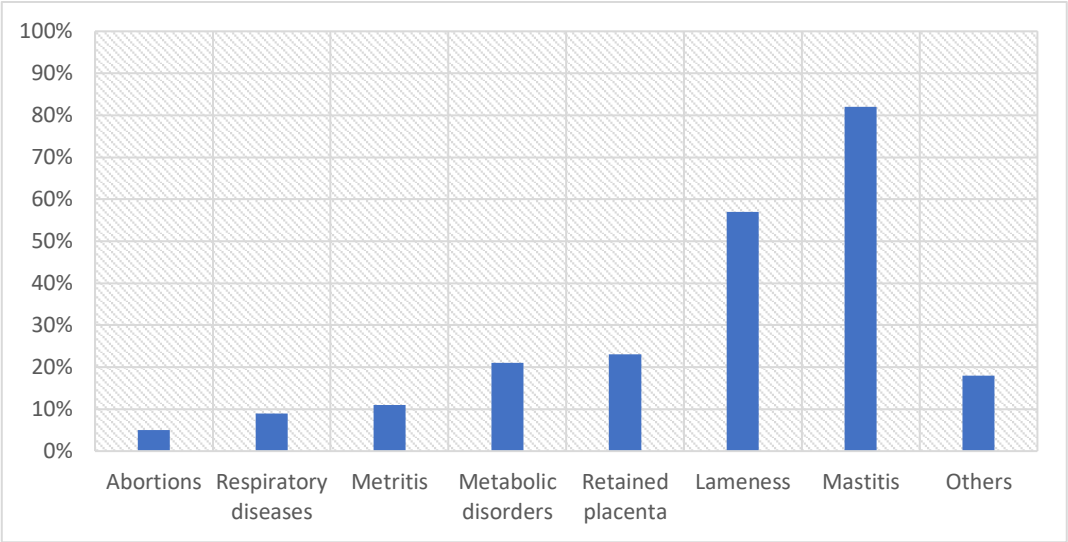

Figure 3. Dominant pathologies on dairy farms in the Mostaganem Province.

3.7. Herd health management

On most of the farms surveyed (90%), animals that were purchased were quarantined as a preventative measure. Around half of all farms (46%) used deworming therapy, but no farmers utilized coprology analysis. According to a plan developed by the agricultural services office, all of the surveyed farmers vaccinated their herd against just two diseases: rabies and foot-and-mouth disease. In terms of hoof trimming, the majority of farmers (79%) did not perform either preventative or curative trimming. A small percentage of farmers (3%) performed curative trimming on cows with lameness, while veterinarians treated lame cows on 11% of farms, and only 7% of farmers practiced preventative hoof trimming (Figure 4).

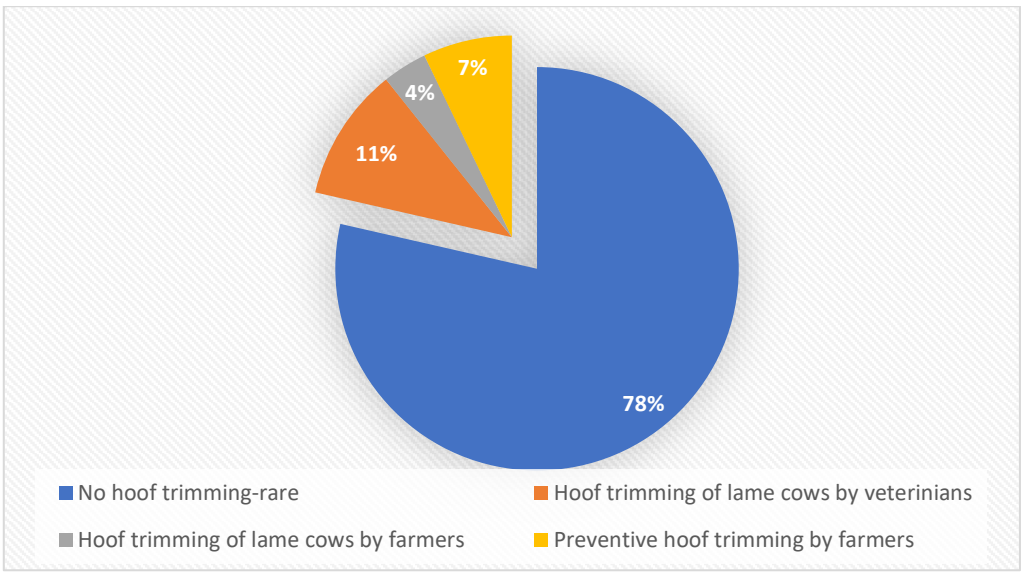

Figure 4. Hoof trimming practices in surveyed farms.

In regards to dry-off therapy, the study found that 11% of farmers used intramammary antibiotics, 67% used them routinely on all cows and 33% used them on cows with previous mastitis. The chi-square test of antibiotic use indicated a statistically significant effect ($P<0.05$). When mastitis occurred, the vast majority of farmers (89%) used intra-mammary antibiotics. Of these, 84% used less than 5 intramammary injections, while 16% used between 5 and 10 intramammary injections. None of the farmers admitted to using antibiotic therapy or self-administered anti-inflammatories on their herd.

4. Discussion

Proper feeding and nutrition management is important for the health and productivity of dairy cows. On the farms surveyed, a single diet was provided to lactating cows, with no consideration for their nutritional needs. The diet consists of separate portions of fodder and concentrate. In contrast, a study by Contreras-Govea et al. (2015) found that 52% of farms in Michigan and Wisconsin feed multiple diets to their cows, based on factors such as stage of lactation, milk production, and body condition score. These farmers also group their cows according to their nutritional needs.

On the surveyed farms in Mostaganem province, none of the farmers used a total mixed ration (TMR) to feed their lactating cows. Instead, they distributed separate portions of oat hay, wheat straw, and an average of 9.85 ±0.32 kg of concentrate per cow. This is similar to the feeding practices of other regions in Algeria (Boukhechem et al. 2019; Meskini et al. 2020). However, this is in contrast to the feeding practices of 80% of Dutch farms with conventional feeding systems, which use a TMR or partial mixed ration (PMR) feed by mixer wagons. These Dutch farms also use 2 to 5 roughages in the formulation of their rations, with grass silage being the most important in the majority of the rations (Bisaglia et al., 2012).

A high percentage of surveyed farms had no crop production. This may be due to a lack of land dedicated to forage production, with an average of only 0.6 ±1.42 ha (Meskini et al. 2022). In the study, only about 32% of farms included corn silage in the rations for their cows. This is a higher proportion compared to the 3.3% reported in a survey of farms in northern Algeria (Boukhechem et al. 2019), but lower than the prevalence of corn silage use on farms in Minnesota. In Minnesota, corn silage is the most common source of forage used in the formulation of total mixed rations (TMR) for dairy cows. All rations given to lactating dairy cows in Minnesota are formulated to meet their nutrient requirements (Endres & Espejo 2010).

In the region studied, a small number of farmers supplemented the rations of their cows. This is in contrast to farmers in Australia, who often include by-products (such as wheat mill mix/millrun, molasses, and oil/fat), buffers and modifiers (such as limestone, magnesium oxide, and sodium bicarbonate), ionophores, and antibiotics in the rations of their cows (Bramley et al. 2012).

Effective reproduction management is important for the productivity of the dairy herd. A small number of farmers in Mostaganem province used artificial insemination, which is similar to the situation on farms in the M'zab Valley in southern Algeria (Bensaha and Arbouche 2014). This differs from the situation in southern Brasilia, where artificial insemination is the most widely used breeding method and most farmers use self-replacement of their herds (Balcão et al. 2017).

The farmers in the surveyed area did not give sufficient attention to estrus detection and only a small number used the recommended daily observation method of checking for estrus three times per day for 20 minutes (Firk et al. 2002). None of the surveyed farms used a sensor system for detecting cows in estrus, unlike Dutch farmers, who used activity meters and pedometers for this purpose at rates of 41% and 70%, respectively

(Steeneveld and Hogeveen 2015). These devices have been shown to improve the accuracy of estrus detection (Hockey et al. 2010; Kamphuis et al. 2012) and investments in activity meters can be profitable (Rutten et al. 2014).

On average, the voluntary waiting period among the examined farms was 76.6 ±3.56 days. The voluntary waiting period is typically expected to be 60 days long and uniform within and between herds. However, a study conducted in Ohio found that the average voluntary waiting period was 56.6 days, with a range of 30 to 90 days, and did not vary by breed (DeJarnette et al. 2007). In the Mostaganem region, farmers mostly used non-return of heat as their method of pregnancy diagnosis, while in the United Kingdom, 77% of farmers used ultrasound for this purpose (Tzelos et al. 2020).

The average calving interval in the region studied was longer than the 12-month interval reported by Benidir et al. (2020) in eastern Algeria. Only 9 out of the surveyed farmers in the region used a calving pen, which is a pen designed to provide a comfortable and hygienic environment for cows giving birth. The use of a calving pen is recommended to reduce stress for the cow and calf and to maintain optimal hygiene (Svensson et al. 2003; Mee 2008).

The milking systems used on the surveyed farms were mainly mechanical, with cows being milked using car milking machines. None of the farms had a milking parlor or automated milking systems, which is a common feature on many farms in developed countries (Holly et al. 2019; Kristensen et al. 2015). The average daily milk yield on the surveyed farms was 18.19 liters per cow, which is comparable to the milk yield in Relizane province (17.4 L/cow, as reported by Meskini et al. 2021a), but lower than the milk production recorded in the United Kingdom (28.27 L/cow, as reported by Fujiwara et al., 2018), Canada (32.6 kg/cow, as reported by Tse et al., 2018), and the states of Wisconsin and Michigan (37.5 kg and 31.8 kg/cow, respectively, as reported by Contreras-Govea et al. (2015).

Ensuring proper milking hygiene is important for the health and safety of the cows and the quality of the milk produced. Additionally, environmental bacteria such as coagulase-negative staphylococci have been identified as a major germ responsible for subclinical mastitis in this region (Meskini et al. 2021b). The farmers in the region studied did not follow any milking hygiene protocols, unlike producers in Canada who typically follow milking procedures such as fore-stripping, washing and wiping the teats, using single cow towels, and applying post-milking teat disinfection (Belage et al. 2017). Mastitis was the most common disease on the surveyed farms, and it was also the most common pathology on dairy farms in Ethiopia, occurring at a rate of 52% (Duguma 2020).

Most farmers isolated the newly purchased animals. It is important for farmers to be aware of the potential risks and to take precautions to prevent the spread of diseases within their herd. However, a study in the northwest of England found that 70% of farmers purchasing new animals from other farms inquire about the seller's farm's disease history before making the purchase (Brennan and Christley, 2012). The diseases of greatest concern for these farmers were bovine viral diarrhea (BVD), bovine tuberculosis, leptospirosis, Infectious Bovine Rhinotracheitis (IBR), and various respiratory diseases. Additionally, 73% of these farmers recorded herd health information about their animals, including diagnoses and test results. In contrast, Canadian farmers were more likely to vaccinate newly acquired cattle (56.8%) than to isolate them (38.7%) or screen for diseases (25%), according to a study by Denis-Robichaud et al. (2019).

Approximately half of the farmers in the surveyed area used deworming prevention measures, while farmers in the United States typically use anthelmintics once or twice a year, in the spring and fall seasons,

after observing a decline in productivity or body condition (Gasbarre et al. 2001). In Saskatchewan, 79% of farmers used internal parasite control as part of their routine management plan, and also to control external parasites (Scott et al. 2019).

Trimming is not conducted regularly on most of the farms in the surveyed region. However, Manske et al. (2002) recommend trimming at least twice per year because most hoof lesions discovered during trimming will recover after a few months, and the prevalence of lame cows and hoof lesions decreases after trimming.

Dairy farms should immunize their cattle against common infections such as BVD, IBR, Bovine Respiratory Syncytial Virus (BRSV), Parainfluenza-3 (PI3), clostridial infections, and leptospirosis to prevent or control disease outbreaks. However, several studies (Derdour et al. 2017; Kaddour et al. 2019) have found that BVD and IBR are present in Algerian dairy herds, even though none of the farmers vaccinated their herds against any of these common infectious agents, excluding rabies and foot and mouth disease. The vaccination program needs to take into account the infectious disease problems in the region as well as other factors.

In Mostaganem province, farmers occasionally culled dairy cows, with the common reasons being mastitis and age. This is similar to the situation on Estonian farms, where the main reasons for culling were hoof/claw disorders (26.4%) and udder disorders (22.6%), according to Rilanto et al. (2020). These findings suggest that improving herd health management, including measures to prevent and treat mastitis and infertility, could potentially reduce the culling rate and improve the overall productivity and efficiency of dairy farms.

The dry-off method used on the farms was the progressive method, which is similar to a study conducted in northern Algeria (Hamlaoui et al. 2021). The average dry-off period was 62.1 days, which differs from the situation on 83% of farms in the United Kingdom, where the average length of the dry period was 56 days and farmers stop milking abruptly, regardless of the milk production level at dry-off (Fujiwara et al. 2018).

Most of the surveyed farmers weaned their calves very late, unlike the situation on Australian farms where weaning typically takes place before 13 weeks (Klein-Jöbstl et al. 2015) or on Swedish farms where weaning occurs at about 8 weeks (Pettersson et al., 2001).

During the dry period, only 11% of the surveyed farmers used intra-mammary antibiotics to prevent mastitis in the next lactation, compared to the 78% of farms found to use such antibiotics in a study by Fujiwara et al. (2018), in combination with internal or external teat sealants.

5. Conclusions

This research identified several key points that could improve the efficiency of dairy farms in Algeria's Mostaganem Province. The study emphasizes the importance of adopting improved dairy farming practices to ensure the success of the dairy industry in the region. To support this goal, the agricultural and economic sectors should consider several factors when designing and implementing policies and extension programs, such as helping farmers to adopt enhanced dairy farming techniques and improve their farming practices; promoting the use of efficient feeding systems for dairy production and improving silage use; encouraging the adoption of technologies and sensor systems to manage the farm; providing training programs to help farmers improve their dairy farming and production skills; improving and controlling herd health programs and addressing health issues that impact economic efficiency; additionally, it will be important to consider farmers' attitudes and knowledge of these issues, including reproductive and feeding management, disease management, and herd health, to support the success of these recommendations.

In future studies, we recommend including data on forage production, artificial insemination performances, and the weaning practices of calves. One limitation of this study was that many farmers did not have regular records of their herd's zootechnical performances, so we were unable to assess the other performances of the farms. Additionally, we were unable to quantify the economic losses resulting from diseases and farmers' decisions and practices. To provide a more comprehensive understanding of dairy farms in Algeria, we recommend conducting a study on a smaller group of farmers and closely tracking herd performances and the economic status of the farms.

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Monitoring of Changes in the Quality Characteristics of Cooked Chicken Döner Kebabs Formulated from Mechanically Deboned Chicken Meat Subject to Refrigerated Storage

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HIGHLIGHTS

- The use of MDCM increased the pH values of the chicken döner kebabs.
- MDCM had no negative effect on the TBARS values of the samples.
- The redness values increased with increasing MDCM addition.
- MDCM increased the flavour scores of the sample on day 0.

Abstract

This study aimed to evaluate the effects of mechanically deboned chicken meat (MDCM) on the physicochemical and sensory properties of chicken döner kebab during 28 days of storage. Five different groups of chicken döner kebab were produced: C1: Control 1 including chicken breast meat, C2: Control 2 including ground chicken breast + transglutaminase, M1: 95% ground chicken breast + 5% MDCM + transglutaminase, M2: 90% ground chicken breast + 10% MDCM + transglutaminase and M3: 85% ground chicken breast + 15% MDCM + transglutaminase. The addition of MDCM to chicken döner kebab samples increased the pH value of the samples ($P < 0.05$). The TBARS values of the chicken döner kebabs increased during the storage period, especially on the 21st and 28th day. Groups M1, M2 and M3 had lower lightness (L^*) and higher redness (a^*) values than the control groups ($P < 0.05$). The addition of MDCM had no negative influence on the sensory parameters of the samples ($P > 0.05$).

Keywords: Colour; Lipid oxidation; MDCM; Poultry product

1. Introduction

Döner kebab, often referred to as "gyros," "donair," "kebab," "chawarma," and "shawirma," is a traditional meat product from Turkey and the Middle East that is eaten throughout the world. The döner kebab has gained popularity in the fast food industry in recent years and has taken on a role in the human diet due to its nutrient density and taste (Barthaloma et al. 1997; Kayışoğlu et al. 2003; Kılıç 2003). Döner kebab is prepared in three ways: as a leaf, minced meat or mixed (leaf-minced meat), depending on how it is offered in the market (TGK 2018). Lamb, beef or poultry can be used for döner kebab production. To prepare döner kebab, the meat is marinated with a marinade sauce containing salt, spices, onions, tomatoes and yoghurt. A certain amount

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of beef or sheep tallow is also added to the marinated meat and prepared into a cone shape. Then the mass is cooled so that the meat and fat particles stick together. After cooling, the raw döner kebab is placed on a vertical skewer and slowly rotated to cook evenly using gas, charcoal or an electric heating equipment. The cooked döner kebab is cut into thin slices and served (Ergönül and Kundakcı 2007; Kayışoğlu et al. 2002; Moeller et al. 1994). Recently, chicken döner kebab has become very popular. This is because poultry meat is easy to digest, contains less fat and cholesterol and is more affordable (Kılıç et al. 2001). It is also an important source of protein, as it is of animal origin and contains many nutrients necessary for the human body, such as essential amino acids, fatty acids and large quantities of minerals (Kaya et al. 2018).

Mechanically deboned meat (MDM) is obtained by the decomposition of the meat remaining on the bones after the meat of the carcass has been removed by mechanical means such as pressure and grinding, and is referred to as mechanically deboned poultry meat (MDPM) or mechanically deboned chicken meat (MDCM) depending on the species from which it is derived (Navarro-Rodriguez et al. 2010; Püssa et al. 2009; Serdaroğlu et al. 2005).

MDPM is often used in the formulation of meat products due to its smooth consistency, good nutritional and functional characteristics, and low cost. The use of MDPM in nuggets, sausages, fermented sausages and restructured chicken products has been well documented (Perlo et al. 2006; Serdaroğlu et al. 2005; Hassan and Fan 2005). This valuable by-product of poultry meat processing is commonly used in restructured meat products such as frankfurters, fermented sausages and restructured chicken products as a substitute for the meat raw material because of its smooth texture, good nutritional and functional properties and low cost. In contrast to these benefits, MDCM has a negative impact on sensory properties (e.g. unpleasant taste and odour in the final product (Mielnik et al. 2002), which has undesirable textural properties and is susceptible to lipid oxidation (Jin et al. 2014).

Song et al. (2014) reported on the effects on quality characteristics of semi-dry dehydrated chicken meat that the use of mechanically deboned chicken meat (MDCM) and collagen can be useful components to reduce production costs and improve processing efficiency. Pereira et al. (2011) found that the added MDPM content affects the proximate composition and textural properties (cohesion and stickiness) of Frankfurter-type sausages, negatively affecting the cooking performance and colour of the final product.

Although there are studies on the use of MDCM in chicken products such as sausages and nuggets (Perlo et al. 2006; Jin et al. 2015; Mohamed et al. 2016; Pindi et al. 2017), there are no studies on the use of MDCM in chicken döner kebab. As far as we know, this was the first study to investigate the use of MDCM in the production of chicken döner kebab. Therefore, the aim of this study was to evaluate the effects of MDCM on lipid oxidation, colour properties and sensory characteristics of cooked chicken döner kebabs during refrigerated storage over 28 days.

2. Materials and Methods

2.1. Materials

The chicken breast used for the study was obtained from a poultry plant (Şen Piliç, Adana, Türkiye). Mechanically deboned chicken meat was supplied by Gedik Piliç in Uşak, Türkiye. The animal fats used in the production of chicken döner kebab were provided by a local butcher in Konya, Türkiye. The transglutaminase (Benosen Food, Tegen 220 DM, China) and the salt (Salina, Ankara, Türkiye) were purchased from a company.

2.2. Production of chicken döner kebab döner samples

The chicken döner kebab production was carried out at the Selçuk University Food Engineering Department. As outlined in Table 1, five groups of chicken döner kebabs were prepared as follows: C1

(produced with chicken breast fillets and no added MDCM, transglutaminase), C2 (produced with ground chicken breast and no added MDCM), M1 (produced with 5% MDCM + 95% ground chicken breast + transglutaminase), M2 (produced with 10% MDCM + 90% ground chicken breast + transglutaminase) and M3 (produced with 15% MDCM + 85% ground chicken breast + transglutaminase). In the formulation of the chicken döner kebab samples, the ground chicken breast was partially replaced by MDCM in groups M1, M2 and M3.

Table 1. Formulations of chicken döner kebab samples

Formulation (g)	Sample Groups				
	C1	**C2**	**M1**	**M2**	**M3**
Chicken breast meat	3500	-	-	-	-
Ground chicken meat	-	3500	3325	3150	2975
Mechanically deboned chicken meat	-	-	175	350	525
Animal fat	875	875	875	875	875
Salt	52.5	52.5	52.5	52.5	52.5
Transglutaminase enzyme	-	87.5	87.5	87.5	87.5

C1: Control 1 including chicken breast meat; C2: Control 2 including ground chicken breast + transglutaminase; M1: 95% ground chicken breast + 5% MDCM + transglutaminase; M2: 90% ground chicken breast + 10% MDCM + transglutaminase; M3: 85% ground chicken breast + 15% MDCM + transglutaminase.

In the production of C1, the chicken breasts were cut into leaf-shaped slices (chicken breast fillets) with a slicer (parallel to the direction of the fibres). The salt and animal fat were added and mixed. Then the chicken breast fillets were skewered on kebab döner skewers and these skewers were tightly wrapped with stretch film and stored at -20 °C for 24 hours.

In the production of C2, M1, M2 and M3, the chicken breasts were ground twice in a meat grinder. The ingredients in the formulation for these groups given in Table 1 were prepared by mixing them with minced chicken for 10 minutes and then placing them in a transparent cylindrical package around the döner skewers. Raw chicken döner kebab is stored at -20°C for 24 hours.

All groups of raw chicken döner kebab blocks were placed 10 cm apart in front of the open vertical gas kebab cooker (oven, burner). Each surface of the kebab block was cooked for 6 minutes. After 6 minutes, the cooked surfaces were cut with a thickness of 5 mm, the meat block was turned over and the cooking process of the other surfaces was continued. During the cooking process, the temperature of the heat source was controlled by the gas valve. This process was continued until the entire kebab block was cooked. The cooked kebab slices were cooled to 20°C at room temperature for about 30 minutes. Then 300 g of the chicken döner kebab samples were vacuum packed and stored at 4°C for 28 days.

pH, TBARS and colour properties of all samples were analysed on the 0th, 7th, 14th, 21st and 28th day during storage and sensory evaluation was performed on the 0th, 14th and 28th day.

2.3. pH determination

The pH values of the chicken döner kebab döner samples were measured with a pH meter (WTW series pH 720, Weilheim, Germany) according to AOAC (2000).

2.4. Determination of TBARS number

The method described by Gökalp et al (2012) was used to determine the lipid oxidation of the samples during the storage periods. The TBA number was expressed as milligrammes of malonaldehyde per kilogramme of the sample (mg MA /kg sample).

2.5. Colour measurement

The colour parameters of the samples were determined with a colourimeter (CR -400 Minolta, Osaka, Japan) with illuminant D65, observer angle of 2°, diffuse/O mode and aperture of 8 mm for illumination. The colour properties (L*: lightness, a*: redness, b*: yellowness) were determined on the inner surface of the chicken döner kebab samples.

2.6. Sensory evaluation

Sensory analyses of the chicken döner kebab samples were conducted by a group of 11 semi-trained panellists from the Department of Food Engineering at Selçuk University. The panellists evaluated the colour, taste, smell, texture and general assessment of the samples using a 9-point hedonic scale. The scale ranged from 1, disliked, to 9, liked very much. Samples were microwaved for 20 seconds and chicken döner kebab slices from each treatment were randomly selected, presented in bowls with random three-digit numbers and served to the panellists with water and bread to avoid a quality carryover effect between samples.

2.7. Statistical analysis

A completely randomised factorial design was used to compare the five treatments (C1, C2, M1, M2 and M3). For the statistical analysis of pH, TBARS, colour and sensory results, a one-way analysis of variance (ANOVA) was performed using the generalised linear mixed model. MINITAB for Windows Release 16.0 was used to estimate the results. Tukey multiple comparison tests were used to determine differences between means at a 5% significance level.

3. Results and Discussion

3.1. pH and TBARS number

The pH values and TBARS numbers of chicken döner kebab döner samples during storage are given in Table 2. When examining the pH values of the chicken döner kebab samples in relation to the storage, there was no significant change in the C1 group ($P > 0.05$), while in the C2, M1, M2, and M3 groups there was a decrease was observed as the storage period progressed. The lowest pH values were determined on day 28 in the C2, M1, M2 and M3 groups. This decrease in pH could be due to microbial growth (especially lactic acid bacteria) in kebabs during storage. Since no microbiological analyses were carried out in our study, it is difficult to draw a definitive conclusion in this regard. On the other hand, previous studies are showing that the pH of meat products decreases due to microbial growth during storage. Lactic acid bacteria (LAB) have been described as the predominant bacteria in vacuum-packed meat products (Sakala et al. 2002). In addition, Nowak and Krysiak (2005) reported that storage of frankfurters in cold storage led to an increase in LAB, so the pH value decreased during storage.

The use of MDCM for each storage period had significant effects on the pH values of the samples ($P < 0.05$). The addition of MDCM in each storage period increased the pH values of the samples compared to the C2 group, except for Day 21. ($P < 0.05$). The reason for this increase in the pH values of the samples containing MDCM could be attributed to the high pH value of MDCM.

Similarly, Perlo et al. (2006) indicated that mechanically deboned poultry meat (MDPM) significantly increased the final pH values of chicken nuggets. Mohamed and Mansour (2012) also reported higher pH values of beef patties with MDPM compared to the control. A similar increase in pH was also reported by Song et al. (2014), who evaluated the effect of collagen and MDCM on the production of semi-dried chicken jerky.

Table 2. pH and TBARS number of chicken döner kebab samples

Analyses	Storage period (Day)	Samples				
		C1	C2	M1	M2	M3
pH	Day 0	6.51 ± 0.00^{ABa}	6.44 ± 0.02^{Ca}	6.47 ± 0.00^{BCa}	6.50 ± 0.01^{ABa}	6.54 ± 0.02^{Aa}
	Day 7	6.48 ± 0.00^{ABa}	6.42 ± 0.00^{Ba}	6.45 ± 0.03^{ABab}	6.45 ± 0.01^{ABab}	6.50 ± 0.03^{Aab}
	Day 14	6.47 ± 0.00^{ABa}	6.42 ± 0.00^{Ca}	6.45 ± 0.00^{BCab}	6.46 ± 0.00^{ABab}	6.50 ± 0.02^{Aab}
	Day 21	6.44 ± 0.06^{Aa}	6.36 ± 0.03^{Aab}	6.42 ± 0.01^{Aab}	6.40 ± 0.00^{Abc}	6.45 ± 0.02^{Aab}
	Day 28	6.42 ± 0.00^{Aa}	6.28 ± 0.05^{Bb}	6.38 ± 0.03^{ABb}	6.35 ± 0.04^{ABc}	6.43 ± 0.02^{Ab}
TBARS number (mg MA / kg sample)	Day 0	0.32 ± 0.06^{Ab}	0.43 ± 0.11^{Aa}	0.41 ± 0.03^{Ab}	0.39 ± 0.06^{Ab}	0.33 ± 0.05^{Ab}
	Day 7	0.66 ± 0.01^{Aab}	0.50 ± 0.18^{Aa}	0.52 ± 0.08^{Aab}	0.53 ± 0.10^{Aab}	0.40 ± 0.04^{Ab}
	Day 14	0.77 ± 0.04^{Aa}	0.62 ± 0.04^{Ba}	0.66 ± 0.04^{ABab}	0.65 ± 0.01^{ABab}	0.44 ± 0.01^{Cb}
	Day 21	0.90 ± 0.04^{Aa}	0.57 ± 0.07^{ABa}	0.70 ± 0.16^{ABab}	0.71 ± 0.09^{ABa}	0.52 ± 0.04^{Bab}
	Day 28	0.80 ± 0.21^{Aa}	0.75 ± 0.08^{Aa}	0.83 ± 0.04^{Aa}	0.73 ± 0.03^{Aa}	0.69 ± 0.08^{Aa}

Within the same row, values with different uppercase superscript letters indicate significant differences ($p<0.05$) Within the same column, values with different lowercase superscript letters indicate significant differences ($p<0.05$). C1: Control 1 including chicken breast meat; C2: Control 2 including ground chicken breast + transglutaminase; M1: 95% ground chicken breast + 5% MDCM + transglutaminase; M2: 90% ground chicken breast + 10% MDCM + transglutaminase; M3: 85% ground chicken breast + 15% MDCM + transglutaminase.

