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Mixtures Created for Artificial Meadow-Pasture Areas According to the Animal Type to Graze and the Effect of Organic Fertilization on Botanical Composition

Rabiya KOYUNCU[1,*], Mehmet Ali AVCI[1]

[1]Selçuk University, Faculty of Agriculture, Department of Field Crops, Konya, Turkey

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ABSTRACT

This research was carried out in Selçuk University Abdülkadir Akçin application area. The aim of the study is to determine the effects of organic fertilization on botanical composition in plant mixtures created for artificial meadow-pasture areas created according to animal grazing habits. 3 different mixes for meadow and pasture; Ovine-poultry (*Lolium perenne, Festuca rubra, Poa pratensis, Trifolium repens*), cattle-1 (*Lolium perenne, Dactylis glomerata, Bromus inermis, Trifolium pratense, Medicago falcata*), cattle-2 (*Festuca arundinecea, Dactylis glomerata, Astragalus cicer, Trifolium pratense, Medicago falcata*) were prepared and 6 different fertilizers (cow-sheep-chicken-worm-chemical-without fertilizer) were applied for these mixtures. The botanical compositions of the mixtures were determined by frame method. Results indicated that the botanical composition of grasses was found the highest in the mixes prepared for ovine-poultry and sheep manure, while the ratio of legume plants was found the highest in the mixture prepared for cattle-2 and in the parcels where chicken manure was applied.

1. Introduction

Meadow and pasture areas are one of the most important natural resources of a country and have a large share in the supply roughage, which is the most important input in animal production (Tutar and Kökten 2019). It also provides benefits in preventing erosion, protecting water resources and biodiversity, maintaining the presence of medicinal plants and wild vegetables (Gökkuş and Koç 2001; Bilgili and Koç 2020). In Turkey, pastures have decreased steadily every year, from 44 million hectares to 14.6 million hectares for nearly six decades (Anonymous 2020). Also, vegetation-covered ratio and botanical composition have decreased in pastures due to the irregular and overgrazing at the same period. This pressure on the pastures and adverse competition conditions lead to the exixting of plants with high forage value and preferred by animals and an increase in invasive species, and also causes erosion risk in sloping areas (Gökkuş and Koç 2001; Palta and Lermi 2019). All these negativities limits the use of our pastureland puts our animal husbandry in an impasse (Gökkuş 2018). For this reason, artificial meadows and pastures are gaining importance in order to meet the feed needs of animals and these areas will become a necessity in the future. Formation of appropriate mixtures with the grasses and legumes that form the basis of the botanical compositions of artificial pastures is of great importance in the supply of feed. These mixtures created have many advantages (Sleugh et al 2000; Berdahl et al 2001; Koç et al 2004; Deak et al 2007). The grass obtained is richer in terms of protein and carbohydrate content, and also in terms of vitamins and minerals. Animals will be able to have a healthier and higher animal yield performance with a balanced diet in terms of nutrient content (Tan 2018). Again, created artificial meadows and pastures ensure that more feed products are taken from the unit area and as a result, animal products increase in the enterprise. Artificial meadow and pasture areas to be established will also reduce the burden of natural meadows and pastures to some extent (Atış and Hatipoğlu 2008). These areas need to be fertilized in order to maintain their continuity. Fertilization has been one of the main improving methods in the production of abundant and high quality feed in areas with sufficient rainfall and in irrigable pasture and highland areas (Büyükburç 1980; Tükel et al 1996; Reis 2002). Recently, many studies from almost all over the world have shown that fertilization has many positive effects on pasture vegetation (Rubıo et al 1996; Cosper et al 1967; Baker and Powel 1982; Yavuz 2007). Based on the positive results obtained from the research, applications in large areas have been started. However, more local studies are needed on the fertilization of our pastures (Bakır 1985;

* Corresponding author email: *rabia@koyuncu.com*

**This study has been produced from a part of the first author's doctorate thesis prepared under the supervision of the second author.