As shown in Table 2, the TBARS numbers of the samples, except the C2 group, increased with increasing storage time. During the 28-day storage period, the change in TBARS levels in the C2 group was insignificant ($P > 0.05$). The lowest TBARS numbers for the C1, M1 and M2 groups were obtained on day 0 ($P < 0.05$). Although the TBARS values for the other storage periods gradually increased, this increase was not statistically significant ($P > 0.05$). In the M3 group, the lowest TBARS values were found on days 0, 7 and 14. When the TBARS numbers for the MDCM treatment were examined, the use of MDCM did not affect the TBARS numbers of samples on days 0, 7 and 28 ($P > 0.05$). However, on days 14 and 21, the lowest TBARS numbers were determined in the M3 group ($P < 0.05$). In summary, the use of MDCM in this study had no negative effect on the TBARS values of the samples. On the contrary, Mohamed and Mansour (2012) found that the TBARS values of beef patties formulated with MDPM (200 g/kg) were significantly higher than the TBARS values of beef patties formulated without MDPM. In contrast to our results, studies on mechanically separated meat have generally reported negative effects on the number of TBARS in the literature (Kılıç and Richards 2003; Pindi et al. 2017; Püssa et al. 2008).

3.2. Colour properties

Colour properties were measured to determine the effects of different levels of MDCM on the colour characteristics of chicken döner kebab samples. Table 3 indicates the L^*, a^* and b^* values of chicken döner samples during storage for 28 days. The storage period did not affect the L^* values of C1 and C2 ($P > 0.05$), while the L^* values of M1, M2 and M3 decreased with increasing storage period ($P < 0.05$). There is a negative correlation between lightness and TBARS values (Hernández-Hernández et al. 2009). In other words, as oxidation increased, lightness decreased (the samples became darker). This relationship was observed in groups M1, M2 and M3, which had the lowest L^* values. The a^* values of the samples, except the C2 and M2 group, increased with increasing storage time ($P < 0.05$). The storage period and the MDCM treatment for the individual storage periods did not affect the b^* values of the samples during the entire storage ($P > 0.05$).

When the L^* values of the samples were examined in terms of MDCM addition for each storage period, it was found that the L^* value decreased with increasing MDCM addition ($P < 0.05$). The highest L^* values for all storage periods were found in group C1 ($P < 0.05$), while the highest value was in group M3 ($P < 0.05$). The

reason for the increase in *L** values in our study could be that MDCM has been reported to have a higher content of haem pigments, resulting in a darker colouration (Perlo et al. 2006). Similarly, Song et al. (2014) reported that the addition of MDCM in amounts greater than 10% significantly reduced the *L** value of semi-dry chicken.

When the *a** values of the samples were examined about the MDCM addition for each storage period, the highest ($P < 0.05$) *a** value was determined in the M2 and M3 groups in all storage periods except on the 21st day. In other words, MDCM addition increased the redness values of samples. This situation could be explained by the fact that the characteristic colour of MDCM is generally reddish, which is due to the admixture of hemoglobin deposited from the bone marrow during the manufacturing process (Ockerman and Hansen 2000). Similarly, Pereira et al. (2011) reported that the *a** values increased by up to 50% with the addition of MDPM to the sausage formulation. Jin et al. (2015) also found that the redness of pork sausages containing MDCM hydrolysates increased significantly after 4 weeks of storage due to the addition of MDCM hydrolysates, ascorbate and sodium erythorbate.

Table 3. Colour characteristics of chicken döner kebab samples

Analyses	Storage period (Day)	Samples				
		C1	**C2**	**M1**	**M2**	**M3**
*L**	Day 0	75.24 ± 0.84^{Aa}	72.23 ± 0.86^{Ba}	71.26 ± 0.16^{Ba}	67.20 ± 0.01^{Cab}	65.75 ± 0.10^{Ca}
	Day 7	77.40 ± 1.05^{Aa}	72.54 ± 0.97^{Ba}	68.86 ± 0.04^{Cc}	68.25 ± 0.12^{Ca}	63.93 ± 0.09^{Dab}
	Day 14	77.81 ± 0.45^{Aa}	71.34 ± 0.35^{Ba}	69.84 ± 0.30^{Bbc}	65.57 ± 0.53^{Cb}	63.37 ± 1.27^{Cab}
	Day 21	77.17 ± 0.13^{Aa}	70.81 ± 0.45^{Ba}	70.24 ± 0.70^{Babc}	66.04 ± 0.60^{Cb}	61.21 ± 0.20^{Db}
	Day 28	75.65 ± 0.69^{Aa}	70.57 ± 0.38^{Ba}	70.54 ± 0.09^{Bab}	66.29 ± 0.85^{Cab}	63.61 ± 0.13^{Dab}
*a**	Day 0	1.46 ± 0.11^{Eab}	2.45 ± 0.03^{Da}	3.61 ± 0.01^{Cab}	4.82 ± 0.26^{Ba}	5.40 ± 0.13^{Abc}
	Day 7	1.08 ± 0.42^{Db}	2.84 ± 0.18^{Ca}	4.14 ± 0.23^{Bab}	4.41 ± 0.32^{ABa}	5.52 ± 0.22^{Aabc}
	Day 14	1.34 ± 0.21^{Cb}	3.51 ± 0.52^{Ba}	3.85 ± 0.45^{Bab}	4.62 ± 0.30^{ABa}	5.81 ± 0.13^{Aab}
	Day 21	1.15 ± 0.08^{Bb}	3.81 ± 0.76^{Aa}	3.34 ± 0.20^{Ab}	4.47 ± 0.30^{Aa}	4.92 ± 0.28^{Ac}
	Day 28	2.41 ± 0.23^{Ca}	3.53 ± 0.77^{BCa}	4.44 ± 0.22^{Ba}	4.79 ± 0.50^{ABa}	6.20 ± 0.14^{Aa}
*b**	Day 0	13.49 ± 0.95^{Aa}	10.44 ± 1.12^{Aa}	10.83 ± 1.34^{Aa}	10.59 ± 0.37^{Aa}	10.54 ± 1.06^{Aa}
	Day 7	11.90 ± 0.51^{Aa}	10.71 ± 0.40^{Aa}	12.44 ± 1.08^{Aa}	10.93 ± 0.13^{Aa}	11.95 ± 1.23^{Aa}
	Day 14	10.98 ± 0.27^{Aa}	11.55 ± 0.42^{Aa}	12.13 ± 0.40^{Aa}	11.47 ± 0.86^{Aa}	11.86 ± 0.16^{Aa}
	Day 21	13.00 ± 0.12^{Aa}	14.79 ± 1.28^{Aa}	11.61 ± 1.21^{Aa}	11.63 ± 1.30^{Aa}	12.48 ± 1.80^{Aa}
	Day 28	10.50 ± 1.48^{Aa}	13.20 ± 0.43^{Aa}	10.52 ± 0.15^{Aa}	12.29 ± 0.01^{Aa}	12.69 ± 0.81^{Aa}

Within the same row, values with different uppercase superscript letters indicate significant differences ($p<0.05$) Within the same column, values with different lowercase superscript letters indicate significant differences ($p<0.05$). C1: Control 1 including chicken breast meat; C2: Control 2 including ground chicken breast + transglutaminase; M1: 95% ground chicken breast + 5% MDCM + transglutaminase; M2: 90% ground chicken breast + 10% MDCM + transglutaminase; M3: 85% ground chicken breast + 15% MDCM + transglutaminase.

3.3. Sensory properties

The odour, colour, flavour, texture and general acceptance scores of chicken döner kebab samples on days 0, 14 and 28 are shown in Table 4. As storage progressed, the differences in the colour, odour and texture scores of the samples were insignificant ($P > 0.05$). For the flavour parameter, the effect of storage time was significant only in the C1 group and the lowest score was obtained on 28th day ($P < 0.05$). Among the general acceptancee, only the C2 group was affected by the storage period and the lowest score was obtained on days 14 and 28 ($P < 0.05$).

The use of MDCM for each storage period had no significant effects on the colour, odour and general acceptance scores of the samples ($P < 0.05$). In the flavour assessment, the differences between the scores of the groups on day 14 and 28 were insignificant ($P > 0.05$), while the use of MDCM on day 0 increased the flavour scores of the samples ($P < 0.05$). It is well known that MDCM leads to a deterioration of sensory properties such as colour, flavour and texture, which could be mainly due to the denaturation of proteins during mechanical separation and the entrapment of lipids and free haem groups from the bone. In contrast to our study, Song et al (2014) observed a significant decrease in satisfaction with colour, taste, tenderness and juiciness with increasing substitution rates of chicken breast with MDCM in semi-dried chicken jerkies. The reason for this discrepancy between our study and the literature could be differences in formulation and manufacturing methods.

Table 4. Sensory evaluation of chicken döner kebab samples

Sensory parameters	Storage period (Day)	Samples				
		C1	C2	M1	M2	M3
Colour	Day 0	7.02 ± 0.26^{Aa}	7.09 ± 0.12^{Aa}	8.25 ± 0.35^{Aa}	7.87 ± 0.66^{Aa}	8.14 ± 0.66^{Aa}
	Day 14	6.20 ± 1.13^{Aa}	5.25 ± 0.35^{Aa}	6.65 ± 1.20^{Aa}	7.14 ± 0.76^{Aa}	7.35 ± 1.63^{Aa}
	Day 28	6.04 ± 0.90^{Aa}	7.45 ± 0.07^{Aa}	7.55 ± 0.07^{Aa}	7.17 ± 0.23^{Aa}	7.49 ± 0.45^{Aa}
Odour	Day 0	7.85 ± 0.50^{Aa}	7.82 ± 0.02^{Aa}	8.84 ± 0.23^{Aa}	8.50 ± 0.71^{Aa}	8.65 ± 0.21^{Aa}
	Day 14	7.22 ± 0.87^{Aa}	6.49 ± 0.97^{Aa}	7.24 ± 0.62^{Aa}	7.05 ± 0.64^{Aa}	6.57 ± 2.50^{Aa}
	Day 28	6.20 ± 0.28^{Aa}	7.24 ± 0.80^{Aa}	7.82 ± 0.02^{Aa}	6.29 ± 0.16^{Aa}	7.29 ± 0.16^{Aa}
Texture	Day 0	7.57 ± 0.33^{Aa}	7.59 ± 0.59^{Aa}	7.85 ± 0.50^{Aa}	7.50 ± 0.00^{Aa}	7.50 ± 0.00^{Aa}
	Day 14	7.50 ± 0.00^{Aa}	7.50 ± 0.00^{Aa}	7.50 ± 0.00^{Aa}	7.50 ± 0.00^{Aa}	7.50 ± 0.00^{Aa}
	Day 28	7.50 ± 0.00^{Aa}	7.50 ± 0.00^{Aa}	7.50 ± 0.00^{Aa}	7.50 ± 0.00^{Aa}	7.50 ± 0.00^{Aa}
Flavour	Day 0	7.20 ± 0.28^{Ba}	8.17 ± 0.23^{ABa}	8.54 ± 0.19^{Aa}	8.10 ± 0.14^{ABa}	8.30 ± 0.42^{Aa}
	Day 14	8.10 ± 0.14^{Aa}	6.34 ± 0.94^{Aa}	7.39 ± 0.30^{Aa}	7.62 ± 1.11^{Aa}	7.39 ± 1.11^{Aa}
	Day 28	6.07 ± 0.37^{Ab}	7.45 ± 0.07^{Aa}	8.02 ± 0.26^{Aa}	7.52 ± 0.45^{Aa}	7.62 ± 1.11^{Aa}
General Acceptance	Day 0	7.39 ± 0.30^{Aa}	7.70 ± 0.42^{Aa}	8.15 ± 0.50^{Aa}	8.35 ± 0.21^{Aa}	8.40 ± 0.57^{Aa}
	Day 14	7.15 ± 0.50^{Aa}	6.02 ± 0.26^{Ab}	6.80 ± 0.28^{Aa}	7.49 ± 0.45^{Aa}	7.44 ± 1.75^{Aa}
	Day 28	6.32 ± 0.73^{Aa}	7.49 ± 0.45^{Ab}	7.82 ± 0.02^{Aa}	7.54 ± 0.19^{Aa}	7.87 ± 0.76^{Aa}

Within the same row, values with different uppercase superscript letters indicate significant differences ($p<0.05$) Within the same column, values with different lowercase superscript letters indicate significant differences ($p<0.05$). C1: Control 1 including chicken breast meat; C2: Control 2 including ground chicken breast + transglutaminase; M1: 95% ground chicken breast + 5% MDCM + transglutaminase; M2: 90% ground chicken breast + 10% MDCM + transglutaminase; M3: 85% ground chicken breast + 15% MDCM + transglutaminase.

4. Conclusions

In this study, the use of MDCM in the formulation of chicken döner kebab was found to be comparable to that of control groups produced with chicken breast and ground chicken breast. The addition of MDCM in each storage period increased the pH values of the samples compared to the C2 group. MDCM had no negative effect on the TBARS values of the samples. The L^* values decreased with increasing MDCM addition, while the a^* values increased. The use of MDCM for each storage period had no significant effect on the colour, odour and general acceptance scores of the samples. In addition, on day 0, MDCM increased the flavour scores of the samples.

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Determination of Disease Severity of *Rhizoctonia solani* Kühn (Telemorph: *Thanatephorus cucumeris* (Frank) Donk) Isolates from Bean, Sugar Beet and Potato Planting Areas in Konya

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HIGHLIGHTS

- While some of the Rhizoctonia, which contain quite different groups, are mycorrhizal, some are saprophytic, many of them are economically important plant pathogens that cause disease in more than 150 agricultural products.
- Barley, wheat, rice, strawberries, beans, sugar beets, potatoes, cotton, tomatoes and cabbage are economically important crops where the disease occurs.
- The fungus can generally be isolated from all soils and is an important pathogen with a wide host range in fields such as agricultural lands, ornamental plants and forest areas.

Abstract

This study was carried out to determine the disease severity of *Rhizoctonia solani* isolates isolated from plant samples collected from bean, sugar beet and potato cultivation areas in Konya in 2020 and the anastomosis groups of the most virulent isolates. A total of 40 *R. solani* isolates were obtained as a result of the isolations made from 86 plant samples (36 beans, 25 sugar beets and 25 potatoes) showing root rot symptoms in general appearance. The number of *R. solani* isolates obtained from these plants, respectively; 10 isolates from beans, 15 from potatoes and 15 from sugar beets. Nine of the bean isolates and 14 of the potato and sugar beet isolates were determined as multinucleic. One isolate each isolated from the bean, sugar beet and potato was determined as binucleic. As a result, a total of 37 multinucleate (MN) and 3 binucleate (BN) isolates were obtained from all plants. As a result of pathogenicity tests, 3 *R. solani* isolates with the highest disease severity for each plant were amplified using ITS1F and ITS4B primers and anastomosis groups were determined. Accordingly, the anastomosis groups of Fa 3.2 (97%), Fa 2.2 (89%) and Fa 1 (86%) in beans were characterized as AG 4HGI. The isolates with the highest disease severity in potatoes (Pa 10, Pa 12.1 and Pa 15.2) were determined as AG 3 group. Disease severity was determined as 50% of Pa 15.2, 44% of Pa 10 and 42% of Pa 12.1. The disease severity of 9 of the isolates obtained from sugar beet was determined as 100%. The anastomosis group of 3 randomly selected isolates from these isolates was characterized as AG 2-2.

Keywords: Anastomosis group; Bean; Potato; Sugar beet; *R. solani*

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1. Introduction

Rhizoctonia solani, the most studied species in *Rhizoctonia* form genus, was detected on a diseased potato by Julius Kühn in 1858 (Gonzalez Garcia et al. 2006; Gondle 2018). *R. solani* Kühn (Telemorf: *Thanatephorus cucumeris* (Frank) Donk) was first recorded in Turkey by Bremer in 1948 (Yıldız and Döken 2002). Afterward, many scientists continued to work on this issue. While some of the *Rhizoctonia*, which contain quite different groups, are mycorrhizal, some are saprophytic, many of them are economically important plant pathogens that cause disease in more than 150 agricultural products. Barley, wheat, rice, strawberries, beans, sugar beets, potatoes, cotton, tomatoes and cabbage are economically important crops where the disease occurs. 27.50% of sugar beet production, 32.50% of bean production and about 7% of potato production in Turkey are realized in Konya (Soylu 2011). In recent years, yield losses have occurred in the fields where the disease has been observed in these plants, which have a significant production amount in Konya. The fungus can generally be isolated from all soils and is an important pathogen with a wide host range in fields such as agricultural lands, ornamental plants and forest areas. It is both soil-borne and seed-borne, and causes different symptoms (seed rot, stem and stolon cancer, leaf blight, yellowing of leaves, root rot and damping off) in different plants (Gonzalez Garcia et al. 2006; Çebi Kılıçoğlu 2009; Gondle 2018).

The number of nuclei in a single cell of the hyphae is an important taxonomic criterion determining whether *Rhizoctonia* species belong to multi-nucleate and binucleate groups (Kuramae et al. 2003). 14 AGs included in *R. solani* have been identified by the studies carried out so far. These are AG 1 to AG 13 and AG-BI (Ogoshi 1987; Sneh et al. 1991; Carling 1996; Carling et al. 2002a; Bienkowski 2012; Liu et al. 2019; Oladzad et al. 2019).

Although some AGs have wide host diversity, some AGs are highly host-specific (Çebi Kılıçoğlu 2009). *Rhizoctonia* groups (AG 1, AG 2-1, AG 2-2 and AG 4), which cause economically important product loss, cause diseases such as root rot, damping off, hypocotyl rot, fruit and seed rot in various vegetables. Some isolates in the same anastomosis group may show differences in terms of cultural characteristics and virulence, like isolates in different anastomosis groups. Binucleate *Rhizoctonia* isolates are grouped between AG-A to AG-S (Sneh et al. 1991; Eken and Demirci 2004) and are generally isolated from the root zone of crop plants, and they are either apathogenic or weakly pathogenic.

R. solani has been reported in every region of the world where beans are produced, and it can cause significant losses ranging from 20-100%. It forms thin, long and reddish-brown lesions of different sizes on the hypocotyl and roots of bean plants and causes softening in the roots. In the later stages of the infection, it has been reported that it causes yellowing of the leaves, stagnation in plant growth and ultimately the death of the plant. In humid periods, the agent can also infect leaves (web blight), petioles, flower, capsules and grains. *R. solani* subgroups that cause root rot in beans are AG 4 and AG 2-2 (Akarca 2013; Palacıoğlu et al. 2019).

R. solani Kühn, which is seen almost everywhere where potatoes are grown, causes black scurf on tubers, stem, stolon and root cancer diseases in the plant. The disease is called stem cancer and black scurf disease. The disease causes rot in the stolon and stem of the plant, causing regression in plant development and yield losses of up to 30-40% in some regions; it also causes a decrease in quality and market value with the black scurf, cracks and malformations it forms on the tuber (Aydın 2008; Bienkowski 2012; Carling et al. 1989). AG 3 isolates from the Solanaceae family, mostly from potatoes, infect the stolons severely in the early developmental stages of the potato and cause the formation of sclerotia called 'black scurf on tubers' (Ogoshi 1987). Potato AG 3 causes necrosis on the stem and stolons of the potato and sclerotia formation on the tuber, while AG 4 causes damping off and stem necrosis in the potato (Anderson 1982; Sneh et al. 1996; Aydın 2008).

Rhizoctonia root rot disease, which is one of the most important factors limiting sugar beet production, causes crown and root rot in the plant. The pathogen damages the plant tissue and proceeds toward the crown

and root of the plant. The first symptoms in the tuber begin as localized, dark, circular lesions, and in the following periods, the lesions take a ladder-like appearance. It causes a color change from dark brown to black in the roots. It has been estimated that an average of 20% of annual sugar beet yield loss is due to Rhizoctonia root and crown rot, and in some it has been observed as high as 30-60% (Hanson et al. 2011). While AG 2-2 causes damping off in the seedling period, it also causes root and crown rot in later periods. AG 4 is the most virulent group that causes damping off in seedlings in the form of superficial lesions. (Scholten et al. 2001; Liu et al. 2019; Avan and Katırcıoğlu. 2019; Barreto et al. 2020; Şahiner 2020).

Our study, it was aimed to determine the disease severity of *R. solani* isolates obtained from economically important bean, sugar beet and potato plants produced in Konya and to determine the anastomosis groups of the most severe isolates for each plant species.

2. Materials and Methods

2.1. Materials

2.1.1. Fungal pathogen

R. solani isolates used as a test pathogen were obtained as a result of isolation from plants showing disease symptoms in bean, potato and sugar beet cultivation areas in Konya province.

2.1.2. Test plants and varieties

To determine the disease severity of *R. solani*, sugar beet, potato and bean seeds from which the pathogen was isolated were used. Varieties used in the tests; Lider in sugar beet (*Beta vulgaris* L.), Amerikan Çalısı in bean (*Phaseolus vulgaris* L.) and Brooke variety in potato (*Solanum tuberosum* L.).

2.1.3. Plant growing media and chemicals

Sodium hypochlorite was used for the surface sterilization of plant parts to isolate the pathogen. PDA (39g/1000) containing Streptomycin sulfate (100 ml/1000ml) was used as the medium. Barley culture medium was preferred for long-term storage of the pathogen.

The number of nuclei of *R. solani* was determined using Safranin O solution (3% KOH (6 ml), 0.5% safranin (10 ml), glycerin (5 ml) and distilled water (79 ml)).

Distilled water agar (WA) (10 g/1000 ml) was used for the pre-germination of seeds to be used in pot experiments. The soil to be used in pot tests was prepared to contain peat/soil/perlite (2:1:1).

2.2. Methods

2.2.1. Collection, isolation and long-term storage of Rhizoctonia solani isolates

In order to obtain pathogens, root, seedling and tuber parts of sugar beet, bean and potato samples showing disease symptoms were collected from Konya (Kadınhanı, Meram and Çumra Districts) in June-September 2020 and placed in paper bags. It was brought to the laboratory after the label information was written.

Plant materials were first thoroughly washed in tap water. With the help of a scalpel, 5 pieces of plant tissue were cut into 1 cm size for each sample, including the diseased and healthy parts. Then, the plant parts were kept in 1% sodium hypochlorite solution for 1 minute and surface disinfection was carried out. Then the plant materials were transferred to sterile distilled water and this process was repeated 3 times. These pieces were transferred to Petri dishes with sterile blotting papers in a laminar airflow cabinet, and after drying, they were placed in a PDA medium containing streptomycin sulfate. After 2-3 days of incubation at 25°C in dark conditions, the Petri dishes were examined macroscopically and microscopically, and an agar plate was taken

from the cultures determined to be *R. solani*, and a pure culture was obtained by transferring it to PDA medium.

Barley culture medium was used for long-term storage of *Rhizoctonia* isolates. The barley grains, which were kept in water for 1 night, were transferred to the tubes and this culture medium was autoclaved at 121°C for 20 minutes. To remove excess moisture, the tubes containing barley cultures were closed with sterile blotting papers and kept at 25°C for 1 day. Then, pure *R. solani* isolates were inoculated into this medium and incubated at 25°C for 15 days, and the growing cultures were stored at +4°C for a long time.

2.2.2. Determination of Nuclear numbers of Rhizoctonia solani isolates

To determine the number of nuclei of the *R. solani* isolates obtained, the isolates were transferred to Petri dishes with a diameter of 9 cm and containing 15 ml of PDA and incubated at 25°C for 5 days. After incubation, developing hyphae were stained with Safranin O and 3% KOH and counted in 25 cells for each isolate at 40X magnification under light microscope. The isolates were classified as multinucleate (MN) or binucleate (BN) according to the number of nuclei (Bandoni 1979; Martin and Lucas 1984; Avcı 2019).

2.2.3. Preparation of the inoculum and pathogenicity test

Pathogenicity tests of the obtained *R. solani* isolates were tested on the host plant species from which each isolate was obtained. *R. solani* isolates preserved in barley cultures were transferred to PDA medium to obtain fresh cultures and were expected to develop at 25^0C for 7 days. An agar plate from growing fresh cultures of *R. solani* was transferred to the prepared barley culture medium for use as an inoculum and incubated at 25°C for 3 weeks. The amount of inoculum was used as 1 barley grain for each seed of bean and sugar beet. In potatoes, each pot soil was inoculated by mixing the pathogen-infected barley culture medium (at the rate of 2%) with the soil before planting the tubers.

The experiment was established as three replications for each isolate and 3 seeds were planted in each pot. 1-liter pots were used for beans and sugar beets, and 2-liter pots were used for potatoes. These pots were filled with a mixture containing peat/soil/perlite (2:1:1) and sterilized at 121°C for 60 minutes.

It was pre-germinated in bean and sugar beet seeds. The seeds were first sterilized with 2% sodium hypochlorite. After the seeds were dried at room temperature, they were placed in a water agar medium and incubated for 2-3 days at 25^0C until primary root formation. Then, the germinated seeds were planted in pots and one of the barley grains wrapped in the mycelium of the pathogen was placed next to each seed. A sterile barley grain was placed next to the seed in the pots used as the control group. In the pathogenicity test of *R. solani* in potatoes, the control group was prepared by mixing 2% sterile barley into the soil. After inoculation, the plants were allowed to grow in 12 hours light and 12 hours dark climate *solani* in potato, the control group was prepared by mixing 2% sterile barley into the soil. room (65% humidity and 25°C) and sugar beet and beans were evaluated for the disease after 4 weeks and potatoes after 6 weeks. For each isolate, the pathogenicity test was provided by reisolation from diseased plants (Buhur 2014; Basbagci et al. 2019).

2.2.4. Evaluation of disease severity of Rhizoctonia solani

To assess disease severity, the uprooted plants were thoroughly washed under running tap water, and then all plants were examined for disease. The 0-4 scale explained in Table 1 was used for sugar beet and bean in the evaluation of disease severity (Muyolo et al. 1993).

R. solani in potatoes was evaluated according to root necrosis of the plant. For this, the 0-3 scale, which is explained in Table 2, was used (Aydın 2008).

Table 1. 0-4 scale in which the severity of the disease caused by *R. solani* in bean and sugar beet is evaluated.

Scale Value	Definition
0	Healthy seedling
1	Very small brown superficial lesions on roots or stem
2	Deep and extensive lesions on the roots or stem, regression in root development
3	Severe root rot, deep lesions surrounding the main root or stem, significantly reduced root length
4	Dead plant

Table 2. The 0-3 scale in which the severity of the disease caused by *R. solani* in potatoes is evaluated

Scale Value	Definition
0	No stem canker
1	Up to 1/3 of the stem under the ground is damaged
2	Up to 1/3-2/3 of the stem under the ground is damaged
3	Up to 2/3 or more of the underground stem is damaged

After the evaluation made according to the scale, the disease severity index was calculated according to the Towsend-Hauberger (1943) formula.

$$\% \text{ Disease Severity Index} = [\Sigma(SD \times BS)/(ESD \times TB)] \times 100 \quad (1)$$

According to the formula; SD: Scale value, BS: Number of plants at the same scale value, ESD: Highest scale value, TB: Total number of plants.

2.2.5. Characterization of anastomosis groups of selected Rhizoctonia solani isolates

As a result of pathogenicity studies, 3 isolates of *R. solani* with the highest virulence for each plant were molecularly characterized. Studies for molecular characterization were carried out by Prof. Dr. Göksel Özer in Bolu Abant İzzet Baysal University Plant Protection Department Laboratory.

Amplification of *R. solani* isolates was performed using ITS gene region ITS-1 (5′-TCCGTAGGTGAACCTGCGG-3′) and ITS-4 (5′-TCCTCCGCTTATTGATATGC-3′) primers (White, et. al., 1990).

2.2.6. *Statistical analysis*

The data obtained as a result of the evaluations were compared with the Duncan Multiple Comparison tests in the SPSS 17.0 statistical program (SPSS Inc, Chicago, IL, USA) at $p<0.05$ significance level.

3. Results and Discussion

As a result of the isolations made from plant samples taken in 2020, it was determined that 10 of 36 bean samples, 15 of 25 potato samples (tuber and stem) and 15 of 25 sugar beet samples were infected with *R. solani* (Figure 1).

After all, isolates obtained were microscopically identified as *R. solani*, they were transferred to a barley culture medium.

To determine the number of nuclei of the isolates, which were microscopically found to be *R. solani*, staining was performed with safranin O (Figure 2).