Gedikli 2019). In studies conducted in our country and in different countries of the world, it has been determined that vegetation can benefit more effectively from rainfalls with fertilization, and increases the grass yield and quality of vegetation can be achieved (Tükel et al 1996). In addition to the increase in yield with fertilization, there are improvements in features such as botanical composition, feed chemical structure, green feed period and feed palatability (Uslu 2005). Fertilization is the application of plant nutrients needed by plants in different ways, in the form they need, at the right time and with the most accurate method (Altın and Gökkuş 2005). The intensive use of chemical fertilizers in meadow and pasture areas causes the soil to become inefficient over time and the ecology to deteriorate. For this reason, studies have been carried out within the scope of organic agriculture in today's agriculture understanding and environmentally friendly practices have started to be developed with this understanding. "Fertilizer and urine", which are animal wastes, gains importance as an organic material that is used for the purpose of increasing plant production and protecting the environment and is called organic fertilizer when used in certain measures in agricultural enterprises. It is thought that the correct use of these fertilizers will be a very smart investment for the sustainable environment and the future of organic agriculture. Considering the increasing importance of organic agriculture today and the increasing demand for organic products, the use of natural fertilizer resources is predicted in this study. In the 21st century, it is observed that people prefer products produced by organic methods instead of animal products produced by chemical methods. Animal products produced by this method, especially in developed countries, find a market with higher prices (Bayram 2005). When meat and dairy farming is carried out by applying organic agriculture in meadow-pasture areas, the product increase of the animals is maintained and the floristic composition of the pastures also improves. For this reason, organic practice in meadows and pastures has become widespread in central Europe in recent years, and very serious projects are being carried out between countries (Isselstein et al 2003; Briemle 2000).

One of the most important features of the study conducted in the light of all this information is to investigate the effect of organic fertilizers on the botanical composition in the artificial meadow-pasture areas created according to the eating habits of the animals. The fact that pastures are widespread in arid areas where agricultural activities are restricted (Holechek 2004), unfavorable conditions caused by drought and often not using pastures in accordance with management principles cause roughage deficits during the grazing season. Setting up artificial pastures is one of the ways to meet this feed deficit (Gökkuş 2014). In addition, drought-resistant plant species were selected in the artificial meadow-pasture mixes we created.

2. Materials and Methods

Field work related to this research was carried out in Selçuk University Faculty of Agriculture Abdülkadir Akçin Application Field. Three different mixtures were prepared to be used in meadow-pasture areas according to the animal type to be grazed. The reasons for choosing the plants used while creating the mixtures: *T.repens* is not oversized and has stolon structure (Geçit et al 2009), *L.perenne* has a high ability to withstand heavy grazing (Jung et al 1996), *F.rubra* and *P.pratensis* are rhizome and are fondly preferred by animals (Palta and Altıntaş 2018), *D.glomerata* is resistant to grazing and mowing and it starts to grow in early spring (Açıkgöz 2001; Can and Ayan 2017), the nutritional value of *A.cicer* is equivalent to alfalfa, its greenness is preserved until late autumn, it does not cause physiological problems for animals (Karakurt 2004), *M.falcata* has a horizontal form resistant to grazing and crushing, the quality and nutritional value of *T.pratense* grass is quite high (Avcıoğlu et al 2009), it is abundant productive and rapid development of *B.inermis* (Elçi 2005), wide adaptation ability of *F.arundinecea* and resistant to mowing – grazing (Manga et al 2002). The seeds were weighed by making appropriate calculations according to the weight of one thousand kernels and the result of the germination test made before. While creating the mixtures, the calculation was made by taking the percentage of the pure planting amount of the seeds. The amount of seeds used in the mixture are given in the Table 1, 2 and 3 for each mixture.