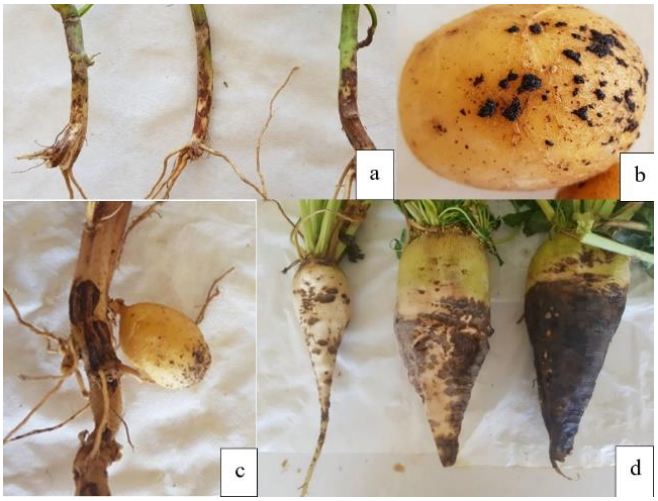

Figure 1. Symptoms of *R. solani* in different plants: **(a)** beans; **(b-c)** potato; **(d)** sugar beet

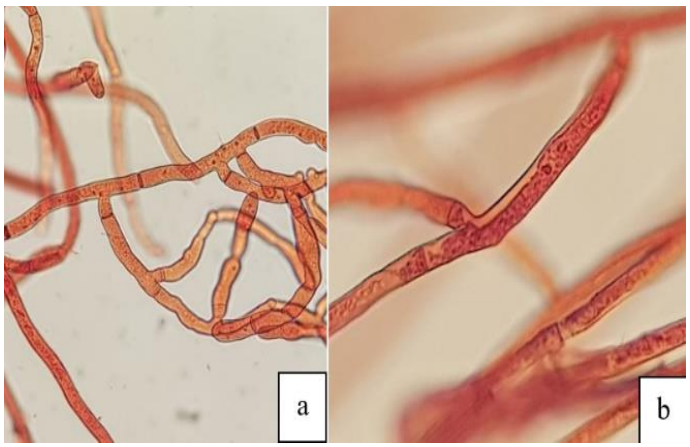

Figure 2. The appearance of the nuclei stained with Safranin O in light microscopy: **(a)** Multinucleic nucleus (MN), **(b)** Binucleic nucleus (BN)

9 out of 10 isolates of *R. solani* obtained from beans, 14 of 15 isolates obtained from potato, and 14 of 15 isolates obtained from sugar beet were determined as multinucleate. It was determined that 1 isolate isolated from the bean, sugar beet and potato was binucleate. As a result, a total of 37 multinucleate (MN) and 3 binucleate (BN) isolates were obtained from all plants.

All of the 10 bean isolates obtained were used in the pathogenicity assay. In addition, the disease severity of Fa-2.2 (89%), Fa-1 (86%), Fa-5.2 (86%) and Fa 2.1 (83%) isolates is also quite high. The disease severity of the isolate Fa-4.2, which was found to be binucleate in the evaluation according to the number of nuclei, was determined at a rate of 17% (Table 3).

Table 3. Disease incidence and severity of bean *R. solani* isolates in bean plants.

Code of Isolates	Disease Incidence (%)	Disease Severity (%)
Fa-1	100a	86ab
Fa-2.1	100a	83b
Fa- 2.2	100a	89ab
Fa-3.1	33c	14cd
Fa-3.2	100a	97a
Fa-4.2	67b	17cd
Fa-5.2	100a	86ab
Fa-6.2	44bc	11d
Fa-7	33c	8d
Fa-8	67b	25c

P<0.05 (There is no statistical difference between the means expressed with the same letter in the same column)

As a result of the pathogenicity test carried out on potato *R. solani* isolates, it was observed that deep necrosis occurred in the stem of the test plants. Pa-15.2 (50%) was the most virulent potato isolate evaluated according to the stem necrosis scale (scale 0-3), followed by Pa-10 (44%) and Pa 12.1 (42%) (Table 4).

Table 4. Disease incidence and severity of potato *R. solani* isolates on potato plants

Code of Isolates	Disease Incidence (%)	Disease Severity (%)
Pa-1.1	64bf	39ac
Pa-2.1	67bf	25cf
Pa-3.1	73bd	33bf
Pa-4.2	57df	26cf
Pa-5.2	69be	36ad
Pa-6.2	67bf	31bf
Pa-7.2	69be	31bf
Pa-8.2	50eg	21df
Pa-9.1	79ac	36ad
Pa-10	85ab	44ab
Pa-11.2	31g	26cf
Pa-12.1	80ac	42ac
Pa-13.2	46fg	18f
Pa-14.2	62cf	28bf
Pa-15.2	94a	50a

P<0.05 (There is no statistical difference between the means expressed with the same letter in the same column)

As a result of pathogenicity tests of *R.solani* isolates obtained from sugar beet, it was observed that all isolates caused diseases in plants. After pre-germination, isolates that caused severe infection in sugar beets caused damping off in seedlings. The disease severity values of 15 *R.solani* isolates obtained varied between 67-100% and 9 *R.solani* isolates caused 100% disease severity in sugar beet plants (Table 5).

For each plant, 3 *R. solani* isolates with high disease severity were divided into anastomosis groups using. Accordingly, *R. solani* isolates (Fa 3.2, Fa 2.2 and Fa 5.2) isolated from beans were determined to belong to the AG 4 HGI anastomosis group. Anastomosis groups of the isolates of *R. solani* (ŞP 2.2, ŞP 7.2 and ŞP 11.1) isolated from sugar beet were determined as AG 2-2. Anastomosis groups of the 3 most virulent *R. solani* isolates (Pa 10, Pa 12.1 and Pa 15.2) from potato isolates were determined as AG-3 (Figure 3).

Table 5. Disease incidence and severity of sugar beet *R.solani* isolates in sugar beet plants

Code of Isolates	Disease Incidence (%)	Disease Severity (%)
ŞP-1.2	100a	100a
ŞP-2.2	100a	100a
ŞP-4.2	100a	100a
ŞP-7.2	100a	100a
ŞP-8.1	100a	100a
ŞP-11.1	100a	100a
ŞP-12.1	89a	89a
ŞP-13.2	100a	100a
ŞP-14.2	67b	67b
ŞP-15.2	89a	89a
ŞP-16.2	100a	100a
ŞP-18.1	89a	89a
ŞP-19	89a	89a
ŞP-20	100a	100a
ŞP-21.2	89a	89a

P<0.05 (There is no statistical difference between the means expressed with the same letter in the same column)

R. solani is a soil-borne necrotrophic pathogen affecting many plant families. Within *Rhizoctonia*, 14 anastomosis groups (AG) have been identified. Although some AGs have wide host diversity, some AGs are highly host specific. For example; AG 1, AG 2-2 and AG 4 infect sugar beets. While AG 2-2 causes root rot, AG 1, AG 2-2 and AG 4 infect the crown and leaves. In many studies, it has been reported that high levels of AG 2-2 are found in isolations made from sugar beet plants and especially AG 2-2 is highly virulent in more mature tubers. In another study, it was determined that the most common group was AG 2-2 IIIB (Herr and Roberts 1980; Windels et al. 1989; Çebi Kılıçoğlu 2009; Strausbaugh et al. 2011; Stojsin et al. 2011; Avan 2020; Wigg 2021). In our research, the most virulent isolates in sugar beet, coded ŞP 2.2, ŞP 7.2 and ŞP 11.1, were isolated by taking samples in the more mature stages of beet and anastomosis groups were determined as AG 2-2, similar to other studies.

AG 3 isolates, which are mostly isolated from potato, infect the stolons severely in the early or mid-development stages of the potato, causing Rhizoctonia canker and black scurfs disease in tubers and roots (Ogoshi 1987).

Thirteen anastomosis groups of this fungus have been identified. Of these, AG 3 causes necrosis on the stem and stolons of the potato, and sclerot formation on the tuber; AG 4 causes damping off and stem necrosis in potatoes (Anderson 1982; Sneh et al. 1996; Aydın 2008). Although *R. solani* isolates isolated from sclerot on the stem, root and tuber of potato are generally in the AG 3 group, there are also different anastomosis groups (AG 1, AG 2-1, AG 2-2, AG 4, AG 5 and AG 9) isolated from potato growing soils (Carling 1989). In our study, the disease severity of Pa-10, Pa12.1 and Pa 15.2 potato isolates was determined to be high and the anastomosis groups of these isolates were determined as AG-3 in parallel with many studies.

R. solani subgroups that cause root rot in beans are AG 4 and AG 2-2, while AG 1-IA, AG-1 IB, AG 1-IE, AG 1-IF, AG 2-2 IV and AG 4 cause web blight in beans. (Godoy-Lutz 2003; Gogoy-Lutz, 2008; Çebi Kılıçoğlu 2009; Valentin Torres et al. 2016). *R. solani* isolates isolated from beans in Turkey (AG 1, AG 2-1, AG 2-2, AG 3, AG 4, AG 5, AG 6, AG 7, AG 9, AG 10 and AG 11), binucleic *Rhizoctonia* AGs (AG-A, AG-B AG-F, AG-G, AG-I and AG-K) and *R. zeae* have also been identified in addition to these groups. AG 1 and AG 4 isolates were obtained from bean seeds, as well as AG-B, AG-E from roots and hypocotyls. The most common anastomosis group seen in beans in the world and our country is AG-4 (Demirci and Döken 1995; Karaca et al. 2002; Eken and

Demirci 2004; Erper et al. 2011). According to our research results, the most virulent Fa 3.2, Fa 2.2 and Fa 5.2 isolates were determined as AG 4 HGI.

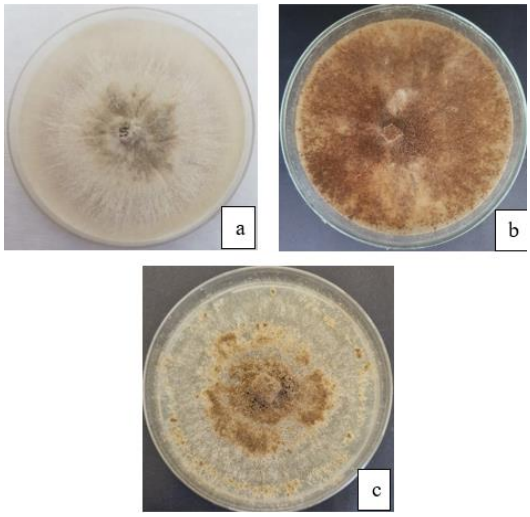

Figure 3. The most virulent *R. solani* isolates isolated from different plants: **(a)** Fa 3.2 (AG 4 HGI) isolated from beans; **(b)** ŞP 7.2 (AG 2-2) isolated from sugar beet; **(c)** Pa 15.2 (AG-3), isolated from potato.

Binucleic *Rhizoctonia* isolates, on the other hand, are grouped between AG-A to AG-S and are generally isolated from the root zone of cultivated plants, and binucleic *Rhizoctonia* is either apathogenic or weakly pathogenic. Generally, these groups are also used as biological control agents against root rot disease (Cardoso and Echandi 1987; Çelebioğlu 2009). However, some of the binucleates (BNs), such as AG-D,-E, -F and -R group isolates, are known to cause root rot or damping off disease in some plants such as beans, radishes, strawberries, sugar beets and onions (Sneh et al. 1991; Karaca et al. 2002; Eken and Demirci 2004). In our study to determine the number of nuclei, it was determined that 1 isolate in sugar beet, potato and bean was binucleate.

The fact that the disease is both soil-borne and seed-borne causes some difficulties in its control compared to other diseases. An integrated approach should be followed in the control against the disease and knowledge about the stages of the disease should be obtained. Cultural measures are very important for the control of the disease, among which methods such as the inoculum source being free from disease, the use of certified seeds, the disease-free soil, the timing of rotation, harvest time and the use of pesticides, and the regulation of soil and water management play a key role (Aydın 2008; Tsror 2010).

The most practical and economical way to control the disease is rotation and the use of resistant plants. Although there are varieties resistant to disease, these varieties have some disadvantages as they are not resistant to some other important diseases and their yield is lower than other varieties. In addition to these methods of control fungicides are also used in some cases. Due to the different effects of fungicides on *R. solani* AGs, it is important that the selected fungicides are suitable for the anastomosis group to ensure effective control of the disease. Flutolanil, azoxystrobin and prothioconazole are effective in chemical control of the disease in sugar beet (Khan et al. 2009; Bolton et al. 2010). Fungicides with active ingredients such as azoxystrobin, azoxystrobin+difenoconazole, fludioxonil, mancozeb are used against root rot in beans (Bost 2006; Knodel et al. 2016; Tvedt 2017). *R. solani* in potatoes inhibits only pencycuron and tolclofos methyl 100% *in vitro*, while azoxystrobin and pencycuron inhibit sclerot formation in tubers the most in the field. Another example is that AG 1, 3 and 5 are moderately affected by fungicides with aromatic hydrocarbons, while the

sensitivity of AG 2-1, 4, 7 and 8 is very low (Tsror 2010). For this reason, determining which anastomosis groups of *R. solani* are virulent in which plants will be a guide in the control. In particular, it is important to know which product group was in the field examined in previous years and to follow up on the disease in the point of control decision, especially in recommending the rotation plant. Biological control studies, which are seen as an alternative to chemical control, have increased considerably in recent years. In particular, the use of commercial biological control products against soil-borne diseases as a part of integrated management will contribute to the suppression of the disease.

Author Contributions: Özden SALMAN planned, established and conducted the study. Nuh BOYRAZ analyzed the data obtained in the study and Özden SALMAN wrote the article. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest: The authors declare no conflict of interest.

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Efficacy of Some *Trichoderma* Isolates as Biocontrol Agents Against *Rhizoctonia solani* Kühn in Bean *(Phaseolus vulgaris L.)*

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HIGHLIGHTS

- *Rhizoctonia solani* is a disease agent that causes significant crop losses in beans in our country. Due to the adoption of environmentally friendly approaches in the world in recent years, it has become necessary to find different solutions for this disease, which is difficult to control.
- This study, it was aimed to determine the in vitro and in vivo effectiveness of *Trichoderma,* which is an important part of biological control, against *R. solani* in beans.

Abstract

This study was carried out to determine the *in vitro* and *in vivo* activities of *Trichoderma* isolates isolated from soil and plants collected from different provinces in 2020-2021 against *Rhizoctonia solani*, which causes root rot in beans. Using the pathogen as a trap, 61 *Trichoderma* isolates were obtained from 65 soil samples from 20 provinces. In addition, 8 *Trichoderma* isolates previously obtained from different plants were included in the experiment. *Trichoderma* isolates showed very strong (4 *Trichoderma* isolates), strong (1 *Trichoderma* isolate), moderate (18 *Trichoderma* isolates) and low level (18 *Trichoderma* isolates) hyperparasitic effects against *R. solani* in *in vitro* experiments with dual culture method. In comparison, some isolates (28 *Trichoderma* isolates) were found to be ineffective. As a result of *in vivo* tests with 10 *Trichoderma* isolates selected according to the effect results *in vitro*, it was determined that *Trichoderma* isolates were 8-89% effective against *R. solani*. The most effective *Trichoderma* isolates against *R. solani* was *Trichoderma virens-130* with an 89% effect, followed by *Trichoderma-106* and *Trichoderma-162.1* with 82% and 75% effect, respectively. According to these results, it was observed that the isolates of *Trichoderma*, which were moderately and highly effective *in vitro*, significantly reduced the severity of the disease *in vivo*.

Keywords: Bean; *Rhizoctonia solani*; Biocontrol; *Trichoderma*

1. Introduction

Beans (*Phaseolus vulgaris* L.) are one of the most important legumes in human nutrition worldwide. Root rot diseases are the main problem limiting bean production in many parts of the world (Ceyhan 2004; Naseri and Hemmati 2017; Tamüksek and Ceyhan 2022; Tekin and Ceyhan 2022). *Rhizoctonia solani* Kühn (Telemorph: *Thanatephorus cucumeris*), one of the critical factors causing root rot diseases, has been reported in every region of the world where beans are produced, and it can cause significant losses ranging from 20-100%. *R. solani* causes thin, long, flattened, and reddish-brown lesions of different sizes on the hypocotyl and roots of bean plants and softening of the roots. In the later stages of the infection, it has been reported that it causes yellowing

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of the leaves, stagnation in plant growth, and ultimately the death of the plant before it matures. In the presence of moisture, the pathogen can infect leaves (web blight), petioles, flowers, capsules, and grains. When it infects the capsules, the disease also transfers to the seeds, causing significant damage to both yield and quality. The fungus survives as mycelium or sclerotia in plant remains in the soil (Akarca 2013; Palacıoğlu et al. 2019).

Binucleic (Telemorph: Ceratobasidium) and multinucleic *R. solani* (Telemorph: *Thanatephorus cucumeris*) and *Rhizoctonia zeae* (Telemorph: *Waitea circinata* var. *zeae*) have been reported as pathogens in beans (Godoy-Lutz et al. 2003; Nerey et al. 2010). *R. solani* and binucleic *Rhizoctonia* spp. isolates are divided into anastomosis groups according to their hyphal anastomosis reactions. Until now, 13 AG of *R. solani*, named AG 1-AG 13, and 16 binucleic AG have been described (Carling et al. 2002; Sharon et al. 2008). Root and collar rot in beans is caused by *Rhizoctonia solani* AG 4, AG 2-2, and AG 5 subgroups. The most common group seen in beans in the world is AG-4 (Godoy-Lutz 2003; Gogoy-Lutz 2008; Çebi Kılıçoğlu 2009; Valentin Torres et al. 2016).

Many fungal microorganisms living in the soil are known as potential biological control agents, and the most well-known among them are *Trichoderma* species (Punja and Utkhede 2003; Ting and Choong 2009). Thanks to *Trichoderma*'s practical biocontrol abilities; many of the commercial products are marketed in Asia, Europe, and the USA. The mechanisms involved in the biocontrol activity of *Trichoderma* spp. against plant pathogens (such as mycoparasitism, competition for space and food, and antibiosis) are essential for planning effective and safe biocontrol strategies (Wolska et al. 2012). *Trichoderma* spp. also produces different antibiotic substances; gliotoxin, gliovirin, viridin, and trichoviridin. It is also known that *Trichoderma* spp. prevent the development of pathogenic fungi by changing the rhizosphere. In addition, *Trichoderma* spp. in the rhizosphere helps the plant to support nutrient/fertilizer uptake, seed germination, and photosynthetic rates (Yedidia et al. 2003).

There are many studies on using *Trichoderma* spp. against *Rhizoctonia solani*, causing stem and root canker in beans. Yobo et al. (2011) investigated the effects of 6 *Trichoderma* (*T. atroviride* 3A, *T. atroviride* 6, *T. harzianum* SY, *T. pseudokoningii*, unidentified *Trichoderma* sp. 2F and *T. harzianum* kmd) and 3 *Bacillus subtilis* (*B. subtilis* B69, *B. subtilis* B77 ve *B. subtilis* B8) isolates seperately and in combination against *Rhizoctonia solani* which causes damping off disease in bean and cucumber, *in vivo*. Fungal and bacterial isolates obtained in the study related to yield applied to the seed in greenhouse and rhizotron studies. In greenhouse experiments, it was determined that seedling dry-weight of beans yielded the highest results when *T. atroviride* strain 6 and *Bacillus subtilis* B69 were applied together. Rhizotron studies have also been found to give results in support of this. In biological control experiments, it was determined that the survival rate of the plants was high when *T. harzianum* kmd, *T. atroviride* 3A and *T. harzianum* SY have applied alone under greenhouse conditions. It has been observed that the efficacy of the combination of *B. subtilis* B69 and B81 is increased when used together with *T. atroviride* 3A, *T. atroviride* 6, or *T. harzianum* kmd. According to the results of this study, the efficacy of each of the *Trichoderma* and *Bacillus* combinations gave better results than the application of *Bacillus* isolates alone.

According to the results obtained, it was determined that the best application for suppressing the disease was the combination of *B. pumilus* INR7 + *T. harzianum*. This application reduced the disease by 54% (Nasir et al. 2018).

Bozdeveci et al. (2019) determined the effects of *T. harzianum* ID11C obtained from tea soil against *R. solani* B227 on biocontrol activity and bean growth. It has been observed that this biocontrol agent is tolerant to heavy metals, has a plant growth-promoting effect and suppresses pathogen growth.

Rhizoctonia solani is a plant pathogen causing significant crop losses in beans in our country. Due to the adoption of environmentally friendly approaches in the world in recent years, it has become necessary to find different solutions for this disease, which is difficult to control. For this reason, this study aimed to determine

the *in vitro* and *in vivo* effectiveness of *Trichoderma* spp., an important part of biological control, against *R. solani* in beans.

2. Materials and Methods

2.1. Materials

2.1.1. Fungal isolates used in tests

In the experiment, an isolate belonging to the AG 4HGI anastomosis group of *Rhizoctonia solani*, isolated from a bean and determined to be pathogenic and anastomosis group, was used.

A total of 69 *Trichoderma* was isolated from different soil samples (61 isolates) and plant materials (8 isolates) as bioagents.

2.1.2. Plant material

To determine the *in vivo* efficacy of *Trichoderma* isolates against *R. solani* AG 4HGI, Üstün 42 variety was used.

2.1.3. Plant growing media and chemicals

Potato Dextrose Agar medium (PDA, Merck) containing streptomycin sulfate was used to obtain fresh cultures of *R. solani* and *Trichoderma*. PDA medium containing Rose Bengal was used to obtain *Trichoderma* from soil samples by trapping method (Table 1).

Table 1. Chemical content of PDA containing Tolchlofos methyl-rose bengal

Name of the ingredients	Concentration
Rose Bengal	32 mg
PDA	39 g
Streptomycin sulfate solution	100 ml
Tolclofos Methyl	6 mg
Distilled Water	1000 ml

In addition, PDA medium amended with antibiotics was used in the dual culture tests of *Trichoderma* spp.-*R. solani*. 2% sodium hypochlorite (NaOCl) was used for the surface disinfection of bean seeds, and water agar (WA) was used to germinate seeds. *Trichoderma* isolates were preserved in 30% glycerol. The culture of *R. solani* has stored in barley grains long-term preservation. A mixture of peat/soil/perlite prepared in a ratio of 2:1:1 (v/v/v) was used in *in vivo* experiments.

2.2. Methods

2.2.2. Fresh cultures of Rhizoctonia solani

Firstly, new cultures of *Rhizoctonia solani* isolates stored in barley culture were prepared. For this purpose, PDA medium containing 100 ml/1000 ml Streptomycin sulfate was prepared. One barley grain covered by the fungus was taken with the help of forceps, placed in the prepared PDA medium and incubated at 25 ^{0}C for 7 days to obtain fresh cultures.

2.2.2. Isolation and long-term storage of trichoderma

To obtain *Trichoderma* isolates used in the experiments, soil samples were obtained from regions with different ecological characteristics, especially from some districts of Konya (Karatay, Çumra, Altınekin, Meram, Sarayönü, Ilgın). Samples were taken from the rhizosphere of well-developed plants in healthy or

pathogen-infested fields. These soil samples were sieved using fine-meshed sieves. Then, a PDA medium containing Rose Bengal was used to trap *Trichoderma* from these soil samples. The medium prepared as given in Table 1 was autoclaved at 121 ^{0}C for 20 minutes and when the temperature of the medium fell to 45 ^{0}C, tolclofos methyl and streptomycin sulfate were added to it (Aydın 2008).

Rhizoctonia solani was used to obtain *Trichoderma* cultures. First, a 7-day fresh culture of *Rhizoctonia solani* was obtained, and then soil samples selected from different regions were covered with soil and incubated at 25 ^{0}C for 14 days. After this waiting period, the soil on the surface of the *Rhizoctonia solani* culture was thoroughly cleaned with sterile distilled water and 5 pieces of agar disc were transferred to a PDA medium containing improved rose bengal and incubated at 25 ^{0}C. Petri dishes were checked frequently and different *Trichoderma* isolates growing in each petri dish were transferred to a PDA medium to obtain a pure culture. According to their microscopic features (conidiophore, branching shape of the conidiophore, number and arrangement of phialides, shape and color of conidia, chlamydospore formation and location) genus level identification of *Trichoderma* were determined, and these samples were stored in 30% glycerol at -20 ^{0}C for long term preservation. 61 *Trichoderma* isolates were obtained using the trapping method from 65 soil samples selected from the 20 provinces where the soil samples were taken. A total of 69 *Trichoderma* isolates were obtained and 8 isolates spontaneously grown on plant materials.

2.2.3. Determination of in vitro efficacy of Trichoderma isolates

In dual culture tests, 7-day-old fresh cultures of *Trichoderma* and *R. solani* were used. Agar plates cut from fresh cultures were placed opposite each other on PDA medium with antibiotics. The evaluation was made after 7 days of incubation at 25 °C. Information on the scale values and definitions used in the evaluation are given in Table 2.

Table 2. Scale values were used to determine the efficacy of *Trichoderma* isolates.

Scale Value	Definition
1	*Trichoderma* completely develops on the pathogen and completely covers the medium.
2	*Trichoderma* covers two-thirds of the media surface.
3	*Trichoderma* and pathogens both cover almost half of the media surface and neither can dominate the other.
4	The pathogen covers two-thirds of the environment and is based on the pressure of *Trichoderma*.
5	The pathogen develops completely on *Trichoderma* and covers the surface.

Scale values of *Trichoderma* isolates evaluated according to the scale ≤2 indicate a high level of hyperparasitic effect against the pathogen (1: Very strong, 2: Strong), and a score of ≥3 indicates low or no hyperparasitic effect (3: Moderately effective, 4 : Less effective, 5: Ineffective) (Bell et al. 1982; Durak 2011). Accordingly, 10 *Trichoderma* isolates with the best effect were used in *in vivo* studies.

2.2.4. Preparation of the Inoculum

A barley culture medium was used to prepare the *R. solani* inoculum. For this, 1/3 of the test tube is filled with barley grain. It was sterilized at 121^{0}C for 60 minutes by adding 2 times its water weight to the barley grain. Autoclaving was carried out twice. Excess moisture was then removed from the tubes. An agar plate from fresh *Rhizoctonia solani* cultures was transferred to the prepared barley cultures and incubated at 25 °C for 3 weeks. One barley grain containing pathogen was used for each bean seed from these prepared barley grains (Carling and Summer 1992).

2.2.5. Determination of in vivo Efficacy of Selected Trichoderma Isolates against R. solani

1 lt pot were used in the experiment. These pots were filled with peat/soil/perlite mixture and sterilized at 121 ^{0}C for 60 minutes. To determine the efficacy of *Trichoderma* isolates, the experiment was set up as three replications for each isolate. 3 seeds (Üstün 42 bean varieties) were planted in a pot.

Pre-germination was done in bean seeds. For surface disinfection, the seeds were first kept in 2% sodium hypochlorite for 1 minute, then passed through sterile distilled water twice for one minute and left to dry on sterile papers at room temperature. Then, it was transferred to petri dishes containing water agar and kept at 25 ^{0}C for 3-4 days.

Trichoderma cultures were first incubated at 25 ^{0}C for 7 days to determine the effectiveness of *Trichoderma* işletesi selected for use in *in vivo* experiments against *R. solani*. A spore suspension of 15 ml was prepared from each *Trichoderma* to isolate to apply to the seeds from these cultures. The density of the spore suspension was adjusted to 10^8 spores/ml by counting on a haematocytometer (Thoma slide). Then the seeds were kept in the solution for 15 minutes. Then, the seeds were placed in pots and one of the barley grains covered with the mycelium of the pathogen was placed next to it with forceps. In the pots used as the control group, a sterile barley grain was placed next to the germinated seed instead of pathogenic barley and covered with soil. The remaining spore suspension was equally divided into pots and poured. Experiments were carried out with 3 replications.

After inoculation, the plants were expected to grow in a climate room with 12 hours of light and 12 hours of darkness (65% humidity and 25 °C) for four weeks before being evaluated for disease. (Buhur 2014; Başbağcı et al. 2019).

2.2.6. Evaluation of in vivo Efficacy of Trichoderma Isolates against R. solani

The activities of *Trichoderma* isolates against *R. solani* were compared by calculating the disease severity. For this purpose, the uprooted plants were thoroughly cleaned under tap water, and then all plants were examined for disease. A 0-4 scale was used to evaluate the severity of the disease (Table 3) (Muyolo et al. 1993).

Table 3. 0-4 scale used in the evaluation of *R. solani* infection in bean plants.

Scale Value	Definition
0	Healthy seedling
1	Very small brown superficial lesions on roots or stem
2	Deep and extensive lesions on the roots or stem, regression in root development
3	Severe root rot, deep lesions surrounding the main root or stem, significantly reduced root length
4	Dead plant

After the evaluation was made according to the scale, the disease severity index was calculated according to the Towsend-Hauberger formula (1943).

$$\% \text{ Disease Severity Index} = [\Sigma(SD \times BS)/(ESD \times TB)] \times 100 \quad (1)$$

According to the formula; SD: Scale value, BS: Number of plants on the same scale, ESD: Highest scale value TB: Total number of plants

The data obtained from the evaluations were compared with the Duncan Multiple Comparison tests in the SPSS 17.0 statistical program (SPSS Inc, Chicago, IL, USA) at a $p<0.05$ significance level. The most effective isolate statistically was sent to BM Labosis for molecular characterization.

3. Results and Discussion

3.1. Trichoderma isolates

To obtain the *Trichoderma* isolates we used as bioagents in the experiments, the province where the soil samples were taken, and the number of *Trichoderma* isolates obtained are given in Table 4. As a result, 61 *Trichoderma* isolates were obtained from 65 soil samples from 20 provinces. In addition, 8 *Trichoderma* isolates that developed spontaneously in isolations made from plants in previous studies were also used in the tests.

Table 4. Soil samples used to obtain *Trichoderma* and the number of *Trichoderma* isolates obtained

Province	Number of Samples	Soil/Plant Organs	Number of *Trichoderma* Isolates
Konya	29		25
Afyonkarahisar	1		2
Van	1		-
Muğla	2		3
Eskişehir	2		2
Adana	1		-
Amasya	2		2
İzmir	4		-
Aydın	3		4
Erzurum	2		2
Kayseri-Develi	2	Soil	2
Çanakkale-Batakovası	2		3
Nevşehir	2		2
Tokat	2		4
Şanlıurfa	2		-
Niğde	1		3
Antalya	1		-
Mersin	2		3
Samsun	2		4
Karaman	2		0
Muğla	3	Root (*Brassica oleracea*)	3
Niğde	3	Tuber (*Solanum nigrum*)	3
Konya	2	Root (*Phaseolus vulgaris*)	2
Total	**73**		**69**

3.2. In vitro efficacy of obtained Trichoderma isolates against R. solani

In dual culture tests, it was observed that a lytic zone was formed in some of the *Trichoderma* isolates and the mycelial growth of the pathogen was disrupted. Other *Trichoderma* isolates that we used in our study showed a hyperparasitic effect and quickly covered the pathogen. Dual culture studies were evaluated at 7 days of age. In some of the Petri dishes that were observed to be effective, *Trichoderma* did not fully develop conidial growth, although it covered *R. solani* mycelium. As a result, different developments were observed in *R. solani-Trichoderma* dual cultures (Table 5).

Table 5. *In vitro* Efficacy of *Trichoderma* Isolates against *R. solani*

No	Code of *Trichoderma* Isolates	Efficacy Level of *Trichoderma* Isolates against *R. solani*	No	Code of *Trichoderma* Isolates	Efficacy Level of *Trichoderma* Isolates against *R. solani*
1	Lahana fet1	VSH	22	108.2	LH
2	Lahana Fet.2	MH	23	113	MH
3	Lahana Fet3	MH	24	118.2	LH
4	Pa Niğde1	VSH	25	126.1	LH
5	Pa Niğde2	MH	26	130	VSH
6	T	MH	27	133	MH
7	TH4K2a	MH	28	138	LH
8	T-2.1	LH	29	153.1	MH
9	T-2.2	LH	30	153.3	LH
10	33	MH	31	160	MH
11	39.1	LH	32	162.1	MH
12	39.2	LH	33	162.2	MH
13	64	VSH	34	187	LH
14	74.1	LH	35	204.1	MH
15	90	MH	36	204.2	LH
16	99	MH	37	216	MH
17	99.2	SH	38	217.1	LH
18	103.2	LH	39	217.2	LH
19	104.1	MH	40	218.1	LH
20	104.2	LH	41	219.1	LH
21	106	MH			

VSH: very strong hyperparasitic, SH: strong hyperparasitic, MH: moderate hyperparasitic, LH: low-level hyperparasitic.

As a result of dual culture studies, 4 of the *Trichoderma* isolates against *R. solani* were determined as very strongly hyperparasitic, 1 strongly hyperparasitic, 18 moderately hyperparasitic, 18 mildly, 28 ineffective. Considering these results, 10 isolates thought to be effective in *R. solani-Trichoderma* dual cultures are as seen in Figure 1.

Similar to our *in vitro* test results, Mayo et al. (2015) determined the efficacy of *Trichoderma* isolates against root rot caused by *R. solani* in beans. The inhibition rate of T003, T004, T006, T020, T022, T012, T013, T025, T016, T007, T024, T005 and T010 is 75-86.70%, while 86.70% of T003, T004, T006, T020 and T022 isolates reported to have the highest inhibition percentage with.

El-Benawy et al. (2020) determined the efficacy of 6 *Trichoderma* isolates against *R. solani in vitro*. The efficacy of these isolates T19, T20 and T22 according to the 5-day dual culture results, respectively; 67.02%, 67.57% and 68.00%. According to the dual culture results we obtained, 4 *Trichoderma* isolates (La-Fet1, Pa-Niğ, 130 and 64) showed a very strong hyperparasitic effect by completely covering *R. solani* in the petri dish.

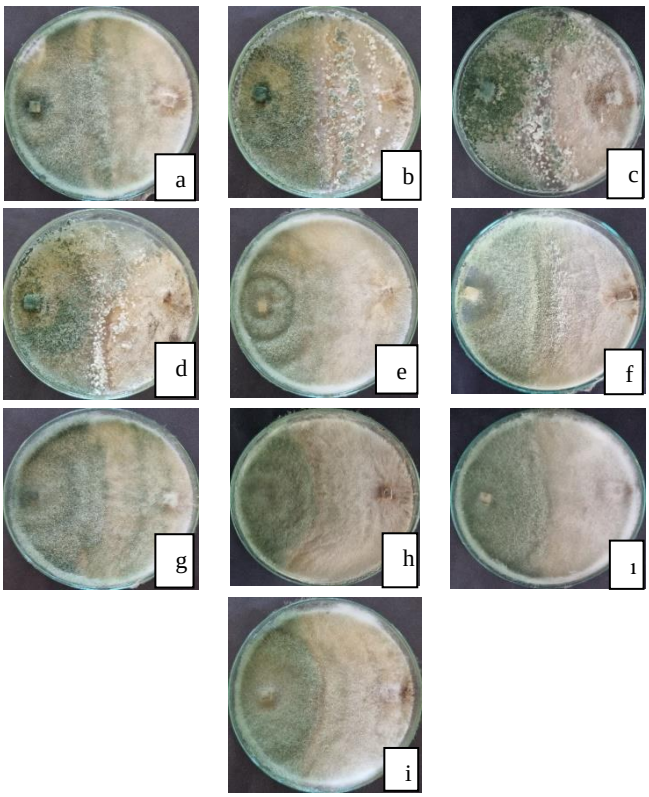

Figure 1. The hyperparasitic effects of different *Trichoderma* isolates against *R. solani* in dual culture tests: **(a)***Trichoderma* Pa-Niğ 1; **(b)** *Trichoderma* La-Fet1; **(c)** *Trichoderma* 64; **(d)** *Trichoderma* 99.2; **(e)** *Trichoderma* 104.1; **(f)** *Trichoderma* 106; **(g)** *Trichoderma* 130; **(h)** *Trichoderma* 133; **(ı)** *Trichoderma* 153.1; **(i)** *Trichoderma* 162.1.

3.3. In vivo efficacy of Trichoderma isolates against Rhizoctonia solani

Trichoderma isolates (10) used against *R. solani* showed an inhibitory effect of 8-89%. The most effective isolate was *Trichoderma virens* 130 with 89% efficiency. This isolate was followed by *Trichoderma* isolates 106 and 162.1, with efficacy rates of 82% and 75%, respectively (Table 6 and Figure 2).

Table 6. *In vivo* Efficacy of *Trichoderma* Isolates against *Rhizoctonia solani*

Code of *Trichoderma* Isolate	Disease Incidence (%)	Disease Severity (%)	Efficiency Rate (%)
153.1	83bc	47d	53f
Lahana Fet 1	100a	44de	56ef
99.2	100a	92b	8h
64	100a	86c	24g
106	78c	18h	82b
162.1	63d	25g	75c
133	100a	39ef	61de
130	44e	11ı	89a
Pa Niğde 1	88b	33f	67d
104.1	100a	33f	67d
+K	100a	100a	0ı

P<0.05 (There is no statistical difference between the means expressed with the same letter in the same column.

In the positive control of *R. solani*, pre-emergence damping-off symptoms occurred. From this point of view, although disease incidence is high, there is a significant decrease in disease severity, which is also seen in *in vivo* tests.

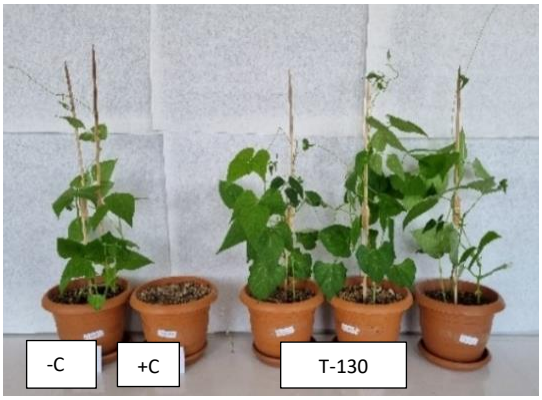

Figure 2. The effect of *Trichoderma virens* 130 against *R. solani in vivo*. (-C: negative control, +C: positive control, T-130: *Trichoderma virens* isolate)

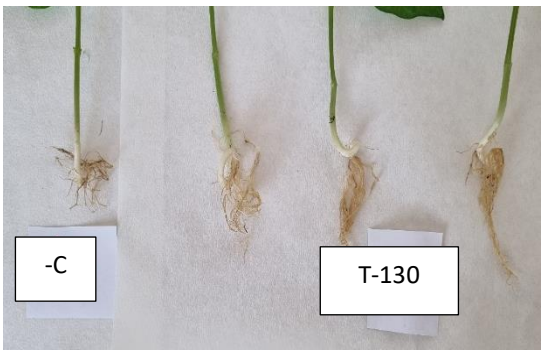

Figure 3. Appearances in the root crown of plants that are effective against *R. solani* against *Trichoderma virens* 130 *in vivo.*

In parallel with our research, it has been reported that *Trichoderma* is effective against *R. solani* in some other studies. Kamala and Devi (2012) determined the effectiveness of *Trichoderma* T10, T17 and T83 isolates, which were effective *in vitro*, in pot experiments, in their study on the effectiveness of 114 *Trichoderma* isolates against *R. solani*. Accordingly, T83 gave the most effective results. The disease was reduced by 11-76.6% in plants inoculated with *R. solani* and T83.

Nofal et al. (2021) described *Trichoderma* species isolated from samples taken from the rhizosphere of healthy beans in 23 locations in Egypt. It was determined that all *Trichoderma* spp. obtained had a positive effect on the development of *R. solani*. The T5 *Trichoderma* isolate was identified as *T. koningii* and inhibited the growth of the pathogen 100%. *T koningii* inhibited *R. solani* mycoparasitic ally. It was also observed that *T. koningii* produced a high amount of chitinase and protease enzymes that hydrolyze chitin.

According to our evaluation results regarding the *in vitro* efficacy of *Trichoderma* isolates against *R. solani*, it was determined that 41 isolates were effective at different levels and 28 were ineffective. Successful results were also obtained from *in vivo* trials of isolates with very strong or moderate efficacy in *in vitro* trials. The most effective isolate was *Trichoderma virens* 130. Although these results do not entirely suppress the disease,

they show that it significantly reduces the severity of the disease and that it can be used. In addition, it should be considered that the most effective isolate can give more effective results with different *Trichoderma* isolates or bacterial isolates.

Making these fungal bioagents, which are naturally present in our country's soil, usable as biofertilizers or biopreparations against diseases will significantly decrease the inoculum level of pathogenic microorganisms in the soil. Obtaining such products from naturally occurring microorganisms in our country's soil flora is important in eliminating fundamental problems that may be encountered and ecologically adapting these microorganisms to the environment in which they are inoculated.

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Research Article

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Measurement of Projected Areas in Some Confectionery Sunflowers (*Helianthus annuus* L.) Seeds by Image Processing Technique

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HIGHLIGHTS

- The continuous development of image processing methods increases the possibilities of obtaining data with digital images of sunflowers and similar flat seeds.
- Low-cost and open-source image processing applications beneficial for studies on agricultural grain products and important for smart farming practices and precision agriculture.

Abstract

This study aimed to demonstrate the practical and low-cost usability of image processing techniques in agricultural grain products by making a sample application in confectionery sunflower seeds. A desktop scanner and an open source software ImageJ were used. Local sunflower cultivars, which were obtained from Manisa, Denizli and Kayseri provinces, were used as a material. After the seeds were scanned with a scanner, their projected areas were calculated in 2D with ImageJ software. Afterward, the dimensions of the seeds were measured with a precision scale and caliper to compare with their projected areas. As a result of the statistical analysis, very high correlations could not be reached between the calculated projected areas and the other measured dimensions. Seed weight, seed length, seed width and hull weight were found to be highly or moderately correlated with the projected area values in all three seed types. Research findings show that the most important reason for not finding very high correlations was the use of local cultivars and the low level of seed purity.

Keywords Image processing, Sunflower seeds, Confectionery sunflower, Seed projected area, ImageJ

1. Introduction

Determination of physical properties such as length, thickness, width, surface area, volume weight and projected area of agricultural products that do not resemble basic geometric shapes and have irregular structures is necessary for the design of new machines. It is difficult to measure them manually. Therefore, modern technologies such as image processing techniques should be used in the measurements. The projected area, which is one of the features above, is an important engineering parameter that should be known for the classification and cleaning of agricultural products (Tunalıgil 1993; Dursun 2001; Demirbaş and Dursun 2007). In the image processing technique, images produced with cameras and scanners are analyzed on computers through customized software (Demirbaş and Dursun 2007).

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Advancements in image processing are vital to science and technology, but as images get larger and more complex, more advanced techniques are needed. In this case, the automation of image processing is getting important. Various image processing software is currently available. ImageJ is one of them, which is open source and written in Java to run on most computer operating systems. ImageJ has advanced image processing tools that range from data visualization to advanced image processing and statistical analysis (Abràmoff et al. 2004; Bourne 2010; Broeke et al. 2015; Hartig 2013; Schindelin et al. 2015).

Sunflower is an important oilseed crop in the World and confectionery consumption is also very common (Akkaya 2006). Although confectionery sunflower seeds are usually long and large, oil-type sunflower seeds are small, short, plump and navel, and the hull rate is low (Terzioğlu 1987). Polatlı (2013), stated that low oil content, high protein content, low hull ratio and wide seed width are accepted by many researchers as the defining features of the confectionery sunflower. The seed weight, which varies according to the genetic structure of the sunflower variety, seed holding efficiency, and hull interior ratio, increases when planting with irrigation and fertilization in fertile soils (Kıllı 2004).

Dursun (2001), used barley, wheat, chickpea, corn, lentil, soybean, bean, and kidney bean seeds as trial material in his study to determine the projected areas of grain products with an image processing technique. The projected areas of the products on three different axes were determined with the "UTHSCSA Image Tool" software. The researcher concluded that the projected areas of small grain products can be determined precisely with the image processing technique.

Demirbaş and Dursun (2007), used UTHSCSA Image Tool software to determine the physical properties of wheat seeds. Atar (2013), measured some leaf properties with ImageJ software in his study to determine germination and morphological characteristics of common hornbeam.

Kabaş and Oten (2015), used image processing techniques with Adobe PhotoShop 6.0, AutoCAD and Global Lab Image software to determine some size and area properties of alfalfa leaves. Özlü and Güner (2016), used ImageJ and Myriad image processing software to detect the projected areas of canola seeds with different moisture contents. Hakimi (2019), calculated the surface areas of adult almond leaves with ImageJ. Cirit et al., (2022) determined that there is a high correlation between the measurements made with image processing software and traditional methods in maize plants.

This study was carried out to determine the feasibility of a low-cost and practical image processing application for dimensional properties of granular agricultural materials due to the increasing interest in the determination of various properties of agricultural products using image processing techniques in recent years. For this purpose, open-source ImageJ software was preferred as image processing software. In addition, confectionery sunflower seeds were used as an example of granular agricultural materials, since they have a flat shape that is more suitable for scanning in desktop scanners. In addition, the projection areas were statistically compared with other manually measured physical dimensions.

2. Materials and Methods

Three different types of local confectionery sunflower seeds collected from agricultural enterprises in Denizli, Kayseri, and Manisa and harvested in 2021 were used as measurement material. Figure 1, shows samples from seeds collected from Denizli (a), Kayseri (b) and Manisa (c).

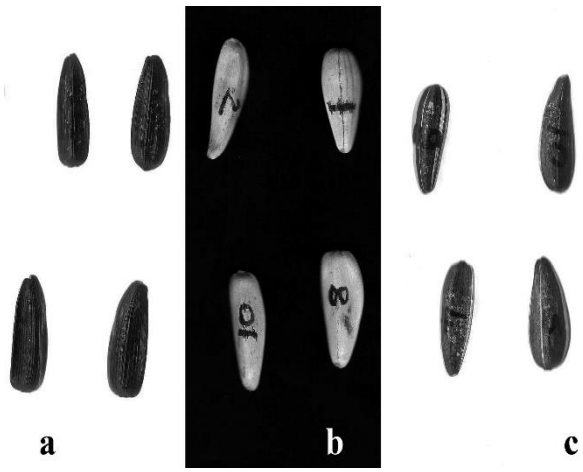

Figure 1. Seeds collected from Denizli (a), Kayseri (b) and Manisa (c)

2.1. Obtaining digital images

From the sample seeds collected for measurements, the damaged ones were removed and the remaining seeds were randomly numbered by taking 50 seeds for each location. The seeds were arranged in 10 pieces on the rectangular area of 5×10 cm determined in the scanning region of the scanner and their flat surfaces were scanned.

Epson RX520, an example of a commonly used desktop scanner, was used to obtain digital images to be used for image processing in the study. The purpose of using a desktop scanner is to measurement measure as practical, fast and low-cost as possible. Scans were made at 300 dpi resolution and 24-bit RGB color.

To create sufficient color contrast between the seeds and the ground in the scanning process; black background paper was used for light-colored seeds of Kayseri origin, and the white background paper was used for dark-colored Denizli-origin seeds. Since the seeds of Manisa origin are in multi-colored tones, sufficient contrast could not be created with white or black paper, and therefore additional illumination was made with a desktop lamp together with white paper.

2.2. Size measurements

After the scanning process was completed, the kernels and hulls of the seeds were separated from each other in the laboratory and weighed separately. Precisa 205A-SCS, accredited by TÜRKAK, precision digital balance with an accuracy of ± 0.0001 grams was used for weight measurements.

Simultaneously with the weighing, the characteristic dimensions of seeds and kernels in length were measured with a digital caliper with a sensitivity of ± 0.01 mm. The characteristic dimensions of sunflower seed (Figure 2) are given by Santalla and Mascheroni (2003). The straight lines show the dimensions of the seed and the dashed lines show the dimensions of the kernel inside the seed. Seed width, seed length, seed thickness, kernel width, kernel length, and kernel thickness are denoted by the abbreviations W, L, T, w, l and t, respectively.

2.3. Image process

The open-source ImageJ software (Version 1.5.3) was used to process the scanned digital images. Scanned images of seeds were opened with the software. Since the scanned images are in standard A4 page size (210 x 297 mm) and a 5 x 10 cm area is used to cover 10 seeds in the images, these areas were determined with the ImageJ selection tool and the images were cropped with the Crop function.

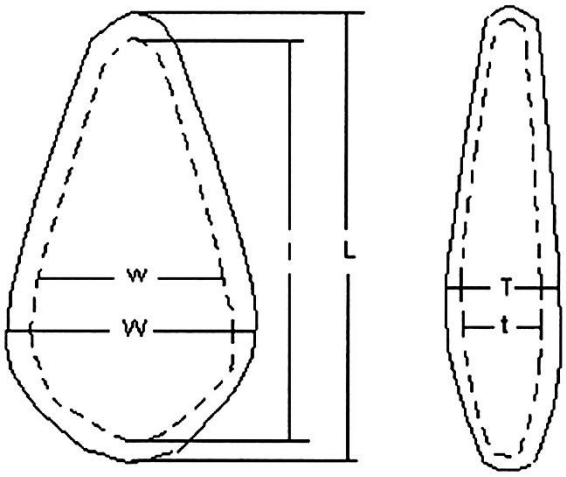

Figure 2. Characteristic dimensions of sunflower seed (Santalla and Mascheroni, 2003)

Since the cropped images are 24-bit RGB color, for image processing; They are converted to 8-bit Black & White (Image>>Type>> 8-bit). Then, by selecting the Threshold function in the software (Image>>Adjust>>Threshold), the most appropriate settings for the separation of seeds and ground were selected. Next; by selecting the Analyze Particles function (Analyze>>AnalyzeParticles), the 2-dimensional projected areas of the flat surface of each particle were found in pixels. The image of the software after the completion of the operations is shown in Figure 3.

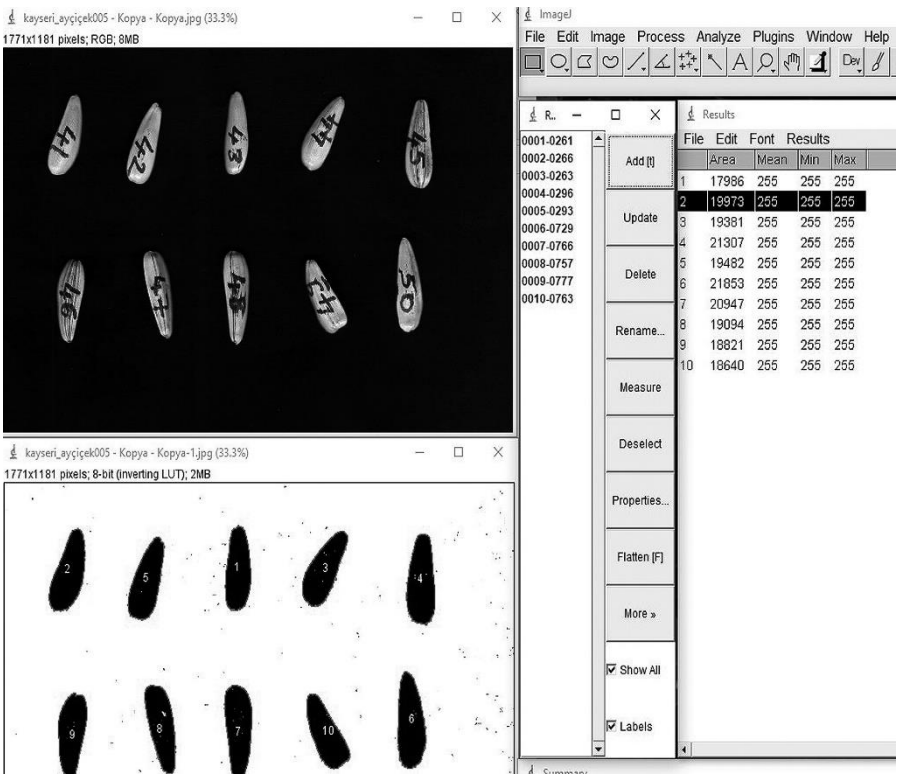

Figure 3. Areas of seeds calculated in ImageJ software.

2.4. Converting pixel values to cm²

A coefficient was calculated to convert the seed areas determined in pixels to cm² units. The measured pixel values are multiplied by this coefficient (6.970311×10-5). To find the coefficient; 623.7 cm2, which is the area value of a standard A4 paper, is divided into 8947950 (2550 x 3509), which is the pixel value of the A4 area scanned in the scanner.

2.5. Statistical Analyses

Descriptive statistics were calculated for each group of sunflower seeds. As in the research of Cirit et al. (2022), Pearson Correlation analysis was performed on values obtained by image processing and conventionally obtained.

3. Results

Descriptive statistics of confectionery sunflower seeds collected from Manisa, Denizli and Kayseri are given in Tables 1-3, respectively. A total of 150 seeds were used, 50 from each group.

Table 1. Descriptive statistics of sunflower seeds collected from Manisa

Dimensions	Abbreviations	N	$\bar{x}$	SD	Min.	Median	Max.
Seed width (mm)	W		8.96	0.78	7.62	8.87	11.43
Seed length (mm)	L		24.39	1.75	19.90	24.49	28.46
Seed thickness(mm)	T		4.06	0.57	3.04	4.02	5.23
Kernel width (mm)	w		5.19	0.69	1.94	5.22	6.43
Kernel length (mm)	l		14.35	1.40	11.09	14.14	19.64
Kernel thickness (mm)	t	50	2.48	0.27	1.86	2.45	3.22
Kernel weight (g)	K		0.1036	0.0180	0.0699	0.1020	0.1491
Hull weight (g)	H		0.0989	0.0195	0.0682	0.0981	0.1460
Seed weight (g)	S		0.2026	0.0296	0.1488	0.2016	0.2810
The ratio of kernel/seed weight	K/S		0.51	0.05	0.33	0.52	0.60
Seed projected area (cm²)	PA		1.70	0.20	1.35	1.67	2.17

Table 2. Descriptive statistics of sunflower seeds collected from Denizli

Dimensions	Abbreviations	N	$\bar{x}$	SD	Min.	Median	Max.
Seed width (mm)	W		9.46	1.08	7.05	9.48	11.43
Seed length (mm)	L		24.03	3.47	18.91	23.12	31.85
Seed thickness(mm)	T		4.87	0.78	3.21	4.94	6.65
Kernel width (mm)	w		5.32	0.55	3.54	5.36	6.48
Kernel length (mm)	l		14.17	1.15	11.53	14.06	16.33
Kernel thickness (mm)	t	50	2.63	0.40	1.64	2.55	4.02
Kernel weight (g)	K		0.1073	0.0197	0.0539	0.1094	0.1364
Hull weight (g)	H		0.1001	0.0285	0.0450	0.1000	0.1796
Seed weight (g)	S		0.2075	0.0359	0.1304	0.2026	0.3007
The ratio of kernel/seed weight	K/S		0.5222	0.0837	0.3521	0.5310	0.6832
Seed projected area (cm²)	PA		1.69	0.37	1.08	1.63	2.59

Table 3. Descriptive statistics of sunflower seeds collected from Kayseri

Dimensions	Abbreviations	N	$\bar{x}$	SD	Min.	Median	Max.
Seed width (mm)	W		8.37	0.83	6.95	8.16	10.35
Seed length (mm)	L		23.06	2.28	18.39	22.80	27.62
Seed thickness(mm)	T		4.12	0.67	2.91	4.10	5.55
Kernel width (mm)	w		4.94	0.54	3.27	4.89	6.40
Kernel length (mm)	l		13.68	1.55	10.99	13.45	17.46
Kernel thickness (mm)	t	50	2.42	0.29	1.63	2.41	2.88
Kernel weight (g)	K		0.0944	0.0221	0.0325	0.0944	0.1487
Hull weight (g)	H		0.0866	0.0203	0.0517	0.0804	0.1288
Seed weight (g)	S		0.1811	0.0353	0.0964	0.1726	0.2488
The ratio of kernel/seed weight	K/S		0.5200	0.0677	0.2930	0.5236	0.6518
Seed projected area (cm^2)	PA		1.61	0.24	1.19	1.55	2.18

3.1. Seeds collected from Manisa

Pearson Correlation Coefficients of seeds collected from Manisa are given in Table 4. As a result of the correlation analysis made on the measured features; very high correlations (0.90-1.00) or high correlations (0.70-0.89) were not found between the measured seed projected area values and other measurements.

Medium relations with seed projected area (0.50-0.69); seed length (0.688), seed width (0.627), hull weight (0.614), and seed weight (0.647). In addition, a high correlation (0.806) was found between seed weight and hull weight. Intermediate relations (0.50-0.69); between seed weight and seed width (0.572), kernel thickness and seed thickness (0.644), kernel weight and kernel thickness (0.616), seed weight and kernel thickness (0.508), and the ratio of kernel/seed weight and kernel weight (0.527). A negative moderate correlation was found between the ratio of kernel/seed weight and hull weight (-0.688).

The above-mentioned relationships of seeds collected from Manisa were found to be statistically significant at the P<0.001 level.

Table 4. Pearson correlation coefficients of seeds collected from Manisa

	W	L	T	H	w	l	t	K	S	K/S
L	0.033									
T	0.463**	-0.004								
w	0.429**	0.463**	0.415**							
l	0.499***	-0.205	0.272	0.067						
t	-0.057	0.312*	-0.105	0.030	-0.034					
K	0.234	0.092	0.644***	0.201	0.198	0.144				
H	0.476***	0.162	0.456**	0.244	0.381**	0.487***	0.616***			
S	0.572***	0.404**	0.550***	0.806***	0.277	0.317*	0.508***	0.770***		
K/S	-0.019	-0.297*	-0.005	-0.688***	0.230	0.312*	0.278	0.527***	-0.131	
PA	0.627***	0.688***	0.256	0.614***	0.219	0.134	0.173	0.399**	0.647***	-0.242

*: P<0.05;**: P<0.01;***: P<0.001

3.2. Seeds collected from Denizli

Pearson Correlation Coefficients of seeds collected from Denizli are given in Table 5. As a result of the correlation analysis made on the measured features; very high correlations (0.90-1.00) were not found between the measured seed projected area values and other measurements.

High (0.70-0.89) relations with seed projected area; seed length (0.878) and hull weight (0.812). Medium relations with seed projected area (0.50-0.69); seed width (0.668) and seed weight (0.583). A negative median relationship (0.50-0.69) was found between the seed projected area and the ratio of kernel/seed weight (-0.692). Besides, other high correlations (0.70-0.89); seed weight and hull weight (0.837), seed weight and kernel weight (0.770), hull weight and seed width (0.726), hull weight and seed length (0.710). In addition, a negative high correlation was found between the ratio of kernel/seed weight and hull weight (-0.785). Intermediate relations (0.50-0.69); seed weight and seed width (0.642), kernel weight and seed weight (0.613), the ratio of kernel/seed weight and kernel weight (0.524). In addition, a negative median relationship (-0.546) was found between the ratio of kernel/seed weight and the seed width.

The above-mentioned relationships of seeds collected from Denizli were found to be statistically significant at the P<0.001 level.