Table 1
Amounts of seeds used in the mixture for ovine-poultry

Ovine-Poultry				
Seed/presence rates in the mix	Seed amount to be thrown (kg da^{-1})	Pure sowing percentage (kg da^{-1})	Germination rate (%)	Seed amount thrown according to germination rate (kg da^{-1})
Lolium perenne (50%)	2.5	1.25	59.5	2.10
Festuca rubra (35%)	1	0.35	9.5	3.68
Poa pratensis (10%)	0.5	0.05	8.5	0.58
Trifolium repens (5%)	0.3	0.015	80.25	0.01

Table 2
Amounts of seeds used in the mixture for cattle-1

Cattle-1				
Seed/presence rates in the mix	Seed amount to be thrown (kg da^{-1})	Pure sowing percentage (kg da^{-1})	Germination rate (%)	Seed amount thrown according to germination rate (kg da^{-1})
Lolium perenne (40%)	2.5	1	59.5	1.68
D. glomerata (20%)	2.5	0.5	50	1.00
Bromus inermis (20%)	2.5	0.5	50	1.00
T. pratense (10%)	0.5	0.05	70.5	0.07
M. falcata (10%)	0.3	0.03	37.5	0.08

Table 3
Amounts of seeds used in the mix for cattle-2

Cattle-2				
Seed/presence rates in the mix	Seed amount to be thrown (kg da^{-1})	Pure sowing percentage (kg da^{-1})	Germination rate (%)	Seed amount thrown according to germination rate (kg da^{-1})
F. arundinecea (40%)	2	0.8	75.75	1.05
D.glomerata (20%)	2.5	0.5	50	1.00
A. cicer (20%)	0.5	0.1	54	0.18
T. pratanse (10%)	0.5	0.05	70.5	0.07
M. falcata (10%)	0.3	0.03	37.5	0.08

Organic fertilizers subject to the study; It is worm, cattle, chicken and sheep fertilizer. In addition, traditional method and fertilizer-free method were applied. The research was established on 22.07.2020 with 4 replications according to the divided plots trial pattern in random blocks. Fertilizers were added to the main parcels and mixtures were applied to the sub plots. Mixtures were planted on the sub plots 1m long and 1m wide. 6x3x4 = 72 sub plots were created. Plot spacing is 2.5m, sub plot spacing is 1m and between replications is 2.5m. The reason for applying organic fertilizer types to the main plots in the trial is to minimize the impact each other of the fertilizers and to prevent excessive growth of the trial area. The fertilizers subject to the study were applied to the soil in a single dose and before planting due to economic factors and ease of application and mixed with soil cultivation tools. The analysis of each fertilizer was made before planting and fertilizers were adjusted to be 8kg pure nitrogen (N_2) per decare. One month after planting, the botanical composition of the plants was determined by the frame method. For this, a frame made of wood with a size of 10x10 cm was used. Plants in 1 dm^2 with frame were counted as pieces. Each plot was counted 3 times and averaged.

3. Results and Discussion

In this study, the effects of mixtures prepared according to different animal preferences and the use of organic fertilizers on the botanical composition formed in meadow-pasture areas were observed. The botanical compositions of grasses and legumes were evaluated separately.

3.1. Grasses in Botanical Composition

The analysis of variance regarding the effect of organic fertilizer applications on different mixtures made in the artificially created meadow-pasture area on plants from the grasses family in botanical composition is given in Table 4.

Table 4
Analysis of Variance Regarding the Effect of Organic Fertilizer Applications on Different Mixtures Made in the Artificially Created Meadow-Pasture Area on Plants from the Grasses Family in Botanical Composition

Grasses (%)				
Source of variation	Degrees of freedom	Sum of squares	Mean squares	F value
Replication	3	1189,49	396,495	2.8311
Fertilizer	5	2559.07	511.814	3.6545*
Error 1	15	2100.76	140.051	
Mixture	2	5248.44	2624.22	55.4088**
Fertilizer x Mixture	10	1503.89	150.389	3.1754**
Error 2	36	1705.000	47.361	
General	71	14306,653		
CV: 28.8633				

*: $p < 0.05$; **: $p < 0.01$

According to Table 4, fertilizer applications were found to be 5% significant according to the variance analysis results of the percentages of grasses found in artificially created meadow-pasture. There were statistically significant differences at 1% level between mixture, fertilizer x mixture interactions. The average values and LSD groups found for grasses percentages for botanical composition are given in Table 5.