Table 5. Pearson correlation coefficients of seeds collected from Denizli

	W	L	T	H	w	l	t	K	S	K/S
L	0.397*									
T	0.424**	-0.303*								
w	0.726***	0.710***	0.151							
l	0.331*	-0.136	0.252	0.076						
t	-0.029	0.232	-0.193	0.039	-0.161					
K	0.052	-0.292*	0.378**	0.046	-0.030	-0.104				
H	0.120	-0.149	0.264	0.082	0.451**	0.301*	0.494***			
S	0.642***	0.481***	0.264	0.837***	0.308*	0.196	0.308*	0.613***		
K/S	-0.546***	-0.612***	-0.027	-0.785***	0.149	0.191	0.231	0.524***	-0.334*	
PA	0.668***	0.878***	-0.109	0.812***	0.026	0.127	-0.201	-0.110	0.583***	-0.692***

*: P<0.05;**: P<0.01;***: P<0.001

3.3. Seeds collected from Kayseri

Pearson Correlation Coefficients of seeds collected from Kayseri are given in Table 6. As a result of the correlation analysis made on the measured features; very high correlations (0.90-1.00) were not found between the measured seed projected area values and other measurements.

High (0.70-0.89) relations with seed projected area; seed length (0.830), and hull weight (0.792). The medium relations with the seed projected area (0.50-0.69); seed width (0.676), and seed weight (0.673). Besides, other high correlations (0.70-0.89); seed weight and kernel weight (0.848), seed weight and hull weight (0.817), kernel weight and kernel length (0.758), hull weight and seed length (0.718), and seed weight and seed length (0.708). Intermediate relations (0.50-0.69); hull weight and seed width (0.533), kernel length and seed length (0.555), kernel weight and kernel width (0.569), seed weight and kernel width (0.535), seed weight and kernel length (0.669), the ratio of kernel/seed weight and kernel weight (0.605).

The above-mentioned relationships of seeds from Kayseri were found to be statistically significant at the P<0.001 level.

Table 6. Pearson correlation coefficients of seeds collected from Kayseri

	W	L	T	H	w	l	t	K	S	K/S
L	0.265									
T	0.315	0.124								
w	0.533***	0.718***	0.415**							
l	0.324*	0.220	0.318**	0.311**						
t	-0.053	0.555***	0.159	0.340*	0.278					
K	-0.092	0.095	0.137	0.131	0.091	0.215				
H	0.063	0.472**	0.278	0.388**	0.569***	0.758***	0.610***			
S	0.346*	0.708***	0.412**	0.817***	0.535***	0.669***	0.456**	0.848***		
K/S	-0.384**	-0.198	-0.091	-0.471**	0.321*	0.401**	0.464**	0.605***	0.108	
PA	0.676***	0.830***	0.284*	0.792***	0.356*	0.365**	-0.005	0.348*	0.673***	-0.366**

*: P<0.05;**: P<0.01;***: P<0.001

3.4. Common parameters of seeds

When the evaluation is made by looking at all three seed groups; It is seen that the parameters that have a high, moderate and P<0.001 level relationship with the seed projected areas (PA) in all three groups are: hull weight (H), seed weight (S), seed length (L) and seed width (W) (Table 7).

Table 7. Common parameters with a high and medium-level relationship with projected areas

Correlation	Manisa	Denizli	Kayseri
Seed projected area × Hull weight	Median	High	High
Seed projected area × Seed weight	Median	Median	Median
Seed projected area × Seed length	Median	High	High
Seed projected area × Seed width	Median	Median	Median

4. Discussion

Cirit et al., (2022) on maize, were able to determine the grain size with a high level of correlation using ImageJ and one other image processing software. This study shows that the ImageJ program is still used to get efficient and precise results for morphological seed evaluations.

Atar (2013), Kabaş and Oten (2015), and Hakimi (2019) measured basic dimensions, areas and similar features with image processing software by scanning some leaves with a flatbed scanner. These researchers found that the measurements made with image processing software were successful.

Atar (2013) and Hakimi (2019) used ImageJ software, and differently, Kabaş and Oten (2015) used Adobe PhotoShop 6.0, AutoCAD and Global Lab Image software. Leaves are one of the best examples of flat plant parts. A combination of a desktop scanner and image processing software can be used successfully in flat seeds as well as in leaves.

Considering the statistical analysis, it was concluded that the most important reason for not finding very high correlations in this study was the use of local cultivars and the low level of seed purity.

5. Conclusions

It is important to find relationships between the digitally measured seed projected areas and conventionally measured dimensions. Considering this relationship, the potential to obtain important information from digital images of confectionery sunflower seeds and similar flat seeds will increase as image processing methods improve and become cheaper.

In this framework, progress will be made in the field of sowing and harvesting machinery, which requires information about the projected area, and in agricultural technologies related to storage and food production. In light of the results obtained in the study; It has been concluded that low-cost image processing applications will be beneficial for studies on agricultural grain products and also important for smart farming practices and precision agriculture.

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Investigation of the Usability of Biodiesel from Horse Oil in Diesel Engines

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HIGHLIGHTS

- Biodiesel is an alternative diesel fuel produced from animal and vegetable oils.
- It was concluded that the cold flow properties of horse oil biodiesel are not suitable for diesel engines.
- Horse oil biodiesel production stages and determination of fuel properties contributed to the usability of horse oil biodiesel for diesel engines.

Abstract

Biodiesel is an alternative diesel fuel produced from animal and vegetable oils. As an alternative and ecologically acceptable substitute for conventional fuel, biodiesel is produced from a wide variety of edible vegetable oils that are usually used for human consumption and whose prices are expected to rise in the future. In this context, reliable and low-cost raw materials are gaining increasing interest for biodiesel production, such as by-products of meat processing industries or waste animal fats. Biodiesel production from waste animal fat, and raw food does not compete with the industry and has a great potential for waste caused by the global decline. In our study, a potential alternative fuel was produced for diesel engines by using the non-food-grade fat portion of horse meat consumed in Middle Asia countries. Solid crude horse oil was liquefied, and its fatty acid components were analyzed and transformed into horse oil biodiesel by the transesterification method. It was determined whether the fuel properties of crude horse oil, horse oil biodiesel, and euro diesel fuel comply with the standard values, and their usability in diesel engines was investigated. As a result of the tests, it has been concluded that horse oil biodiesel does not meet the standards in terms of cold flow properties and can only be used at a rate of low volumetric ratios in diesel engines. This article will contribute to the use of horse oil biodiesel production stages and fuel properties in diesel engines and future studies.

Keywords: Euro diesel, *Fuel properties*, Horse biodiesel, *Horse oil*, Standards

1. Introduction

The oil and fat materials used as raw materials are estimated to represent 60% to 80% of the total cost of biodiesel production (Busic et al. 2018). Therefore, it is important to choose the best materials in each case, as they are influenced by geographic location, agriculture and climate (Mahlia et al. 2020). One of the main applications of inedible animal fat products is biodiesel production (Baladincz and Hancsok 2015).

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Compression ignition engines it is considered to be an ideal alternative biodiesel fuel (Keskin et al. 2020). Biodiesel, with about 10% to 15% oxygen content, non-toxic, biodegradable, and renewable fuel and its combustion behavior is similar to that of petroleum-based diesel fuel. Therefore, today's modern compression ignition engines can be fueled with biodiesel without any modification (Ağbulut et al., 2019). The alternative fuel must be technologically acceptable, environmentally friendly, economically competitive and easily accessible (Snader et al. 2018). The greatest potential is seen in biodiesel emissions because previous studies have shown that biodiesel combustion is greatly reduced, so biodiesel is currently the most widely used renewable energy source (Guru et al. 2010). In addition to reduced emissions, the transportation sector, biodiesel production, which will ease its dependence on fossil fuels and to a great extent available, thanks to renewable and environmentally friendly raw materials will promote economic development (Chakraborty et al. 2014). Biodiesel consists of mono-alkyl esters of long-chain fatty acids produced from fat or oil, but the use of vegetable oil adds a high price to biodiesel, which has led to the use of animal fats as an interesting alternative to biodiesel (Reig et al. 2020). In addition to its renewable league, biodiesel is an alternative because it offers better lubrication than diesel fuel. At the same time, biodiesel has a high flash point (Nigam et al. 2011). Biodiesel also contributes to sustainability by reducing its carbon footprint, as it produces lower CO_2 emissions compared to fossil diesel fuel (Mansir et al. 2018). Biodiesel can be mixed with diesel fuels up to 20% in most countries, and can be used without the need for engine modification (Gumahin et al. 2019). Biodiesel is named as B_5, B_{10} or B_{20} for blends of 5%, 10% and 20% respectively, in terms of volume content. Today, more than 78% of diesel vehicles that come off production lines are approved for use at B_{20} (Anonymous 2020). Biodiesel must comply with EN 14214 in Europe and ASTM 6751 in the USA to be blended with normal fossil diesel (Efpra 2016). Behçet et al. (2015), produced biodiesel from fish oil and chicken oil, examined its fuel properties, and mixed 20% of the biodiesel they produced into diesel fuel. They have obtained performance and emission results by testing their test fuels in a single-cylinder four-stroke diesel engine. According to the test results, they determined that mixed fuels increased NO_x emission and specific fuel consumption compared to diesel fuel, and reduced power, moment, CO, CO_2 and HC emissions.

The innovative aspect of this study is that there is no study in the literature on horse oil biodiesel production. Due to the limited sources of alternative fuel used in internal combustion engines, we have determined in our research that horse meat consumed as food in Middle Asia countries is a potential alternative fuel that does not have the quality of food and is not used. Thanks to the horse oil biodiesel production stages and fuel properties, its usability in diesel engines will be determined with this study and will shed light on future studies.

2. Materials and Methods

In this study, biodiesel production was carried out from crude horse oil imported from Kyrgyzstan's capital Bishkek. In the production stages, methyl alcohol was used as alcohol and sodium hydroxide was used as a catalyst. Production was carried out by the transesterification method in Selcuk University Biodiesel Laboratory. Euro diesel fuel was provided from BP Company. The fuel properties of the horse oil biodiesel and euro diesel oil produced were measured in the laboratory in accordance with the standards and the analysis results are given in Table 1. In addition, during the measurements, occupational safety rules were observed. During the production stages; 1 kg of solid horse oil was chopped into small pieces, heated up to its melting temperature in a container, and the cartilage structure was removed and the oil became liquid after the water evaporated was filtered and taken into a beaker. The crude horse oil in liquid form was filtered again in a paper filter and heated up to 110 °C in a heated magnetic stirrer, and the water contained in it was removed from the oil (Figure 1).

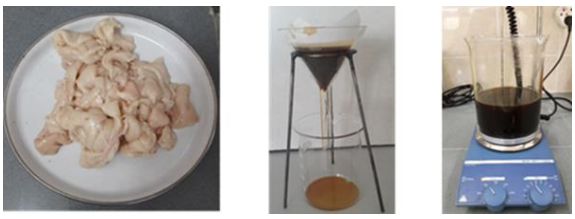

Figure 1. Crude horse oil (solid-liquid)

Table 1. Analysis results of the test fuels

Characteristic	The Units	Crude Horse Oil	Horse Oil Biodiesel	Euro Diesel Fuel	Limiting Value	
					TS EN 590 Diesel	TS EN 14214 Biodiesel
Color Determination	ASTM 1500 (0,5 – 8 unit)	5,4	3,5	1,2	--------	--------
Density (at 15^{0}C)	g/cm^3	0,9088	0,8728	0,8331	0,82 - 0,84	0,86 – 0,90
Kinematic Viscosity (at	mm^2/s	37,869	4,999	3,065	2 - 4,5	3,5 - 5
Flash Point	^{0}C	180	122	60	Min 55	Min 120
CFPP	^{0}C	6,2	8,9	-12,5	-20	--------
pH	——	6	5	4	--------	--------
Cloud Point	^{0}C	8,7	11,9	-8,1	--------	--------
Pour Point	^{0}C	1,8	5,2	-14	--------	--------
Freezing Point	^{0}C	0,2	0,5	-20	--------	--------
Copper Rod Corrosion	——	1a	1a	1a	No:1	No:1
Calorific Value	Cal/gr	8962	9284	9858	--------	--------

In the production by the transesterification method, 150 ml methanol and 2.7 gr sodium hydroxide mixture were made for 600 ml crude horse oil and methoxide was formed. Since the sample is animal fat, the molar ratio was 5.5: 1. In production, crude horse oil was treated with a magnetic stirrer with heater in a beaker at 55 0C for 1 hour reaction time. Then, after waiting 12 hours, the decomposition of glycerin was observed. The decomposed crude biodiesel was placed in another beaker and washed in a 50% distilled water shower method (Figure 2).

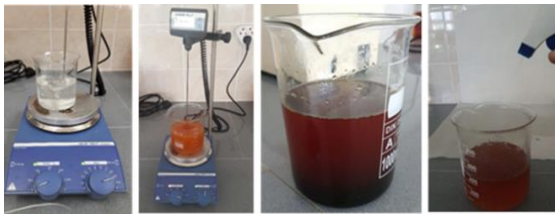

Figure 2. Horse oil Biodiesel production stages

Then, by waiting 12 hours, phase separation was achieved, and the crude biodiesel was heated at 110 ^{0}C for 120 minutes on a heated magnetic stirrer and the water in it was removed. Thus, biodiesel production was realized from horsefoot (Figure 3).

Figure 3. Horse oil biodiesel final form

2.1. Fatty Acid Components of Horse Oil

The fatty acid components of horse oil used in biodiesel production were measured in Necmettin Erbakan University Engineering and Architecture Faculty Food Engineering Laboratory. In the preparation of fatty acid methyl esters, the In Situ method of Park and Goins (1994), was modified and used. According to this; After taking 150 µL of the sample, adding 100 µL dichloromethane and 1 mL 0.5 N methanolic NaOH, waiting at 90 ^{0}C for 10 minutes, cooling at room temperature, adding 1 mL of 14% methanolic BF_3, waiting at 90 ^{0}C for 10 minutes, cooled down. Then 1 mL of distilled water, 500 mL of hexan were added, mixed for 1 minute in the vortex, centrifuged. (5 minutes / 2500 rpm) Sodium sulfate was added. After the phase separation took place, it was taken from the clear phase in the upper layer into vials of 2 mL volume and stored in the deep freezer to be injected into the GC. Fatty acids and analyses of oil samples converted into methyl esters are given in the Shimadzu GC-2025 model Gas Chromatography device, flame ionization detector (FID) and qualifications are given in Figure 4; It was constructed using HP-Innovax capillary column (L: 30m, ID: 0.25mm, DF: 0.25µm). The temperature program for the method is given in Figure 5; detector temperature: 240 ^{0}C, injector temperature: 250 ^{0}C, column (furnace) temperature: 2 minutes at 70 ^{0}C, 15 ^{0}C/min to 220 ^{0}C; Waiting time at 220 ^{0}C is 2 minutes; from here 250 ^{0}C to 3 ^{0}C/min; Waiting time at 250 ^{0}C 10 minutes, total analysis time: 34 minutes. Injection: Split 1: 100. Gas flow rates: carrier gas: helium 3 ml/min (constant flow pattern); hydrogen, 40 mL/min; dry air was set at 400 mL/min. The sample was injected into the instrument 1 µL. For the diagnosis of fatty acids, a mixture of methyl esters of fatty acids Supelco 37 Component FAME Mix (Sigma-Aldrich Co. USA) Food Industry FAME Mix 37 components (Restek Corporation USA) was used as a standard. Chromatograms of fatty acid methyl esters and ratios of fatty acids were obtained on computer by SHIMADZU GC solution program. The peaks in the chromatograms of the analyzed samples were identified by comparing the retention times of the methyl esters of all fatty acids in the standard and benefiting from professional experience. The results are given as a qualitative value in% fatty acid. The chromatography image is given in Figure 6.

Oils gain value according to the fatty acids they contain and their ratios. Fats in terms of chemical structure; are collected in 3 groups saturated, monounsaturated and polyunsaturated oils. These three groups are present in all oils, but their proportion varies according to the oil type. The ratio of unsaturated fatty acids to saturated fatty acids (P/S) in oils is an important quality factor. The higher this ratio, the higher the conversion rate of fats into ester.

Figure 4. Column attributes

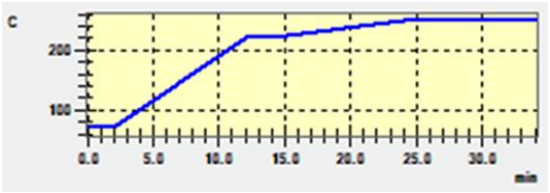

Figure 5. Temperature program

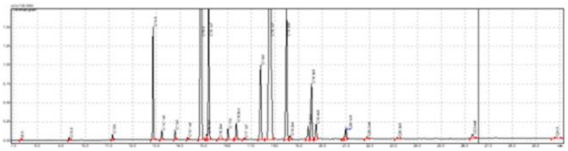

Figure 6. Chromatogram

Table 2. Fatty acid components

Analysis	Unit	Analysis Result
Caprylic Acid	C8:0	0,024
Capric Acid	C10:0	0,081
Lauric Acid	C12:0	0,184
Myristic Acid	C14:0	3,768
Nervonic Acid	C15:0	0,370
Palmitic Acid	C16:0	28,246
Palmitoleic Acid	C16:1	0,242
Margaric Acid	C17:0	0,507
Stearic Acid	C18:0	4,395
Oleic Acid	C18:1	38,640
Linoleic Acid	C18:2	7,247
Linolenic Acid	C18:3	0,821
Arachidic Acid	C20:0	0,113
Gadeloic Acid	C20:1	0,582
Behenic Acid	C22:0	0,402
Lignoceric Acid	C24:0	0,225

Animal oils are rich in saturated fatty acids. The fatty acid compositions of the oil are given in Table 2. As seen in Table 2, horse oil's myristic fatty acid amount is 3,768%, the palmitic acid amount is 28,246%, stearic fatty acid amount is 4,395%; It is an oil with a good oleic acid amount of 38,640 and a linoleic acid amount of 0,821. The horse oil used in the research is a medium-value oil in terms of oleic acid amount and linoleic acid amount. In this case, it is possible to say that oils containing long, branched and single double-bonded fatty acids are suitable diesel alternatives. Some properties of biodiesel depend on the raw material from which it is obtained. Fatty acids used in biodiesel production are grouped as saturated, mono and polyunsaturated. However, ideal biodiesel can only be made from monounsaturated fatty acids. For this reason, it is desirable that the monounsaturated fat content of the oil to be produced biodiesel should be high. Oxidation resistance

is better in high oleic acid oils. The composition of common vegetable oils varies as the ratio of the different types of fatty acid chains in each oil. The proportions of these chains affect the physical properties of each fluid. Monounsaturated chains are good for oxidation resistance. Polyunsaturated chains give poor oxidation resistance but improve low-temperature behavior. The low-temperature resistance of the saturated fatty acid chain is very low. Since the saturated fatty acid component of horse oil is high, oxidation resistance and cetane number are expected to be good. However, as the saturation increases, the cold flow properties may not be very good (Öğüt and Oğuz 2006).

3. Results and Discussion

3.1. Color specification

When the color specification test results were examined, it was seen that the crude horse oil color was darker than the horse oil biodiesel. Euro diesel fuel is the lightest colored among the test fuels (Figure 7). When horse oil is examined in terms of biodiesel color values, it is appropriate to use it as fuel in diesel engines according to ASTM 1500 standards.

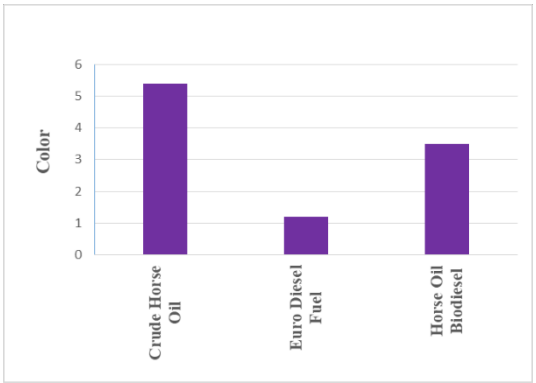

Figure 7. Color test results of fuels (ASTM 1500)

3.2. Density

When the test results were examined, it was determined that the density of crude horse oil was higher than other test fuels, and the density values of horse oil biodiesel and euro diesel fuels were at standard values. This shows the usability of horse oil biodiesel in diesel engines (Figure 8).

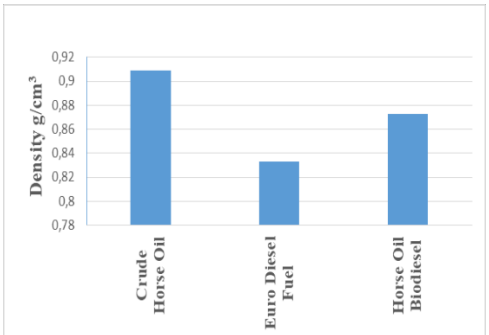

Figure 8. Density test results of fuels

3.3. Kinematic viscosity at 40 °C

The viscosity value should be low enough to allow the fuel to flow easily even at low operating temperatures. When the test fuels are examined, it shows that their kinematic viscosity at 40 ^{0}C is high in crude horse oil, horse oil is at standard values in biodiesel and euro diesel fuels and is within the limits that can be easily used in diesel engines (Figure 9).

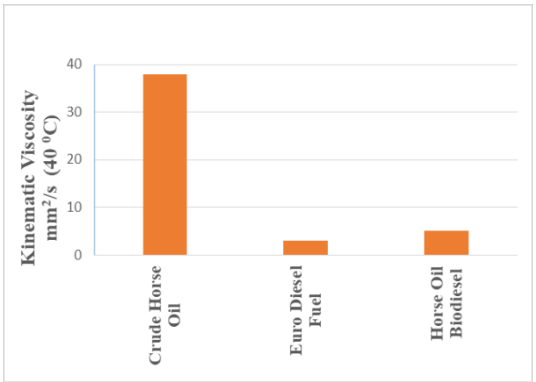

Figure 9. Kinematic viscosity test results of fuels at 40 ^{0}C

3.4. Flash point

When the flash point test results are examined, it is seen that the flash point value of crude horse oil is high, while horse oil biodiesel and euro diesel fuel are within standard values. Horse oil biodiesel and euro diesel fuels can be easily used in diesel engines in terms of their flash point values (Figure 10).

3.5. Cold filter plugging point (CFPP)

When the test results are examined, it is seen that the cold filter plugging point values of crude horse oil and horse oil biodiesel are not 100% suitable for use in diesel engines compared to euro diesel fuel. For this reason, horse oil can be used by mixing biodiesel with diesel at low volumetric ratios (Figure 11).

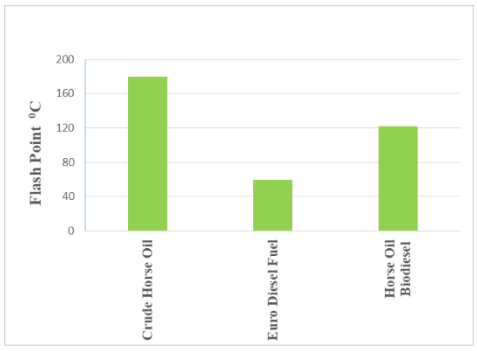

Figure 10. Flash point test results of fuels

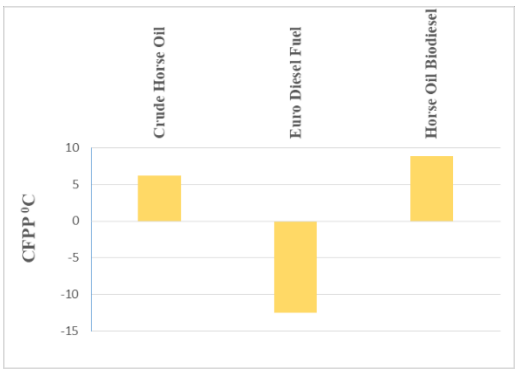

Figure 11. CFPP test results of fuels

3.6. pH

When the PH value test results of the fuels were examined, it was determined that the pH values were below 7 and acidic. In this respect, all test fuels are within the limit values used in diesel engines in terms of pH value (Figure 12).

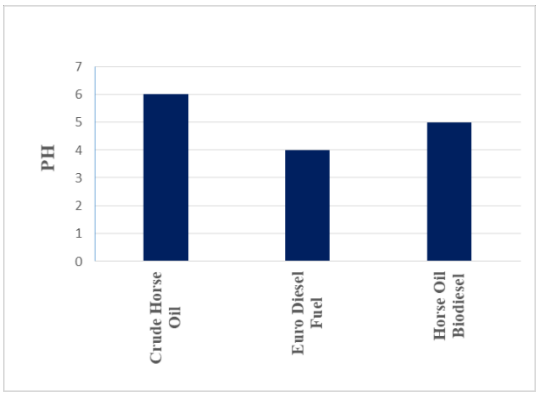

Figure 12. pH test results of fuels

3.7. Cloud point

When the test results are examined, it is seen that the cloud point values of crude horse oil and horse oil biodiesel are not 100% suitable for diesel engines compared to euro diesel fuel. This is a disadvantage for the engine to run in cold conditions. For this reason, horse oil can be used by mixing biodiesel with diesel at low volumetric ratios (Figure 13).

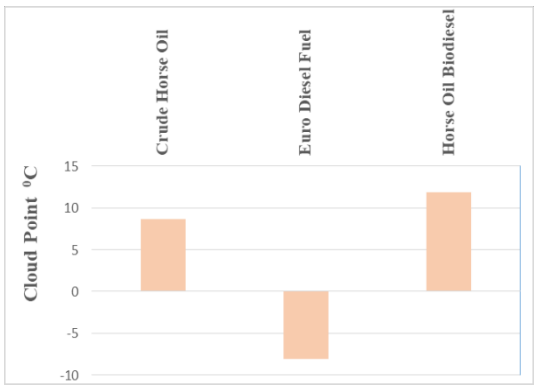

Figure 13. Cloud point test results of fuels

3.8. Pour point

When the test results are examined, it has been determined that the pour point values of crude horse oil and horse oil biodiesel are not 100% suitable for diesel engines compared to euro diesel fuel, and this will cause problems such as late starting and ignition difficulty for the engine to run in cold weather. For this reason, horse oil can be used by mixing biodiesel with diesel at low volumetric ratios (Figure 14).

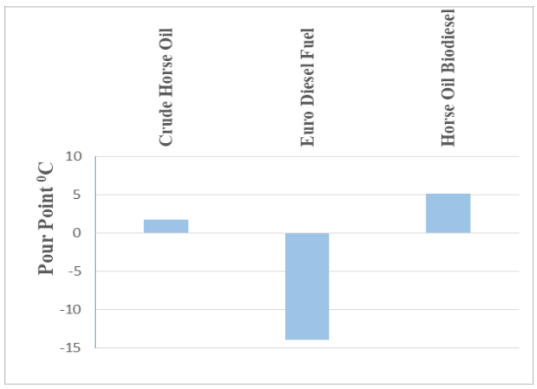

Figure 14. Pour point values of the test fuels

3.9. Freezing point

When the test results are examined, the freezing point values of crude horse oil and horse oil biodiesel are positive values, as shown in Table 1, while the values for euro diesel fuel are -20 ^{0}C. This shows that crude horse oil and horse oil biodiesel are not 100% suitable for diesel engines compared to euro diesel fuel. For this reason, horse oil can be used by mixing biodiesel with diesel at low volumetric ratios (Figure 15).

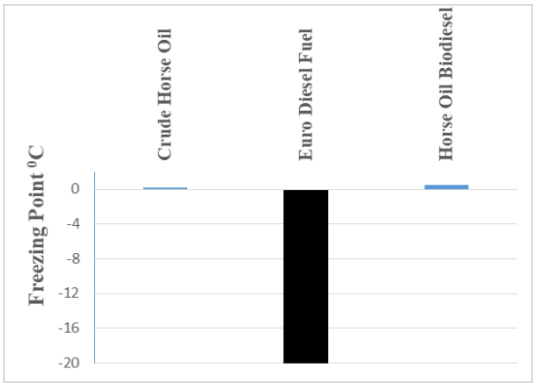

Figure 15. Freezing point test results of fuels

3.10. Copper rod corrosion

When the copper rod corrosion test results of test fuels were examined, a 1a value was obtained for all fuels. Therefore, the results could not be shown graphically.

3.11. Calorific values

When the test results are examined, it is seen in Table 1 that the calorific value of horse oil biodiesel is close to that of euro diesel fuel. This shows that horse oil biodiesel can be used in diesel engines without any problems in terms of thermal value (Figure 16).

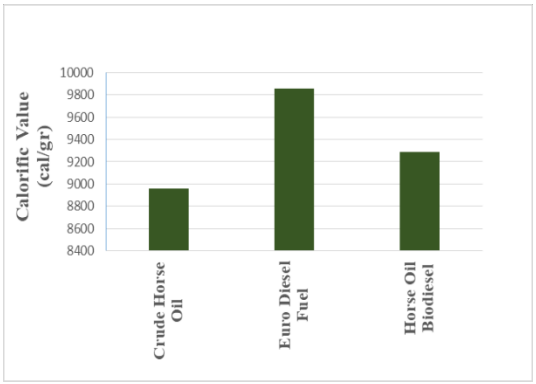

Figure 16. Calorific values test results of fuels

4. Conclusions

As a result of this study;

- It was concluded that the cold flow properties of horse oil biodiesel are not suitable for diesel engines.
- As the amount of Capric Acid, Lauric Acid (C12:0), Myristic Acid (C14:0), Palmitic Acid (C16:0), Stearic Acid (C18:0) increases, the cold flow properties increase. So, it gets worse. It gets better as the number of ligaments increases.
- However, it has been concluded that can be used by mixing horse oil biodiesel with diesel at low volumetric ratios.

- Horse oil biodiesel production stages and determination of fuel properties contributed to the usability of horse oil biodiesel for diesel engines.

Abbreviations

^0C	Celsius Degree
ASTM	International American Society for Testing and Materials
B_5	5 % Biodiesel
B_{10}	10 % Biodiesel
B_{20}	20 % Biodiesel
B_{50}	50 % Biodiesel
B_{100}	100 % Biodiesel
CFPP	Cold Filter Plugging Point
CO	Carbon Monoxide
CO_2	Carbon Dioxide
EN	European Norm
HC	Unburned Hydrocarbons
NO_x	Nitrogen Oxides
TS	Turkish Standard
US	United States

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Conflicts of Interest: The authors declare no conflict of interest.

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Research Article

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Determination And Comparison of Soil Deformation Areas, Stubble Burial Rates and Stubble Quantities of Single-Acting Disc Harrow Driven by The Tail Shaft and Single-Acting Disc Harrow That Takes Its Movement from The Soil

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HIGHLIGHTS

- The effects of the single-acting disc harrow moving from the tail shaft and the single-acting disc harrow moving from the soil on the soil deformation area were determined and compared.
- The effects of the single-acting disc harrow driven by the power take-off shaft and the single-acting disc harrow driven by the soil on the stubble residue were determined and compared between applications.
- Stubble embedding rates of the single-acting disc harrow moving from the power take-off shaft and the single-acting disc harrow moving from the soil were determined and a comparison was made between the applications.

Abstract

In this study; soil-driven single-acting disc harrow and PTO-driven single-acting disc harrow machines were used. The single-acting disc harrow, which moves from the soil, was tested with two different disc diameters (610 mm and 660 mm) and three different direction angles (16^{o}- 23^{o} and 30^{o}), while the single-acting disc harrow, which moves from the tail shaft, was tested with two different disc diameters (610 mm and 660 mm), three different direction angles (16^{0}- 23^{0} and 30^{0}) and three different disc speeds (104.97-119.97 and 143.96 min^{-1}). As a result of the treatments, the effects on soil moisture retention, deformation area, stubble burial rate and stubble amount were compared for both machines. It was determined that the cutting width and working depth increased with the increase in disk diameter and direction angle, and the deformation area increased accordingly. The lowest amount of stubble was obtained from D1N3Y3, D1N3Y2 and D2N3Y3 treatments as 20.67 g m^{-2}, 22.67 g m^{-2} and 25.33 g m^{-2}, respectively. The highest stubble burial rate was 87.30%, 86.07% and 84.02% in D1N3Y3, D1N3Y2 and D1N2Y3 treatments. While the lowest u/v ratio was obtained from D1N1Y1 with 3.03, the highest u/v ratio was obtained from D2N3Y3 with 4.63, the lowest skidding rate was obtained from D1N3Y1 with 3.17% and the highest skidding rate was obtained from D2Y3 with 11.99

Keywords: Deformation Area, Angle of Direction, Disc, PTO, Stubble

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1. Introduction

This study aims to determine the appropriate structural and operational characteristics for the use of a single-acting disc harrow driven from the PTO to ensure that agricultural activities are carried out on time, soil and plant residues are broken and mixed with the least number of passes, and the engine power of the tractor is used more effectively and efficiently.

Wan et al. (2017) reported that when the hydraulic-driven disc harrow and passive disc harrow were compared in terms of soil cutting, the hydraulic-driven disc harrow discarded a larger amount of soil, the ploughing depth was deeper. They also reported that the soil was worked more effectively and the good throwing effect was more favourable for subsequent agricultural works.

Nalavade et al. (2010), operating the tillage disk with an external power has a significant effect on the processing of soil volume and hence on the forces acting on the disk. The free rotating disk is unable to till the soil properly. An increase in the disk angle increases the volume of soil to be cultivated, resulting in higher soil reaction values. Finally, it was concluded that the externally powered disc is advantageous over the free-rotating tillage disc in terms of reduced tractive power consumption, energy use, easy soil volume processing and lateral displacement.

Çelik and Malaslı (2016), according to the average values of the depth of the furrow, it was determined that the depth of furrow increased as the disk direction angle increased.

Keçecioğlu and Gülsoylu (2002) stated that the furrow base of disc harrows is not flat like the furrow base of eared plows and that disc harrows form ridges and grooves on the furrow base. The height of the ridges formed is affected by the diameter of the discs, their angles, working depth and the distance between the discs. Especially the disk angle and the working depth of the disk have a significant effect on the size of the contact area of the disk with the soil. Working by arranging the discs in batteries ensures that the soil areas the discs grasped overlap.

Raper (2002) found that implements with disked tillage implements buried significantly more residue at different tillage depths than implements with chisel-type tillage implements. He also stated that the time of year of tillage did not affect the percentage of residue cover or the total mass remaining on the soil surface.

Damanauskas et al. (2019) reported that the rate of mixing plant residues into the soil ranged between 0.80 and 0.96 in their study with an individually bedded disc harrow.

Nalavade et al. (2013) reported that the notched cutting edge of the tillage disc provided better cutting of weeds and crop residues in the harrow with a disc moving from the tail shaft, while the free-rotating disc harrows could not cut the residues properly despite the use of a notched disc. They carried out a study to determine the stubble embedding rates for the PTO and free-rotating disc harrows operated at different feed rates and the plant residue rates after three different speeds in the PTO disc harrows. As a result of this study, they reported that 86.98%, 92.03% and 89.29% stubble burial rates were obtained with the disc harrows moving from the tail shaft, while the free-moving disc harrow buried only 69.32%, 66.81% and 65.66% of the plant residues at three different feed rates.

It is stated that the presence of coarse and insufficiently broken stems in the soil interrupts the contact between the seed and the soil and this event may adversely affect germination (Önal and Aykas, 1997).

Zeng et al. (2021) investigated the soil shear forces, soil overturning, stubble residue cutting and mixing performances of three discs of different shapes at two different working depths and dry maize stalks were used in the experiments. They reported that the working depth of the discs was more significant in affecting the tillage performance than the disc type. Increasing the working depth resulted in an increase in soil shear forces, soil tilth and residue mixing.

Upadhyay and Raheman (2020a) found that both stubble burial rate and soil clod fragmentation increased with an increase in speed rate.

Dursun et al. (1999) reported that the rate of stubble burial increased by 8% for the ear plough and 13% for the disc plough when the working depth increased from 15 cm to 25 cm. In addition, they determined that the stubble burial rate increased by 8.6% with an increase of 4o in the angle of repose and by 12% with an increase of 100 in the angle of repose with disc plough, and the stubble burial rate increased by 12.7% with an increase of 160 to 240 in the angle of repose with disc plough. They reported that the most uniform stubble distribution along the tillage depth was achieved with a disc plough.

Unger (1984) reported that the stubble embedding rates of eared and disc ploughs were 90%, disc plough, offset and tandem disc harrow were 50%, chisel was 25%, weeder and cultivator were 10%.

Göknur and Özarslan (1995) examined the effect of tractor travelling speed on the burial rate of surface residues and stated that the highest burial rate was obtained at travelling speeds between 3.69 km.h-1 and 5.92 km.h-1.

Raper (2001) determined that at high working depths, disc tillage machines were more effective in burying plant residues compared to chisel.

Singh et al. (1978) reported that a decrease in directional angle and an increase in working speed had opposite effects on the working depth of the disc harrow. They reported that a decrease in the directional angle of the disc harrow at a constant working speed resulted in shallow working, whereas an increase in the working speed at a constant angle resulted in deeper working.

This study was carried out in field conditions to compare the stubble embedment rate, the amount of stubble remaining on the surface after tillage, and the soil deformation of the single-acting disc harrow moving from the PTO and the single-acting disc harrow that takes its movement from the soil.

2. Materials and Methods

A sheet metal plate with a thickness of 5 mm, a length of 1000 mm and a width of 600 mm, lime, a digital camera and a fiji- imagej image processing programme were used to determine the deformation area. Canon Eos 1300D digital camera was used to take the photographs. In order to determine the deformation area of the discs, after passing the machine, a sheet metal plate was immersed in the soil at the tillage depth perpendicular to the direction of movement and the soil in front of it was cleaned and the sheet metal plates were removed (Figure 1). Afterwards, the treated areas were calcified and the regions were determined (Topakcı, 2004; Marakoğlu et al, 2010).

After the sheet metal was removed, a picture of the degraded soil mass was taken with a digital camera from the front façade. For the determination of the deformation area, labels with an area of 1 cm2 were placed on the side of the disturbed soil sample before the picture was taken as a reference. The images taken with the camera were saved as image format in the computer environment.

Figure 1. Crude horse oil (solid-liquid)

Imaging software was used to digitize the deformation area. The photographs captured by the imaging software were opened in JPG format, the boundaries of the deformation areas were determined, and the determined areas were painted. The same procedure was followed for the 1 cm^2 area used as a reference.

The values of the total deformation area after coloring and the 1 cm^2 area taken as reference were calculated in square pixels and these values were converted to cm^2 to determine the total deformation area.

In determining the amount of stubble, the stubble in a 1x1 m^2 frame was collected from different parts of the experimental area before the pre-tillage trials and then weighed with the help of a precision balance. Weighing was carried out in three replicates in each treatment plot and the amount of stubble was determined as (g m-2).

After tillage, the amount of stubble remaining on the soil was determined by the same method and the stubble burial rate was found by using the following equation (Göknur and Özarslan, 1995)

$$F=(A-B)/A \times 100 \quad (1)$$

F: Stubble burial rate (%)

A: Stubble amount before tillage (g)

B: Stubble amount after tillage (g)

During the trials, two signaling apparatuses and a digital stopwatch were used to determine the running speed. Skidding was calculated by utilizing theoretical and actual speeds.

In order to determine the progress speed in the trials, the time taken to take the distance between the jalons placed at two points with a distance of 50 m during the work with the tractor in the field was measured in three replicates with the help of a stopwatch. According to this distance and measured time, the progress (actual speed) was calculated with the help of the equation given below.

$$v=L/t \quad (2)$$

v : Actual tractor travelling speed (m s^{-1})

L : Distance between jalons (m)

t : Time taken for the distance between the jalons (s)

In order to find the skid ratio, the tractor drive wheel circumference and the distance travelled in one revolution were calculated. Then, the distance between the two jalons was divided by the distance that the wheel should take in one revolution and the number of revolutions that the tractor wheel will make in the specified distance was found. The theoretical speed was calculated with the following equation.

$$Vt=(\pi.D.n)/60 \quad (3)$$

Vt= Theoretical speed ($m.s^{-1}$)

D = Wheel diameter (m)

n = Wheel speed (min^{-1})

With the help of the data determined above, the skid rate is calculated by the following equation.

$$S=(Vt-V)/Vt \times 100 \quad (4)$$

S = Skid rate (%)

v = actual tractor travelling speed ($m\ s^{-1}$)

Vt = Theoretical speed ($m\ s^{-1}$)

3. Results and Discussion

The deformation areas of the trials are given in Figures 2 and 3 for both diameter treatments.

In D1 diameter disc treatments (Fig.2), the deformation areas varied between 154.59 -619.81 cm^2. The minimum deformation area was obtained from D1Y1 with 154.59 cm^2, while the maximum deformation area was obtained from D1N3Y3 with 619.81 cm^2.

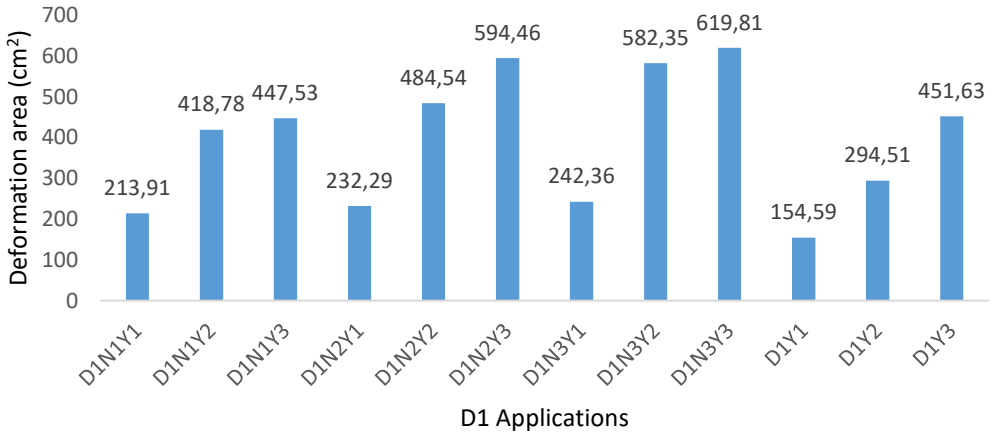

Figure 2. Deformation areas of the D1 applications

In D2 diameter disc applications (Figure .3), deformation areas varied between 187.8 - 903.71 cm^2. While the minimum deformation area was obtained from D2Y1 with 187.8 cm^2, the maximum deformation area was obtained from D2N3Y3 with 903.71 cm^2.

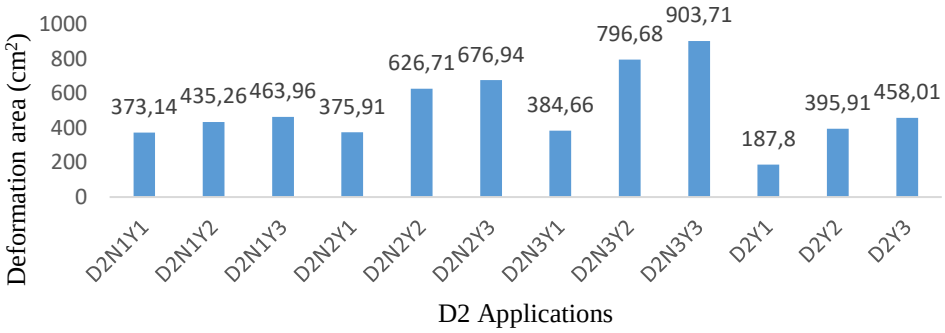

Figure 3. Deformation areas of the D2 applications

When Figures 2 and 3 are examined, it is seen that the deformation areas also increase when both disc diameter (D), same speed (N) and disc direction angle (Y) increase. Depending on the increase in disc diameter and disc direction angle, the increase in the cutting width and a working depth of the disc caused an increase in the deformation area.

While the highest deformation area was obtained from the D1N3Y3 application, the lowest deformation area was obtained from the D1N1Y1 application with the increase in disc speed of the PTO moving disc harrow with D1 disc diameter. Similarly, Nalavade et al. (2010) reported that when the disc harrow disc is driven by any power source, it has a significant effect on the processing of soil volume and thus on the forces acting on the disc and at high disc direction angles, it increases the volume of the processed soil.

Stubble quantities of the experiments are given in Figures 4 and 5 for both diameter treatments. The average stubble amount per square meter before tillage obtained from different points was 162.67 grams.

The lowest amount of stubble per unit area was obtained from D1N3Y3 with 20.67 g m^{-2} in D1 diameter disc treatments, followed by D1N3Y2 with 22.67 g m^{-2} and D1N2Y3 with 26 g m^{-2}. The highest amount of stubble was obtained from D1Y1 with 45.33 g m^{-2}, followed by D1Y2 with 42.67 g m^{-2} and D1N1Y1 with 34.67 g m^{-2}.

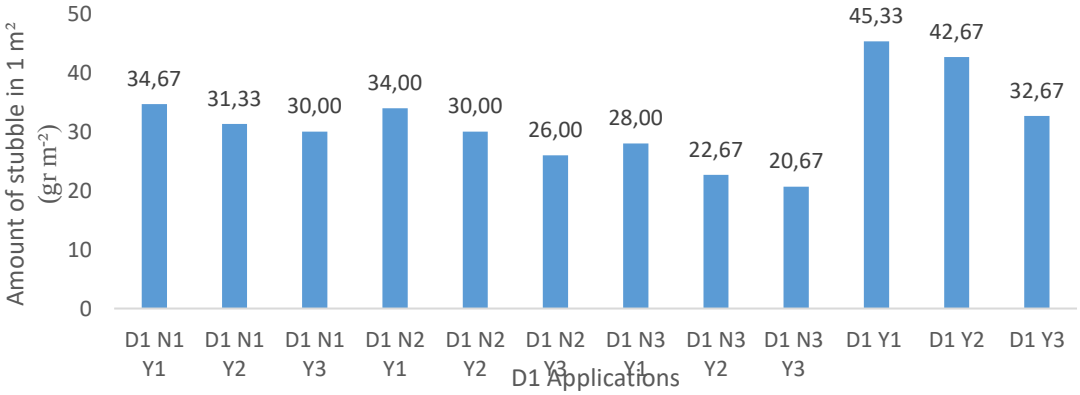

Figure 4. The amount of stubble in 1 m2 for D1 applications

In D2 diameter disc treatments, the least amount of stubble was obtained from D2N3Y3 with 25.33 g m^{-2}, followed by D2N3Y2 with 30.67 g m^{-2} and D2N2Y3 with 31.33 g m^{-2}. The highest amount of stubble was obtained from D2Y1 with 72 g m^{-2}, followed by D2Y2 with 50 g m^{-2} and D2Y3 with 42 g m^{-2}.

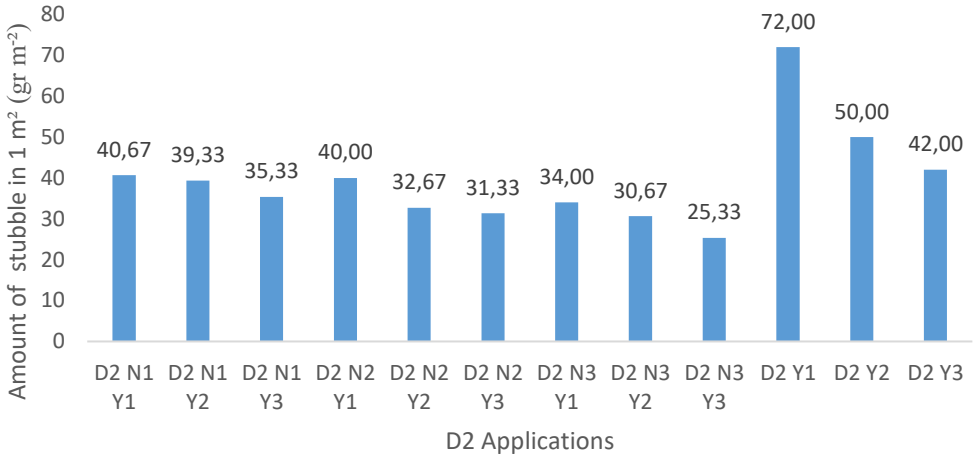

Figure 5. The amount of stubble in 1 m2 for D1 applications

Stubble burial rates of the trials are given in Figures 6 and 7 for both diameter treatments.

In D1 diameter disc treatments, the highest stubble burial rate was obtained from D1N3Y3 at 87.30%, followed by D1N3Y2 at 86.07% and D1N2Y3 at 84.02%. The lowest stubble burial rate was obtained from D1Y1 at 72.13%, followed by D1Y2 at 73.77% and D1N1Y1 at 78.69%.

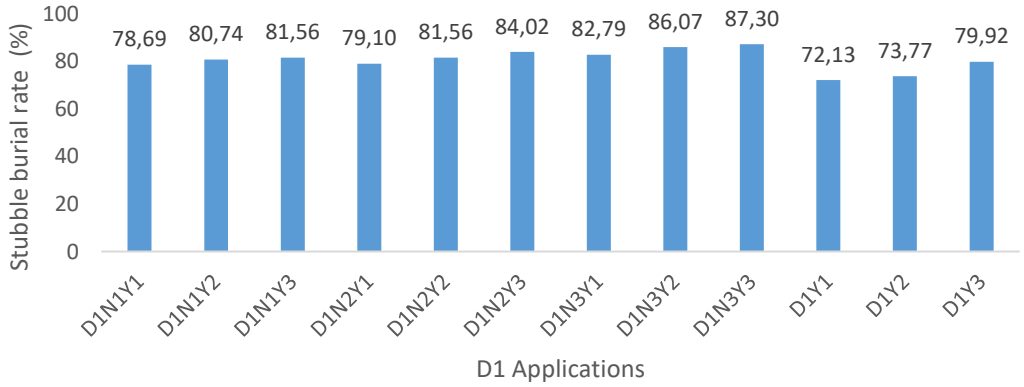

Figure 6. Stubble burial rate for D1 applications

In D2 diameter disc treatments, the highest stubble burial rate was obtained from D2N3Y3 at 84.43%, followed by D2N3Y2 at 81.15% and D2N2Y3 at 80.74%. The lowest stubble burial rate was obtained from D2Y1 at 55.74%, followed by D2Y2 at 69.26% and D2Y3 at 74.18%.

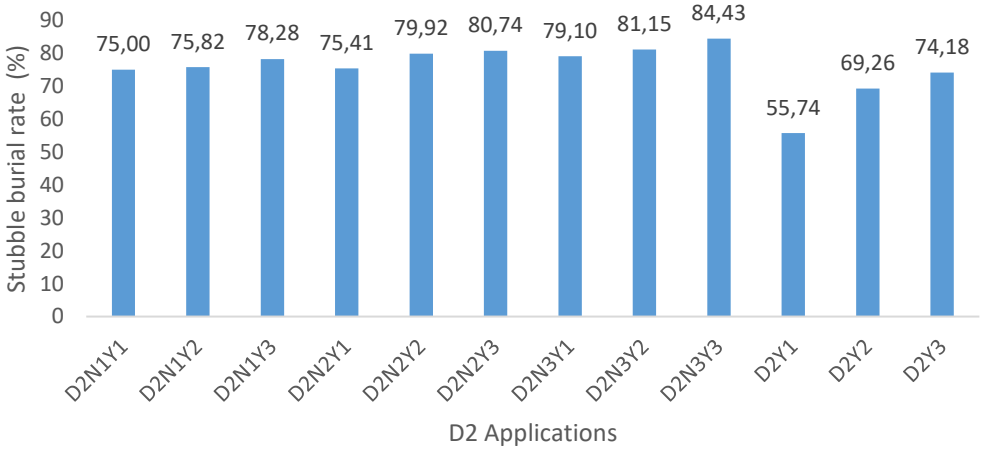

Figure 7. Stubble burial rate for D2 applications

As a result of the measurements and calculations made for the amount of stubble after tillage, it was observed that the amount of stubble on the soil surface decreased as the disc speed and direction angle increased in both disc diameters.

While the lowest amount of stubble in the disc harrow applications, which takes its movement from the soil in both disc diameters, was obtained from Y3 applications, the highest amount of stubble in all applications was obtained from Y1 applications. The fact that the working depth was lower in the applications where low disc speed and disc direction angle were used is seen as the reason why the stubble was not sufficient to be cut and mixed into the soil.

Increasing the working depth caused an increase in soil shear forces and soil and residue mixing (Zeng et al., 2021). It was observed that the treatments with the highest stubble burial rates were in the treatments with the lowest stubble amount. Upadhyay and Raheman (2020a) found that both crop residue embedding efficiency and pollination of soil clods increased with an increase in speed ratio (increase in disc speed and decrease in feed rate), and that there was a significant improvement in tillage quality when disc speed was increased from 95 to 133 min^{-1} (Dursun et al, 1999) reported that the stubble burial rate increased at rates ranging from 82.9% to 87.6% with the increase in the state and direction angles of the disc in disc ploughing and that the stubble burial rate increased by 12.7% with the increase of the direction angle from 160 to 240 in disc stubble disturbance ploughing.

It is seen that the amount of stubble decreases as the speed increases at different disc speeds with the same disc direction angles. While the amount of stubble was 34.67 g m^{-2} in D1 disc diameter, N1 speed and Y1 direction angle, it was 34 g m^{-2} in the D1N2Y1 application and 28 g m^{-2} in the D1N3Y1 application.

It was observed that increasing the disc diameter increased the amount of stubble at the same speed and direction angles. While the amount of stubble obtained from the D1N3Y3 application was 20.67 g m^{-2}, the amount of stubble obtained from the D2N3Y3 application was 25.33 g m^{-2}. The amount of stubble obtained from the D2N3Y3 application was 18.39% more than the amount of stubble obtained from the D1N3Y3 application.

It was observed that increasing the disc diameter at the same direction angle in the disc harrow applications, which takes its movement from the soil, caused an increase in the amount of stubble. While the amount of stubble was 45.33 g m^{-2} in the D1Y1 application, it was 72 g m^{-2} in the D2Y1 application.

Working speeds (v), disc peripheral speed (u) and u/v ratios for both diameter applications are given in Table 1.

Feed and disc peripheral speeds were determined separately for each application for PTO moving machine applications. Depending on the determined disc circumference speeds, the ratio of disc circumference speed to feed speed was calculated.

Table 1. Feed rates, disc peripheral speeds and u/v ratios of the applications.

D_1	**u**	**v**	**u/v**	**D_2**	**u**	**v**	**u/v**
Uygulamalar	**(m s^{-1})**	**(m s^{-1})**		**Uygulamalar**	**(m s^{-1})**	**(m s^{-1})**	
$D_1N_1Y_1$	3.35	1.11	3.03	$D_2N_1Y_1$	3.63	1.09	3.31
$D_1N_1Y_2$	3.35	1.09	3.08	$D_2N_1Y_2$	3.63	1.08	3.36
$D_1N_1Y_3$	3.35	1.07	3.13	$D_2N_1Y_3$	3.63	1.07	3.39
$D_1N_2Y_1$	3.83	1.11	3.45	$D_2N_2Y_1$	4.14	1.10	3.76
$D_1N_2Y_2$	3.83	1.10	3.49	$D_2N_2Y_2$	4.14	1.09	3.79
$D_1N_2Y_3$	3.83	1.07	3.57	$D_2N_2Y_3$	4.14	1.07	3.87
$D_1N_3Y_1$	4.60	1.11	4.13	$D_2N_3Y_1$	4.97	1.11	4.47
$D_1N_3Y_2$	4.60	1.10	4.17	$D_2N_3Y_2$	4.97	1.10	4.53
$D_1N_3Y_3$	4.60	1.08	4.28	$D_2N_3Y_3$	4.97	1.07	4.63
D_1Y_1		1.09		D_2Y_1		1.08	
D_1Y_2		1.06		D_2Y_2		1.05	
D_1Y_3		1.02		D_2Y_3		1.01	

The lowest u/v ratio among the treatments was obtained from D1N1Y1 with 3.03 and the highest u/v ratio was obtained from D2N3Y3 with 4.63. The fact that the disc peripheral velocity was higher than the feed velocity and thus the u/v ratio was high, was effective in good soil cultivation and the plant residues were cut and shredded and mixed into the soil. Upadhyay and Raheman (2020b) recommended that the peripheral speed and feed rate ratio (u/v) of the discs should be kept between 3.0 and 4.0 to obtain the best performance. In terms of tillage performance index, Upadhyay and Raheman (2020a) recommended tillage at a forward speed of 4.55 km.h^{-1} corresponding to a speed ratio of 3.09 and 133 min^{-1} with a double-acting disc harrow with front discs driven by PTO and rear discs free moving, considering the overall performance.

The skidding rates of the trials are given in Figures 8 and 9 for both diameter treatments.

In D1 diameter disc treatments, the lowest skidding rate was observed in D1N3Y1 treatment with 3.17%. This was followed by D1N2Y1 and D1N1Y1Y1 with 3.40% and 3.70%, respectively. The highest skidding rate was realised in D1Y3 treatment with 11.45%. This was followed by D1Y2 and D1N1Y3 treatments with 7.89% and 7%, respectively.

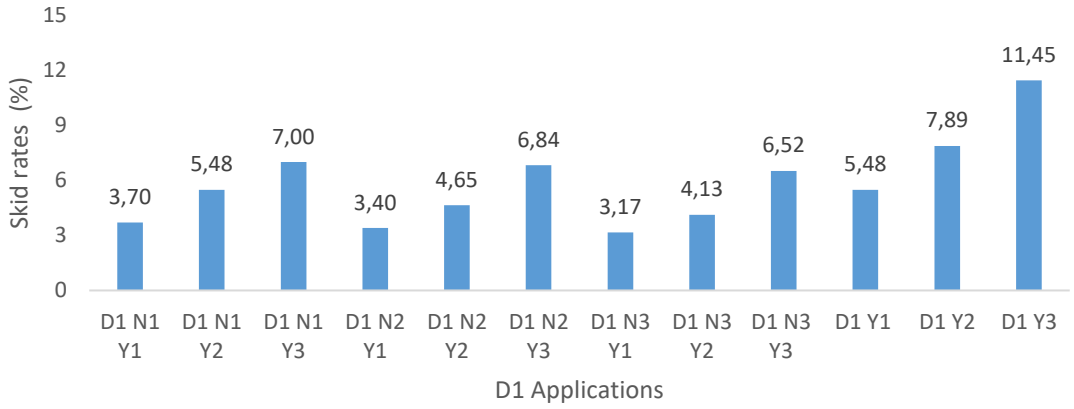

Figure 8. Skid rates for D1 applications

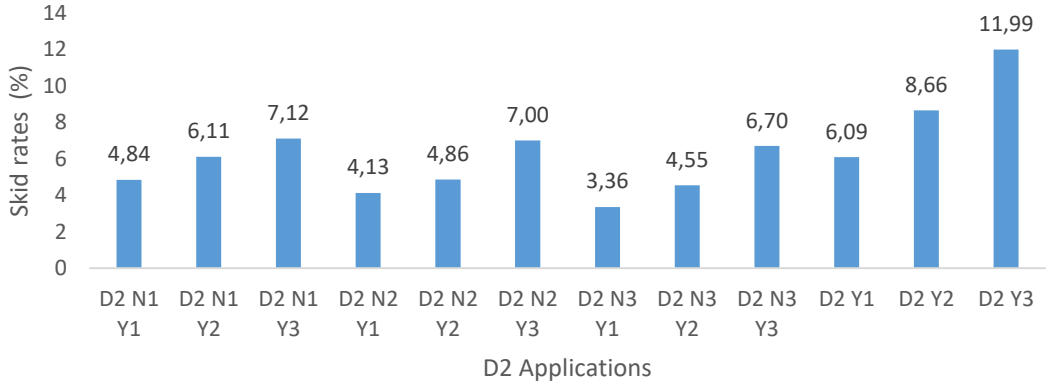

Figure 9. Skid rates for D2 applications

In all applications, it was determined that the increase in the directional angle caused the feed rate to decrease as a result of the effect of increasing working depth and as a result, the skidding rate increased. Similarly, Alamin (2017) reported that the effect of disc direction angle on the skidding rate of the tractor was statistically significant at α: 0.01 level, and the skidding of the tractor increased with the increase in disc direction angle. Upadhyay and Raheman (2020b) determined that at disc speed of 95-150 min^{-1}, feed rate of 3.46-6.82 $km.h^{-1}$ and working depths of 80-120 mm, tractive force requirement and wheel slippage were 47.8% and 69% less, respectively, for a double-acting disc harrow with front battery driven by PTO and rear battery driven from the soil compared to a disc harrow driven from the soil.

As a result of the deformation area measurements made after the trials, it was observed that the deformation area increased as the direction angle increased in both disc diameters. It was concluded that the reason for this was the increase in tillage depth as the direction angle increased and as a result, the volume of soil cut by the disc increased. It was determined that disc speed, disc diameter and disc direction angle were effective on the deformation area.

In all applications, increasing the disc diameter at the same disc speed and direction angle and increasing the direction angle and disc speed at the same disc diameter caused an increase in the stubble burial rate and a decrease in the amount of stubble on the surface.

The tillage depth of the disc harrow increased as the disc direction angle and disc speed increased. While the working depth of the machine was determined as 95 mm at minimum direction angles, it was observed that it increased up to 205 mm at maximum direction angles.

Single-acting disc harrow driven from the tail shaft provides a smooth soil surface, reduces penetration resistance, increases the content of clods with a total diameter of less than 15 mm, increases the stubble burial rate, reduces the need for towing power and skidding compared to the disc harrow that takes its movement from the soil.

Since the stalk residues of some crops cannot be broken into short or small enough pieces in the traditional tillage method, doubling or even tripling operations in the fields with clods are carried out to break the stubble or stalks of these crops. This situation enables the stubble or stalks to be broken down, although not sufficient, but in addition to this, harmful effects such as reducing the water retention ability of the soil by breaking down too much and forming a layer of cream after sowing also occur.

Mixing the stalks and stubble into the soil will also contribute to the sustainability of our agriculture by increasing the organic matter ratio of our country's soils, which are insufficient in terms of organic matter

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Conflicts of Interest: The authors declare no conflict of interest.

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Research Article

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Evaluation of Energy Efficiency of Different Sowing Methods in Grain Corn Production

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HIGHLIGHTS

- Grain yields of conventional, cross and parallel corn planting methods were determined.
- Energy inputs and outputs of conventional, cross and parallel sowing methods have been determined.
- Energy efficiency of conventional, cross and parallel sowing methods has been determined.
- Energy efficiency was compared between conventional, cross and parallel sowing methods

Abstract

In the study, the mean germination time (MED) was determined as 16.6 days, 21.08 days, and 9.75 days in the conventional sowing method, cross double row sowing method and parallel double row planting method, respectively, and the germination rate index (ERI) in the same order. It was found as 0.31 - 0.52 - 0.40 pieces/m day. Grain yield was 15260 kg/ha in conventional sowing method, 22330 kg/ha in cross double row sowing method and 18300 kg/ha in parallel double row sowing method. As a result of the experiments and calculations, the net energy yield was found to be 297.353,23 MJ/ha, 238.986,57 MJ/ha, 194.782,97 MJ/ha, respectively, then the cross-double row planting method, parallel double row planting method and conventional planting method. The maximum energy efficiency was obtained in the cross-double row planting method as 0.79 kg/MJ, followed by the parallel double row planting method and the conventional planting method with the values of 0.66 kg/MJ and 0.55 kg/MJ, respectively. The maximum output/input ratio was found in cross double row planting with 11.54%, then parallel double row planting with 9.59% and conventional planting with 8.03%. This study reveals that the cross-planting method is more advantageous than other methods and that this method can be used economically.

Keywords: Energy efficiency, Cross double row planting, Parallel double row planting

1. Introduction

One of the problems caused by various global causes and uncontrolled population growth in the world is the increasing need for food resources. This unfavourable situation has once again revealed the importance of agricultural production. It is known that increasing the food resources will be realised by expanding the

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agricultural lands where agricultural production is made and increasing the amount of product obtained from the unit area. The increase in population leads to the growth of human living areas and industrialisation and causes a decrease in agricultural lands, which in turn leads to a decrease in agricultural production and a decrease in human and animal food resources.

Maize plant is cultivated in our country due to the reasons such as the high yield of the product obtained from the unit area and the effective use of agricultural machinery compared to other products, and the production area and production amount are increasing every year. In general, a significant portion of the maize produced in our country and in the world is used as feed in the food sector and animal husbandry, and some of it is utilised in different industrial sectors. As a result of the increasing use of advanced agricultural machinery, there are about seven varieties of maize used for different needs (Sönmez et al., 2013).

Bakal and Arıoğlu, (2013) stated that the highest seed yield was obtained 112.97 kg/da in double row sowing method, while the lowest seed yield was obtained from single row classical sowing method with 84.87 kg/da yield.

Cox et al. (2006) determined that the yield obtained from the planting method with narrow row spacing was higher than the yield obtained from the planting method with 76 cm row spacing.

Taşçılar, (2008) reported that the highest yields were obtained from the double row sowing method in a 2-year study to determine the effect of different sowing densities on green grass yield and grain yield in single and double row sowing methods in the production of main crop grain maize and silage maize. As a result of the 2-year study, it was reported that double row sowing method was 4.6-6.9% and 7.6-10.0% higher in green grass and grain corn yield, respectively, compared to single row sowing method.

In agricultural production, it is always desirable to obtain the maximum yield with minimum energy inputs (Alam et al., 2005). With the efficient use of energy in agriculture, not only financial savings will be achieved, but also the reduction of fossil fuel consumption and consequently the reduction of air pollution will be ensured. As a result, sustainable agricultural production will be made (Uhlin, 1998; Azarpour et al., 2013).

This study was conducted to determine the energy efficiency of different sowing methods in the production of grain maize, which has an important place in terms of the economy of our country. This study was carried out to determine the most suitable planting method for maize production by comparing three different methods as conventional maize planting, cross double row maize planting and parallel double row maize planting after tillage.

2. Materials and Methods

The experiments were carried out in Sarıcalar Application Farm of Selçuk University, Faculty of Agriculture. The plot sizes were 6x100 m for each treatment. In order to determine the energy efficiency of conventional sowing, cross double row sowing, and parallel double row sowing methods in maize grain production, the experiments were carried out in irrigated agricultural conditions with 3 replications. The total annual rainfall of the experiment area was 272.5 mm.

In the sowing process, a 4-row pneumatic cross double row precision sowing machine was used and the conventional single row and double row sowing methods were carried out with the same machine. Single row sowing was carried out by closing each unit of the double rows in the machine. The working width of the double row seeder used during the sowing process was 280 cm.

Figure 1. Twin row pneumatic precision seed drill used in the trial

The maize variety used in the experiment is in the FAO 500 maturity group and has a growing period of 110 days. Since it is an early variety, it can easily adapt to arid conditions and water stress. It is widely cultivated as grain in Central Anatolia region.

In the 1st application, after tillage, conventional maize sowing was carried out with 70 cm between rows and 16 cm above rows with a plant density of 8900 seeds/ha (Figure 2).

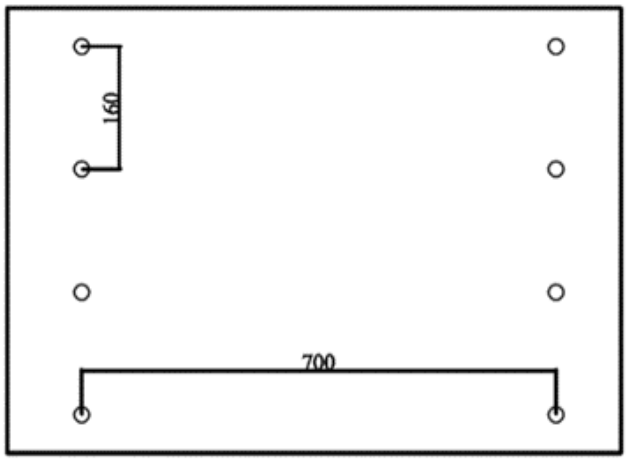

Figure 2. Conventional maize sowing practice

In the 2nd application, after tillage, double row cross sowing method was applied with a plant density of 16428 seeds/ha with 50 cm between rows (70 cm between centres) and 16 cm above rows (Figure 3).

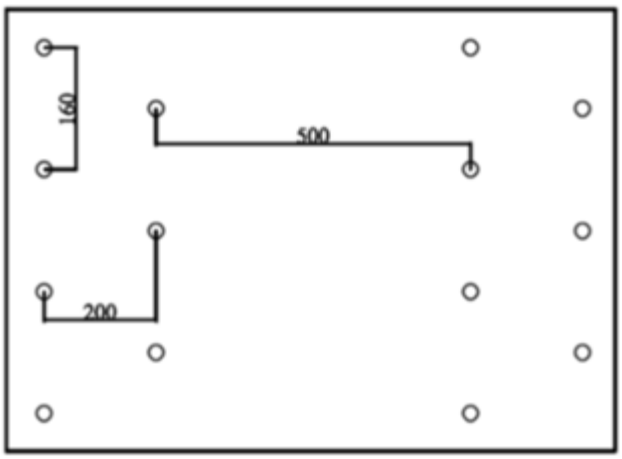

Figure 3. Double row cross sowing method

In the 3rd treatment, sowing was done after tillage (parallel) with double row sowing method with a plant density of 8900 seeds/ha with 50 cm between rows (70 cm between centres) and 25 cm above rows (Figure 4).

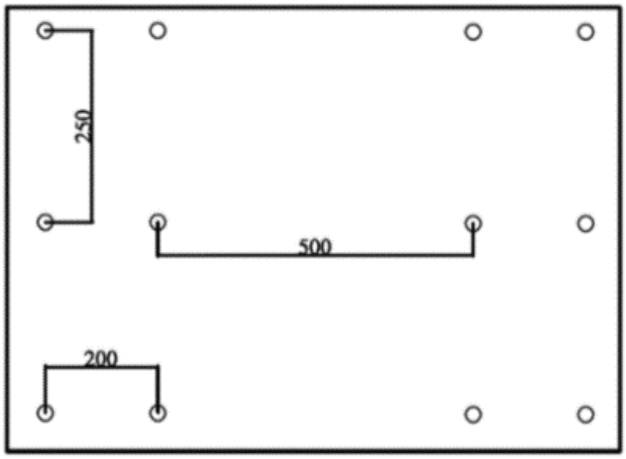

Figure 4. Double row sowing application

In order to determine the average germination date, germination rate index and field sprout emergence values of maize, 3 randomly selected strips of 1 m length from 3 different lines in each plot were observed during the germination period and the sprouts emerging on the soil surface were counted and calculated using the following relations (Konak and Çarman, 1996).

$$MED = \frac{N_1D_1+N_2D_2+\cdots.N_nD_n}{N_1+N_2+\cdots.N_n} \quad (1)$$

$$ERI = \frac{Total\ Number\ of\ Germinated\ Seeds\ in\ One\ Metre}{MED} \quad (2)$$

$$FED = \frac{Total\ Number\ of\ Germinated\ Seeds\ in\ One\ Metre}{Total\ Number\ of\ Seeds\ Sown\ in\ one\ Metre} \quad (3)$$

MED: Mean germination time (days)

N: Number of germinated seeds in each count

D: Number of days after sowing (days)

ERI: Germination rate index (pcs $m^{-1}day^{-1}$)

FED Field shoot emergence degree (%)

Table 1. Inputs and outputs in the Energy Balance Sheet

Specifications		Unit	Energy Equivalent (Mj/Unit)	References
A. Inputs				
Labour force		h	2.3	Kızılaslan(2009),Barut et al. (2011)
Machine		h	121.3	Doering (1980), Barut et al. (2011)
Tractor		h	158.3	Doering (1980), Barut et al. (2011)
Fuel-oil		L	41	Reinhardt, 1993
Drug		kg	120	Çanakçı et al.,(2005);Mandal et al.,2002; Singh 2002
Fertiliser	N	kg	60.6	Bojaca ve Shrevens (2010) Öztürk(2011)
	P	kg	11.1	Kaltschmittc ve Reinhardt, 1997
Irrigation		m^3	2.93	Çalışır (2007)
Seed		kg	14.58	Pimentel (1980)
B. Output				
Grain		kg	14.58	Pimentel (1980)

Table 2. Energy use units

Parameters	Unit	Definitions
Total energy input	MJ /ha	EI
Total energy output	MJ/ ha	EO
Total energy output	MJ/ ha	Total energy output - Total energy input
Outpru/İnput rate	%	Total energy output / Total energy input
Net energy rate	%	Net energy yield / Total energy input
Energy efficiency	Kg/ MJ	Grain and biomass yield / Total energy input
For unit product energy required	MJ/ kg	Total energy input / Grain and biomass yield

Table 3. Agricultural machinery used in the experiment

	Work width (cm)	Conventional sowing method (L/ha)	Cross double row sowing method (L/ha)	Parallel double row sowing method (L/ha)
Plough	187,5	18.2	18.2	18.2
Cultivator+ rotary harrow (2 times)	320	10.9	10.9	10.9
Roller	280	9.1	9.1	9.1
Pneumatic single grain sowing machine	280	9.5	7.5	7.5
Mineral fertiliser spreading machine	1000	3	3	3
Spraying machine	1000	3	3	3
Intermediate hoeing machine	195	5.5	5.5	5.5
Total		70.1	68.1	68.1

3. Results and Discussion

The mean germination time (MED) values varied between 16.6 days and 21.08 days. Germination rate index values were found between 0.31 and 0.52 pcs m.day^{-1} (Table 4).

Table 4. MED, ERI, FED values of the applications

	MED (days)	ERI pcs/m day	FED (%)
Conventional sowing method	16.6	0.31	100
Cross double row sowing method	21.08	0.52	100
Parallel double row sowing method	19.75	0.40	100

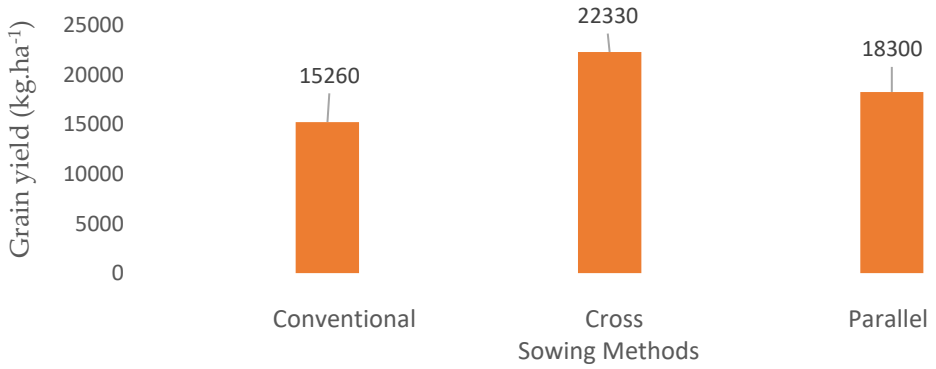

Figure 5. Applications grain yield

Table 5. Energy input and output of applications

A. Inputs		Conventional		Cross		Parallel	
		MJ/ha	%	MJ/ha	%	MJ/ha	%
Labour		11.96	0.04	11.96	0.04	11.96	0.04
Tractor		267.45	0.97	267.45	0.95	267.45	0.96
Machine		197.83	0.71	235.43	0.83	235.43	0.85
Fuel-oil		2792.10	10.08	2874.10	10.19	2874.10	10.33
Drug		276.20	1.00	276.20	0.98	276.20	0.99
Fertiliser	N	9792.96	35.34	9792.96	34.70	9792.96	35.19
	P	1223.22	4.41	1223.22	4.33	1223.22	4.40
Irrigation		12716	45.89	12716	45.06	12716	45.70
Seed		430.11	1.55	820,85	2.91	430.11	1.55
Total Input		27707.83	100	28218.17	100	27827.43	100
B. Output							
Yield		222.490,80		325.571,40		266.814,00	

As seen in Table 5. It is seen that irrigation energy has the highest share among the production inputs of the treatments, followed by Energy input and output of applications fertiliser, fuel-oil, seed, machinery and pesticide energies, respectively.

The share of irrigation energy values in total energy inputs was determined as 45.89%, 45.06% and 45.70% for conventional, crossed double row and parallel double row sowing methods, respectively. Fertiliser energy values were determined as 39.75%, 39.03% and 39.59% for the conventional and parallel double row sowing methods, respectively.

The reason why seed inputs are higher in cross sowing method than other methods is due to the high number of seeds per unit area.

Table 6. Energy rates of applications

	Conventional	**Cross**	**Parallel**
EI	27.707,83	28.218,17	27.827,43
EO	222.490,80	325.571,40	266.814,00
Net Energy Yield	194.782,97	297.353,23	238.986,57
Output/Input Ratio	8.03	11.54	9.59
Net Energy Ratio (%)	7.03	10.54	8.59
Energy Efficiency (kg/MJ	0.55	0.79	0.66
Energy Required for Unit Product (MJ/kg)	1.82	1.26	1.52

As seen in Table 6. When the treatments were analysed in terms of the energy value required for the production of one kg of product, the best result was obtained from the cross-double row sowing method with 1.26 MJ/kg, followed by the parallel double row sowing method and the conventional sowing method, respectively.

In terms of net energy yield, the highest value among the treatments was obtained from cross double row sowing method with 297.353,23 MJ/ha, followed by 238.986,57 MJ/ha from parallel double row sowing method and 194.782,97 MJ/ha from conventional sowing method.

When the treatments were analysed in terms of energy efficiency, the highest energy yield was obtained from the cross-double row sowing method with 0.79 kg/MJ, 0.66 kg/MJ from the parallel double row sowing method and 0.55 kg/MJ from the conventional sowing method.

Table 7. Energy types of applications

Energy Input Types	**Conventional**		**Cross**		**Parallel**	
	Energy Input (MJ/ha)	**Rate (%)**	**Energy Input (MJ/ha)**	**Rate (%)**	**Energy Input (MJ/ha)**	**Rate (%)**
Renewable Energy (Human Labour, Water, Seed)	13.158,07	47.49	13.548,81	48.01	13.158,07	47.28
Non-Renewable Energy (Fuel, Fertiliser Drug, Machinery)	14.549,76	52.51	14.669,36	51.99	14.669,36	52.72
Total	27.707,83	100	28.218,17	100,00	27.827,43	100
Direct Energy (Human Labour, Water, Fuel)	15.520,06	56.01	15.602,06	55.29	15.602,06	56.07
Indirect Energy (Seed, Fertiliser, Chemicals, Machinery)	12.187,77	43.99	12.616,11	44.71	12.225,37	43.93
Total	27.707,83	100	28.218,17	100,00	27.827,43	100

-The net energy yield per unit area obtained from the cross-double row sowing method was 52.6 % higher than the conventional sowing method and 24.44 % higher than the parallel double row sowing method.

When the practices were evaluated in terms of energy efficiency, it was determined that the energy efficiency of the cross-double row sowing method in production was 43 % higher than the conventional sowing method and 19,6 % higher than the parallel double row sowing method.

The output/input ratio obtained from the cross-double row sowing method was 43.7 % higher than the conventional method and 20.3 % higher than the parallel double row sowing method.

Energy consumption per unit crop was found to be 44.4 % higher than cross double row sowing and 19.7 % higher than parallel double row sowing.

-The fact that the energy required for the unit crop amount is less in the cross-double row sowing method compared to the other methods, and that the cross and net energy yield is the highest in the cross-double row sowing method, is effective in the formation of the opinion that the double row sowing method is economically feasible and can be an alternative application to other applications.

-The fact that the yield obtained in the cross-double row sowing method is higher than the other methods despite the high input in the cross-double row sowing method, the net energy ratio is 49,9 % higher than the conventional sowing method and 22,7 % higher than the parallel double row sowing method.

As seen Table 7. It was determined that the ratio of renewable energy was the highest and the ratio of non-renewable energy was the lowest among the energy inputs of the cross-double row sowing method.

The above-mentioned evaluations show that the cross-sowing method is more advantageous than the other methods and that this method can be used economically

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Food Safety in Foreign Trade of Agricultural and Food Products: Evaluation of Risk Analysis Stages and Process

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HIGHLIGHTS

- Food safety has become an important concept due to the structural characteristics of foods.
- The long duration of international trade adds importance to the food safety dimension.
- Risk analysis is an effective method to use in international trade.
- Risk communication is important for the effectiveness of risk assessment and risk management.

Abstract

Foods have become open to physical, chemical, and biological degradation due to their structural properties. The concept of food safety includes measures that can be taken against these types of may occur hazards and risks. Risk analysis is a planned approach created to identify risks to food safety and to reduce likely occur risks in terms of human health. The processes take a long time of storage, transportation, and distribution of products in international agriculture and food trade make them more vulnerable to physical, chemical, and biological risks. Food control systems applied in foreign trade of agricultural and food products are carried out based on risk analysis. In this study, the place and importance of risk analysis in foreign trade of agricultural and food products have been mentioned, and it has been tried to reveal the worldwide legislation regulations, practices, and development related to risk analysis.

Keywords: Codex; Food safety; International trade; Risk analysis processes; Standards

1. Introduction

Risk, the word origin, is coming from the French word "risque", if the Turkish Language Association Dictionary is meant the danger of exposure to harm (Turkish Language Association 2020). The word risk is been used in connection with food safety and health in recent years, one of the modern systems of food safety has been used risk analysis (Samimi and Samimi 2020). Risk analysis, on the other hand, means the process of estimating the probability and consequences of previously encountered and prioritized risks (Basset et al. 2019).

Foods, which are the basic life substances of humanity, are open to all kinds of risks due to their chemical, physical and biological properties. Food-borne risks have ensured that measures are taken by uncovering the concept of food safety. These risks are watched against biological and chemical hazards, to reduce the risks while political regulations involve direct measures, biosecurity regulations constitute indirect measures

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(Donohoe et al. 2018). Environmental events such as climate change, global warming, pollution of air and natural resources, water scarcity, natural disasters, population growth, obesity, and depletion of natural resources are also the main factors that endanger food security (Hanjra and Qureshi 2010).

Food security is defined as the physical, social, and economic accessibility of people to sufficient, safe, and nutritious food that meets their food preferences and nutritional needs for an active and healthy life (FAO 2019). Globalization and its expansion with it bring, to continue to observe that the concept of food safety in the food system poses a major risk, to reliable food supply important was made (Charlebois and Hielm 2014).

From the production stage of food to the consumption stage; in food legislation applications are based on risk analysis for reasons such as Protecting human health and ensuring food safety. Risk analysis should be, based on scientific evidence, independent, transparent and impartial (Turkey - Legal Gazette 2004). It covers the risk analysis practices in food safety, the probability of the risk that may occur due to the consumption of food and the determination of the effect on human health and the policies that will regulate the determination of these risks (Cebioglu and Onal 2018).

In the international literature, many studies have been conducted on the food safety applications of the risk analysis system. These studies; Examples of risk analysis in the applications of food codex (Demortain 2012), the importance of risk assessment in the development of international food standards (Karanusagar 2015), risk assessment for microbial and chemical hazards in food safety in the agricultural food chain (Jacxsens et al. 2016), risk communication in food safety (Aytekin 2015), the use of risk analysis and evaluation in the food safety control system (Godefroy et al. 2019) and the contribution of risk analysis to global food safety (Adamchick and Perez 2020) were realized on their subjects.

Although risk analysis practices are made a certain procedure by the WTO in international agriculture and food trade, these procedure implementations are dependent on the cultural and legal authority of the countries (Demortain, 2012). Compliance with standards and food safety requirements in international agriculture and food trade, the importance of applications increased (Malorgio et al. 2016). In this study, general lines of risk analysis and applied intended for applied to food safety in international agriculture and food trade were mentioned. The control mechanisms applied as risk analysis in food safety in foreign trade around the world have been emphasized, and solutions have been tried to propose to make them more effective.

2. Risk Analysis and Risk Analysis Processes in Food Safety

Risk analysis is not just for assessing the risks to agricultural practices and food businesses, it is an integrated approach that sees the food chain as a whole. For this purpose, a multidimensional approach is required in the economic, social, environmental, technical, and theoretical framework (Devos et al. 2019). In this context, risk analysis aims to protect consumers by controlling the raw material and production stages of food-borne hazards that will affect human health (Ozdemir and Topsumer 2017). In this way, risk analysis has formed the basis of food safety policy and was become the element that connects the food chain and food safety.

In developed countries, risk analysis contributes to improving public health by playing a major role in reducing foodborne diseases and understanding the risk of food (Roesel et al. 2015; FAO 2018). However, to reduce the risk that may occur in addition to the increasing costs of the measures taken, it is necessary to consider the economic losses that may occur in production and sales (Kunze 2016).

Foods are included for physical, chemical, and bio-logic sources risks in the process from production to consumption, especially chemical and biological hazards vary according to the structural characteristics of the food. With food safety and risk analysis, practices are minimized at every stage of the food chain diseases that may occur caused by food. Risk analysis, as well as human health and life, has been established to protect

animal and plant health and to ensure food and feed safety (Turkey - Legal Gazette 2010). Risk analysis can be an effective tool in food safety through the regulation of limited resources and quick decision-making by decision-makers (Safefood 2018). Yet, there is occurring speculation about the high cost of collecting and analyzing data related to food safety risk, the complexity of the link between contamination and harm, and the setting of standards established as a result (Lytton 2019).

Risk analysis is a process consisting of three main topics, which are risk assessment, risk management, and risk communication, with the framework drawn by the Codex Alimentarius Commission (CAC) (Figure 1). These components are scientifically based such as standards and criteria for food safety (Jacxsens et al. 2016). Thanks to these three frameworks that make up the risk analysis, it aims to increase food safety and minimize food-borne diseases by improving the food safety decision-making process with a realistic and scientific approach (Sampedro et al. 2016).

Figure 1. Relationship Between Risk Analysis Processes (Source: (FAO, 2021a))

3. Risk assessment

Risk assessment; consists of including hazard characterization, exposure assessment and risk characterization four scientific stages on independent and consecutive (FAO 2021a). Risk assessment stages are carried out by independent risk assessors working in organizations such as research institutes, universities, and research institutions. This stage is a scientific-based framework that requires multidisciplinary expertise, such as microbiological, chemical, public health, food production, processing technology, occurs in the form of present or absent (Karanusagar 2015; Edinger 2016).

The risk assessment process is realized qualitatively and quantitatively depending on the quality of the information and data obtained and the questions to be answered. The qualitative process consists of risk ranking, while the quantitative ranking consists of decisive or probability (Jacxsens et al. 2016). Since the results of risk assessment in food safety, it is based on risk management decisions and provided scientific information for risk communication, more effective use of resources is must essential (Wu et al. 2018). Besides the effective use of resources, should be included taking into account the consideration as well potential for human error in the risk assessment process (Walsh and Leva 2019).

If there is a risk occurrence condition as a result of risk assessment in the product put on the market, crisis management comes into play. Crisis management consists of communication, recall, destruction, and cost-benefit ratio stages (Szekacs et al. 2018). Risks may occur in food, in the risk assessment phase, each stakeholder making a separate assessment, stages of the supply chain is made difficult (Rathore et al. 2017).

In this study, general lines of risk analysis and applied intended for applied to food safety in International agriculture and food trade were mentioned. The control mechanisms applied as risk analysis in food safety in

foreign trade around the world have been emphasized, and solutions have been tried to propose to make them more effective.

4. Risk Management

Risk management consists of stages of problem identification, generating alternatives, developing policy tools (consulting, negotiating, and coordinating), decision-making, implementation, and evaluation of effectiveness (Aven 2016). It has been determined by "ISO 31000 Risk Management Principles and Guidelines" to create risk management to a certain standard. On the other hand, since the perception of risk differs from society to society, socio-cultural dimensions (sociological, cultural, and psychological) should be taken into account during the implementation phase of the standard (Aytekin 2015).

Since considering the risks that may arise during the risk management phase, CAC in food and agricultural products is based on risk management while setting international standards (Van der Meulen and Szajkowska 2012). In addition to setting international standards, legal risk management is aimed at protecting high levels of consumer health, harmonization national standards, and monitoring the (optimal) functioning of the internal market in the regulation of the European Food Safety Authority (EFSA) (OJ 2002).

For effective and accurate risk management businesses should do to follow the supply chain, which includes the production, processing, and distribution process, with traceability (Yaralı 2019). The agriculture and food industry must be sustainable to essential because they have a complex structure supply chain (Choirun et al. 2020). For this purpose, it is aimed to control the comprehensive and complex food supply chain by evaluating the danger with traceability and scientific data thanks to food safety management systems, especially HACCP (Hazard Analysis and Critical Control Point) (Walsh and Leva 2019). This means HACCP is an example of a new approach accepted by the CAC as a food safety practice, it is a systematic approach to the identification, assessment, and control of hazards (FAO/WHO 2005).

5. Risk Communication

Risk communication within the scope of food safety is defined as the exchange of information and views on risk-related factors and perceptions by risk evaluators and managers, consumers, industrialists, academic representatives, and other stakeholders in the risk analysis process (FAO 2021b). In short, risk communication helps communicate the complexity of the uncertainty of different levels in the risk assessment process of stakeholders. However, risk assessment experts can perceive the terms "hazard" and "risk" differently in risk communication, depending on the perspectives of the stakeholders (Barlow et al. 2015).

The quality and scope of the risk communication method have closely related to the use of effective tools, for means termination of the crisis and conveying correct information to the public (Aytekin 2015). Bridging consumers with scientific experts, policymakers, healthcare professionals and industry marketers for good risk communication in food safety help consumers accept and consider food-borne risks (Rutsaert et al. 2014).

Risk communication with consumers should be an effective implementation of risk management and their decisions on the exchange of information and ideas (Essumang 2018). Risk communication with this method, consumers who are unsure of their food safety, can have an impact on increasing trust by giving messages to social actors (Jonge et al. 2007).

6. Risk Analysis Applications on Foreign Trade of Agriculture and Food Products

The effects of food security are not limited to public health, also are affected agriculture, trade, and therefore international trade (INFOSAN 2015). The increase in international agriculture and food trade leads

to becoming global dangers and risks that will adversely affect public health. The increase in the volume of international agriculture and food trade has increased the importance of monitoring the dangers and risks that have become global (Messens et al. 2019).

In international agriculture and food trade, the analysis of border controls is not enough for food safety and food safety is ensured through a chain approach based on hazard and risk (King et al. 2017). Food safety legislation is divided that two hazard and risk-based, controls in international agriculture and food trade are carried out with a risk-based approach (Sampedro et al. 2016). It is provided a general assessment of risks with a risk-based approach in international trade and with the functioning of the food safety method, it is ensured that the standards are better determined (Hathaway 1999).

Risk analysis, depending on food safety, is responding to expected but unknown developments in the future and it laid the groundwork for promoting participation in global markets (Adamchick and Perez 2020). The application of risk analysis related to food safety was first brought to the agenda in 1983 by the National Academy of Sciences (NAS) in the USA the risk of cancer caused due to chemicals. In foods, assessing Risk analysis specific to agricultural and food products, came to the agenda after the food crisis experienced in the late 1990s. The European Union, with the white document published in January 2000, accepted as a principle to realize risk analysis in food safety. To handle food safety more centrally and comprehensively, EFSA was established in 2002, headquartered in Parma, Italy. The European Food Safety Authority (EFSA) was intended to create risk analysis by participating in all stages of food safety (EFSA 2020). The European Union, in this way, has provided to prevent the complexity of the control systems that member countries will implement separately.

Risk analysis within the scope of food safety in international trade was first started, after the establishment of WTO (World Trade Organization), in 1995 in the implementation and development of food standards focused on scientific-based risk assessment oriented. Subsequently, risk management and food safety began to be implemented in 1997, food standards and food safety with risk communication in 1998, and a risk assessment system for microbiological risks in 1999 (WHO 2008; Safefood 2018). In 2008, risk analysis became a global standard that established a framework for food security by CAC, which sets standards in international trade (Demortain 2012). International trade of agricultural and food products adopted risk analysis principles, it is also standardized procedures, besides simplifying transactions (WHO 2007). The impact of the food crisis experienced after the 1990s and the establishment of the WTO on international agriculture and food trade was observed after the 2000s, and this situation has further increased the importance of risk analysis practices (Figure 2).

The fact that retailers are responsible as well as producers in food safety, information sharing is important to supply to keep the spread of dangers under control in international agriculture and food trade has made risk communication an important process (Essumang 2018). In this context, a global network system was established in 2004 by the World Food Organization (FAO) and the World Health Organization (WHO) the name of the International Network of Food Safety Authorities (INFOSAN). This network consists of the national food safety authorities of over 190 member countries and its secretariat is run by WHO. The International Network of Food Safety Authorities (INFOSAN) is an important risk management tool that is effective in foodborne illness and disease prevention (FAO 2020).

To identify the risks that may arise from food, EFSA has created the Emerging Risk Exchange Network (EREN) system. In this system, EFSA is shaped to define the risk identification procedure as the definition of the priority problems, collecting data by determining data sources and evaluating the emerging risks (Donohoe et al. 2018). In addition, for biohazards, chemical deterioration, food consumption, and the risks that may occur as a result of consumption independently, transparently, confidentially, and clearly to

communicate somehow by monitoring information and data to develop a comprehensive risk assessment application with the scientific committee and panel experts were to aim (Ozbek and Fidan 2010; EFSA 2019).

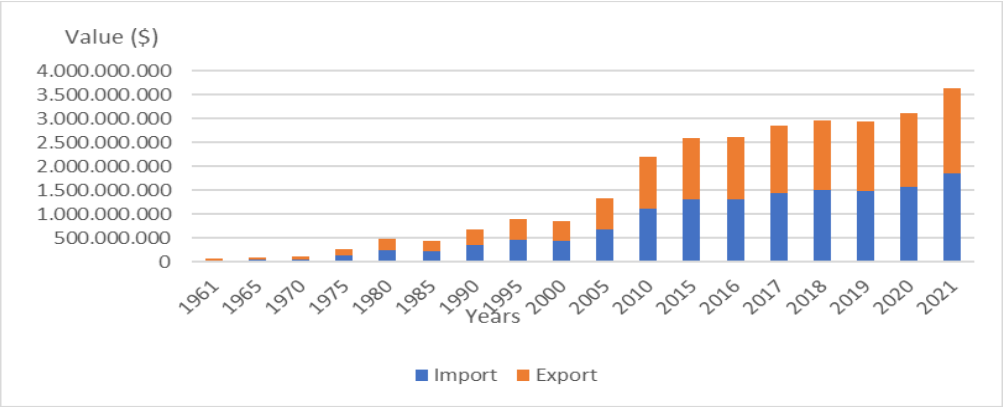

Figure 2. Development of international agriculture and food trade by years (Source: FAO)

In international trade, The World Food Organization (FAO) and WHO is included in the risk assessment process in terms of food safety (FAO 2018b). The Agreement on Sanitary and Phytosanitary (SPS), created with the establishment of the WTO in 1994, has formalized the practice of risk analysis in food safety; to protect the plant, animal, and human health, risk assessment, which is a component of risk analysis, has come to the fore. With the implementation of this component, the concept of the "Risk Assessment Paradigm" has emerged. Risk Assessment Paradigm, risk assessment and risk-related factors, the policies in the SPS Agreement aim to evaluate the measures that can be taken with commercial partners within the legal framework (Roberts 2012; Karanusagar 2015). This paradigm, as a result, risk analysis has ultimately led to not only covering scientific aspects but also such ethics, labor, and consumer choice (Smyth et al. 2015).

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The import security practices in the European Union in foods are accepted as the most strictly applied system worldwide compared to the codex (Malorgio et al. 2016). With the establishment of EFSA, the Rapid Alert System in Food and Feed (RASFF) system was developed, which had been established in 1979 to provide

risk analysis in food and feed imports. In the RASFF system, besides the European Union countries, in Non-EU countries such as Norway, Rapid Alarm System in Food and Feed (RASFF) system is an online system and applications of negative results are forwarded with feedback. In recent years, RASFF and INFOSAN have cooperated and all risks identified in the European Union are detailed and shared with INFOSAN, and encountered these risks are informed to INFOSAN members (Savelli et al. 2019).

Different approaches to risk analysis in food safety between Europe and the United States are reflected in their applications also in international trade. In the United States, the Operational and Administrative System for Import Support (OASIS) has been created under the leadership of the Food and Drug Administration (FDA) to reduce the risks in the import of agricultural and food products. The OASIS system measures the risk in imported agricultural and food products according to the product and country of origin, making risk assessments and reducing increasing concerns (Welburn et al. 2016; Yue 2016).

One of the five basic principles of the HACCP system, which became stronger with the SPS and TBT (Technical Barriers in Trade) agreements that came into force with the establishment of the World Trade Organization, is the risk analysis used for international trade agricultural and food (Ababouch et al. 2005). International trade agriculture and food (Ababouch et al. 2005). The HACCP system provides to codex based on food safety and quality with its wider application, especially in traditional inspection methods that are insufficient at the import stages (Al-Kandari and Jukes 2011). Risk analysis also contributes to fulfilling the obligations of SPS agreements, supporting the reliability of the food control system and detecting gaps in implementation (Godefroy et al. 2019).

There are criticisms that the SPS agreement in import transactions causes a loss of income and welfare by increasing production and trade costs during the implementation phase. However, under the SPS agreement, it can increase product demand by increasing product safety and quality by solving information problems about the product in terms of consumers. International standards created based on the scientific part of the SPS agreement, personal assessments to depend on consumer demand for food safety and the flow of international trade should also be considered (Yue 2016). In addition, the use of risk assessment tools in audits contributes to the fact that the standards are result-based rather than prescriptive (Cole and Martinez 2009).

7. Conclusions

It has become an increasingly important concept for reasons such as food security, growing population, a decrease in natural resources, and climate change risk analysis is accepted as an approach that promises to contribute to the development of food safety. Risk assessment, risk management, and risk communication that makes up the risk analysis are to enter on intertwined with each other in a process that aims to provide communication between scientific and political authorities about the risks that may occur in food. Since the risk assessment process is a scientific process and the information obtained forms the basis of risk management and risk communication, it should have a strong infrastructure.

The importance of risk analysis has increased due to the possibility of increased dangers and risks that may occur due to the long process from producer to consumer in international agriculture and food trade. The basis of risk analysis process practices in international agricultural and food trade was constituted by the establishment of the WTO in 1994. The standards and codexes applied with the SPS and TBT agreements created with the establishment of the WTO were created based on risk analysis. In the last period, some legislative regulations about risk analysis have been made, and these regulations should be made open to current changes.

Risk analysis applications in international trade create a certain cost, it makes it necessary to use risk analysis more effectively in international trade, especially in agricultural and food products imported from underdeveloped countries that do not have adequate surveillance and control mechanisms. Therefore, it has

contributed to the development and sustainability of risk analysis practices in international trade, thanks to the systems created in the main EU and the USA. In recent years, the continued work in the cooperation of application systems will contribute to minimizing the dangers and risks in international trade and will further increase the importance of risk analysis practices in food safety.

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Review

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In Vitro Micropropagation of Fruit Species Using Next Generation Bioreactors

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HIGHLIGHTS

- Use of bioreactors in fruit species.

Abstract

This review provides a summary of the most recent advancements in bioreactor systems, which have become more popular over the past few decades due to the outstanding qualities they offer for the creation of plant tissue and organ cultures in the laboratory as well as on a large scale. It provides a comprehensive discussion on the application of bioreactor systems in fruit cultivation as well as current research. This review presents a solution for researchers who are interested in the cultivation of diverse fruit species, as well as describes the methods that are used in the bioreactor system to propagate various fruit species.

Keywords: Bioreactor systems, In vitro, PLANTFORM, RITA, SETIS, TIS

1. Introduction

With the world's population growing at an alarming rate, so does the demand for food. Food production cannot adequately fulfill people's nutritional needs. As a result, it must produce more crops per unit of area. Plant biotechnology, which increases and improves productivity, also allows for the production of additional food raw materials from small-scale areas. Plants have been highly beneficial to mankind since the beginning of time. Plant biotechnology advances aim to improve and replace certain plant components such as carbohydrates, proteins, lipids, and vitamins over time.

In recent years, plant tissue culture methods have become increasingly important in plant reproduction, resource conservation, and secondary metabolite production. These strategies provide long-term solutions to a variety of difficulties in new and medicinal plant breeding and conservation biology (Yoshimatsu 2008; González-Rábade et al. 2012; Hussain et al. 2012; Chandana et al. 2018; Chand-ran et al. 2020). Micropropagation allows for the rapid and low-cost production of a large number of plants (Ozkaynak and Samancı 2005). In addition to the numerous benefits of micropropagation, there are some drawbacks. Labor expenditures account for 45-60% of production costs in micropropagation. Furthermore, hyperhydricity, which results in substantial losses, necessitates the employment of a large number of culture containers and

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semi-solid nutritional media (Rathore et al. 2004; Berthouly and Etienne, 2005). There are challenges with the disproportionate distribution of plant growth regulators in semi-solid and solid cultures, as well as in the nutritional medium, and varying sensitivity levels in cultured tissues depending on agar brand (Gupta and Prasad 2006).

One of the most expensive tissue culture components is agar. As a result, a variety of thickening components, such as plant-derived starches (Babbar and Jain 1998), resins (Babbar et al. 2005), and resins (Teng and Liu 1993), have been investigated as alternatives to agar (Bhattacharya et al. 1994; Prakash et al. 2004). Furthermore, resins are less attractive because they do not completely harden the medium. In reality, there has yet to be developed a commercially effective low-cost gelling agent. In vitro micropropagation has become an incredibly expensive and time-consuming method as a result of these factors. More success was achieved in this area with the use of liquid cultures in bioreactors to improve shoot propagation rates, growth, and quality while lowering process costs.

Bioreactor systems are classified as largely closed and regulated systems in a liquid environment that operates under aseptic circumstances and controlled settings (pH, temperature, ventilation). It gives benefits such as easy management of environmental conditions, high yield, and quality plant production thanks to bioreactor systems. It also protects against both abiotic and biotic stressors. There are simple and effectively built bioreactors for molecular agriculture and phytoregulation de-toxification of hazardous substances, which are utilized in the manufacture of aromatic and therapeutic metabolites (Shaposhnikov et al. 2009).

2. Bioreactor System and Types

The challenges in alternative propagation methods have been attempted to be eliminated as a remedy to the problems faced in propagation with plant tissue culture techniques and conventional methods (Cheong 2012). Although biotechnological technologies can produce solutions to difficulties faced by traditional methods, they are expensive. In terms of cost, gelling agents rank first (Quiala et al. 2012). However, the sole objective of bioreactor systems is not to be an alternative, but to rapidly-produce a huge number of plants while lowering costs. Recently, temporary immersion bioreactor systems have been employed for this, which have numerous advantages over gelling agent-based approaches.

The bioreactor system technology has emerged with the in vitro micropropagation of *Begonia x hiemalis* in MS medium and erlenmeyer flasks with kinetin hormone. For propagation in these erlenmeyers, the plants were shaken at 180 rpm (Takayama and Misawa, 1981). Haris and Mason conducted the first investigation using this technique in 1983, using *Solanum tuberosum* and *Coffee arabicana* species (Harris and Mason, 1983; Etienne and Berthouly, 2002). This approach, which was first utilized in the 1990s, is more efficient than typical agar-containing micropropagation systems. (Alvard et al. 1993; Escalona et al. 1999). Teisson and Alvard (1995) developed bioreactor systems that combine the benefits of semi-solid and liquid culture. Bioreactor systems have therefore been employed for large-scale micropropagation of several plant species or plant parts (Paek et al. 2001). To prevent this issue, bioreactors with temporary immersion systems (TIS) boost the benefits of liquid cultures by ensuring explant *in vitro* performance (Godoy et al. 2017). TIS bioreactors, culture medium, and in vitro explants are immersed for short periods of time, just long enough for the plants to absorb nutrients and plant growth regulators. Aeration within the explant tank also leads to a high-pressure ambient gas exchange to the explants, resulting in the improved shoot or plant growth and development. Bioreactors offer numerous benefits and drawbacks (Table 1) (Georgiev et al. 2014).

Table 1. The general characteristics, benefits, and drawbacks of the most prevalent TIS

TIS	POWER INPUT	CONSTRUCTION MATERIALS	STERILIZATION	PROS AND COS
Twin-Flask	Pneumatic	Glass	Autoclavable	Complex automation Have a low moisture content in the headspace The nutrient medium cannot be Replenished
RITA	Pneumatic and gravity	Polypropylene	Autoclavable	It has a basic automation system. Simple to use and safe functioning system Have a high level of humidity in the headspace With limited device positioning space
SETIS	Pneumatic and gravity	Polypropylene	Autoclavable Gamma irradiation	With basic automation that is simple to utilize It has a big region that is lit Enhanced drainage system Low energy consumption Low initial investment
PLANTFORM	Pneumatic and gravity	Polycarbonate	Autoclavable	There is no nutritional medium replenishment Reliable operation Easy to handle Easy access to light The apparatus is stacked on top of each other
PLANTIMA	Pneumatic and gravity	Polycarbonate	Autoclavable	No nutrient media replenishment Reliable operation Simple automation The apparatus is stacked on top of each other Low investment cost No nutrient media replenishment

TIS bioreactor systems are commonly used in horticultural crop research. This technique is defined as a method of developing physiologically healthy plants while decreasing plant hyperhydricity. TIS is a system in which plant cells, tissues, and organs are semi-automatically immersed in a liquid media for a set amount of time in a bioreactor (Hwang et al. 2022). By enhancing the airflow of the culture container, this device boosts the development rate of plants in many species (Bello-Bello et al. 2019). TIS promotes physiological processes such as photosynthesis, respiration, chlorophyll formation, and stomatal function during acclimatization, allowing plants to adapt well to the ex vitro environment (Aragón et al. 2014).

Transient Immersion (RITA®), Transient Immersion Bioreactor (TIB®), and Tidal Bioreactor (Tisserat and Vandercook, 1985; Ducos et al. 2007) are the most common TIS (Figure 1). MATIS® (Etienne et al., 2013) and SETIS (Hwang et al. 2022) are both Monoblock Forward Temporary Immersion Systems (Figure 2). The goal of this study was to find the best medium for *Schisandra chinensis* plants in two temporary immersion bioreactor systems, RITA® (Figure 4) and PlantForm bioreactor system (Figure 3). The tests lasted between 20 and 60 days. As a consequence, of the evaluated bioreactors, the RITA® bioreactor produced the greatest results in terms of biomass production and lignan (a valuable substance that can help prevent chronic diseases such as some types of cancer and cardiovascular disease) (Rodrguez-Garca et al. 2019; Szopa et al. 2017).

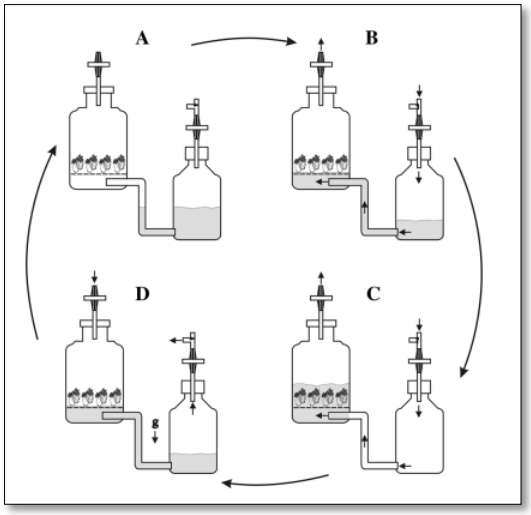

Figure 1. Technological design and operating principle of the Twin-Flask bioreactor system: (A) exposure time (B) Displacement of the liquid medium. Air pressure is applied to the media storage tank and the liquid media moves into the culture chamber; (C) immersion time; (D) evacuation of the nutrient medium. The air pressure is turned off and the medium flows back into the middle storage tank due to gravity.

SETIS is a TIS bioreactor with the advantage of a relatively large culture tank, approximately 6 L, and ease of operation (Kim et al. 2020). It has successfully produced virus-free apple seedlings (*Malus domestica*) in TIS, and sweet cherry (*Prunus ovatum*) and *Colocasia esculenta* seedling growth has also been reported in this system (Godoy et al. 2017; Arano-Avalos et al. 2020). Temporary immersion systems (TIS) are successful based on immersion period, frequency, and fluid volume per explant (Martnez-Estrada et al. 2019). With the broad adoption of these systems in recent years, it has become one of the most widely utilized micropropagation systems (Ruta et al. 2020). TIS is also known to have a positive effect on physiological processes such as stomatal function and chlorophyll production.

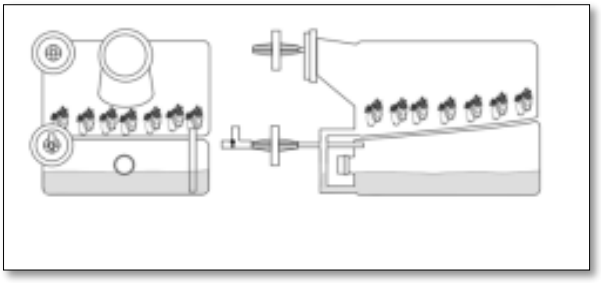

Figure 2. SETIS bioreactor systems

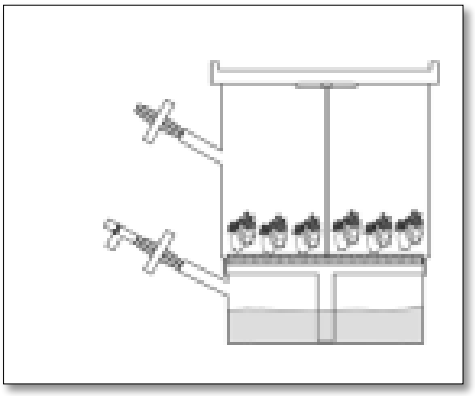

Figure 3. PLANKIMA bioreactor system

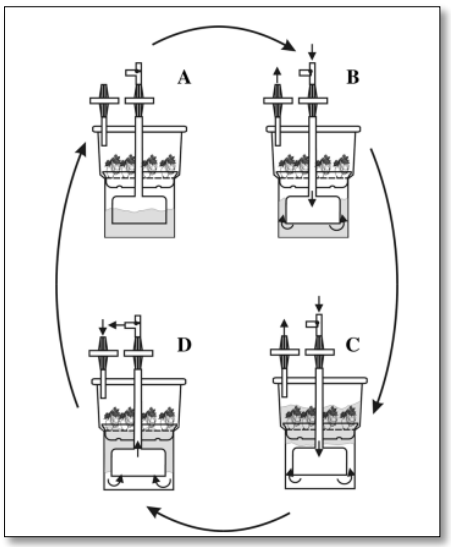

Figure 4. Technological design and operating principle of the RITA system: (A) exposure time; (B) Displacement of the liquid medium. Air pressure is applied to the lower chamber through the middle pipe. Liquid media moves to the upper chamber; (C) immersion time; (D) evacuation of the nutrient medium. The airflow is stopped and the medium flows back into the lower chamber due to gravity.

2.1 Studies in Fruit Growing

The TIS system was employed for the first time in banana micropropagation (Alvard et al. 1993). Many investigations using TIS have been reported to overcome the constraints of semisolid and liquid culture (Businge et al. 2017; Posada-Pérez et al. 2017).

Attempting propagation with a bioreactor system can yield successful results, especially in species that could not achieve successful outcomes with micropropagation (Hautsalo et al. 2017). Cuttings are used to propagate blackcurrant (*Ribes rubrum* L.), which is not an appropriate method. Their goal in their work is to establish an appropriate micropropagation methodology for blackcurrant and to investigate the impacts of various LED lighting. Combinations of white, red, and blue wavelengths improved the shot's quality. They also discovered that using a bioreactor boosted plantlet shoot height and roots. However, a multitude of procedures for blackcurrant propagation, roots, and acclimation are now available for use.

PlantForm and conventional tissue culture procedures were used to perform micropropagation and rooting studies on five different blackberry cultivars (Black Diamond, Black Pearl, Chester, Triple Crown, and New Berry). Plant growth regulators BA (Benzyl Adenine) and GA_3 (Gibberellic Acid) were added to the MS basic nutritional medium in solid culture micropropagation tests on five distinct blackberry cultivars. NAA (Naphthalene Acetic Acid) and IBA (Indole Butyric Acid) growth regulators were evaluated in MS nutritional medium for solid culture rooting studies. High micropropagation values were achieved from nutrient media containing 1 mg/L BA, and the best rooting success was obtained from 1 mg/L NAA plant growth regulator concentrations in the solid culture experiment findings. According to their findings, the PlantForm technology outperformed the solid culture approach for all five blackberry varieties. The PlantForm bio-reactor system was shown to be more effective than solid culture media for micropropagation and roots in this study (Umarusman et al. 2020).

They wanted to test a novel type of TIS bioreactor with *Myrtus communis* L. agar medium, a therapeutic aromatic plant species. For propagation, they employed MS medium supplemented with 1 mg/l BAP and 1 mg/l IBA. The solid agar medium and two different immersion periods (4 and 8 hours) were compared. After 8 hours of immersion, they got improved results. Plantlets cultivated in PlantForm bioreactor systems outperformed those grown in solid media. They discovered that their outcomes in micropropagation and rooting were once again more successful (Aka Kaçar et al. 2020

It has been attempted to reproduce in high antioxidant content blueberry semi-solid and RITA® bioreactor culture dishes. It was grown from blueberry leaves in semi-solid DM and TDZ-containing medium. They got shoot elongation in the propagated shoots' agar-free and bioreactor systems (Debnath 2011).

In raspberry and strawberry plants, TIS and RI-TA® type bioreactors were compared. Fresh weights rose in both types of TIS bioreactors. This rate rose dramatically in liquid culture compared to solid culture in strawberry plants in bioreactor systems. Micropropagation for strawberries can be done entirely in a liquid medium, while for raspberries, there is a risk of hyperhydration if the plants are kept in a liquid medium for too long. A protocol for mass propagation of raspberries is given, which combines plant propagation in a liquid medium (TIS bioreactor) and roots in a solid medium (Georgieva et al. 2016).

The TIS bioreactor system was used to study the micropropagation of axenic shoots generated from the germination of *Pistacia lentiscus* L. seeds. Different immersion times (5, 10, 15 minutes) and frequencies (4, 8, 16, 24, 32 hours) investigations were attempted. The best immersion frequency and time were determined to be 32 hours and 10 minutes. They observed that the vitrification rate in TIS trials fell from 100% to 8% as a result of changes in immersion frequency and time. *Pistacia* species can benefit from bioreactors. Studies have also revealed that it may be suitable as a medium for protoplast culture (Ekingen 2016).

The development of *Myrtus communis* L. and *Olea europaea* was compared in semi-culture and PlantForm bioreactor systems. They concluded that PlantForm bioreactor systems improved plant survival and quality in both species. During the reproductive phase of olives, the zeatin hormone offers a favorable reproduction environment. This system increases the rate of growth at lower concentrations. As a result, the bioreactor system produced superior outcomes (Carla et al. 2015).

Dipping was used for 2 minutes every 4 hours in a semi-solid nutrition medium and bioreactor system in a study on the banana plant, an industrial fruit crop in high demand in export markets. They were evaluated at two TDZ doses (0, 0.125, and 0.250 mg/l). As a consequence, the temporary bioreactor system produced the best shoot propagation results at 0.125 mg/l TDZ concentration (Daungban et al 2017).

3. Conclusions

The introduction of bioreactor systems and their usage in in vitro plant cells, as well as current fruit investigations, were assessed in this review. The usage of bioreactor systems in fruit cultivation, which began with the first banana (Alvard et al. 1993), has risen significantly in recent years among other species. Bioreactor systems, as opposed to the solid gelling agents used in *in vitro* micropropagation, are less expensive and produce a greater number of plants. Plant tissues that are constantly in contact with the nutritional media experience physiological concerns such as hyperhydration (vitrification). Because they make brief contact with the liquid nutritional media, temporary immersion bio-reactor systems reduce hyperhydration in plant tissues (Niemenak et al. 2008).

Many types of bananas (Alvard et al. 1993), raspberry and strawberry (Georgiev et al. 2014), olive (Carla et al. 2015), blackcurrant (Hautsalo et al. 2017), citrus rootstocks in the world and our country (Cengiz and Kaçar 2019), apple and sweet cherry seedlings production (Godoy et al. 2017; Arano-Avalos et al. 2020) and blackberry (Umarusman et al. 2020) bioreactor systems have been used successfully.

The Monoblock Forward Temporary Immersion System (MATIS® (Etienne et al. 2013)) and SETIS (Hwang et al. 2022) systems for *in vitro* micropropagation are being evaluated in comparison to more traditional methods such as semi-solid culture and liquid fixed cultures. In bioreactor systems, bulk propagation is more effective. Cost and labor savings are made, particularly in large-scale production. Studies have demonstrated that fruit species plants regenerate, develop, and accumulate biomass in bioreactor systems at their best rates. It demonstrated that an increase in cell size is the cause of the superb growth of regenerated plants cultivated in bioreactor systems. *Chrysanthemum* has demonstrated that secondary xylem formation from the stem is necessary for plant survival and growth following ex vitro transplantation (Hwang et al. 2022). The findings of this review demonstrated that bioreactor systems can be the best method for the industrial-scale production of fruit species, ornamental plants, and medicinal plants.

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