Table 5
Average values (%) and LSD groups belongs to the ratio of grasses plants in the botanical composition of artificially created meadow-pasture of organic fertilizer applications belonging to mixtures.

Mixture	Grasses (%)						
	Sheep	Cow	Chicken	Worm	Chemical	Without fertilizer	Average
Ovine-poultry	80.50A	52.75B-F	49.75C-H	64.00B	55.75B-E	58.00B-D	60.12A
Cattle-1	61.25BC	51.00B-G	38.75G-I	42.50F-I	48.25C-H	47.00D-I	48.12B
Cattle-2	41.50F-I	34.75I	37.00HI	44.50E-I	43.50E-I	34.50I	39.29C
Average	61.08a	46.16b	41.83b	50.33b	49.16b	46.50b	49.17

$LSD_{mixture}$ = 5.403; $LSD_{fertilizer}$ = 10.30; $LSD_{fertilizer\ X\ mixture}$ = 13.23

According to Table 5, sheep manure (61.08%) had the highest statistical effect on the ratio of cereal plants in botanical composition. This was followed by worm (50.33%), chemical (49.16%), without fertilizer (46.50%), cow (46.16%) and chicken manure (41.83%) in descending order. However, except sheep manure, other fertilizers are in the same group. The mixtures that make up the artificial meadow-pasture are divided into 3 groups and the mixture with the highest rate of wheat in the botanical composition is the mixture of ovine-poultry (*Lolium perenne*, *Festuca rubra, Poa pratensis*) with 60.12% ratio. This is followed by a mixture of cattle-1(*Lolium perenne*, *Dactylis glomerata*, *Bromus inermis*) with a ratio of 48.12% and a ratio of cattle-2 (*Festuca arundinecea, Dactylis glomerata*) with a ratio of 39.29% in descending order. When we look at the fertilizer x mixture intreactions, the highest value was found in the parcel where ovine-poultry mixture and sheep manure was applied with 80.50%. The lowest botanical composition ratio was obtained in cattle-2 mixture with 34.50% and the plot without fertilizer.

3.2. Legumes in Botanical Composition

The analysis of variance regarding the effect of organic fertilizer applications on different mixtures made in the artificially created meadow-pasture area on plants from the legumes family in botanical composition is given in Table 6.

Table 6
Analysis of Variance Regarding the Effect of Organic Fertilizer Applications on Different Mixtures Made in the Artificially Created Meadow-Pasture Area on Plants from the Legumes Family in Botanical Composition

Legumes (%)				
Source of Variation	Degrees Of Freedom	Sum Of Squares	Mean Squares	F value
Replication	3	1191.61	397,204	2.8212
Fertilizer	5	2544.44	508.889	3.6145*
Error 1	15	2111.89	140.793	
Mixture	2	5270.36	2635.18	55.6402**
Fertilizer x Mixture	10	1497.97	149.797	3.1629**
Error 2	36	1705.000	47.361	
General	71	14321,278		
CV: 27.9544				

*: $p < 0.05$; **: $p < 0.01$

According to Table 6, fertilizer applications were found to be 5% significant according to the variance analysis results of the percentages of grasses found in artificially created meadow-pasture. There were statistically significant differences at 1% level between mixture, fertilizer x mixture interactions. The average values and LSD groups found for grasses percentages for botanical composition are given in Table 7.

Table 7
Average values (%) and LSD groups belongs to the ratio of legume plants in the botanical composition of artificially created meadow-pasture of organic fertilizer applications belonging to mixtures

Mixture	Legumes (%)						
	Sheep	Cow	Chicken	Worm	Chemical	Without fertilizer	Average
Ovine-poultry	19.50I	47.25D-H	50.00B-G	36.00H	44.25E-H	42.00F-H	39.83C
Cattle-1	38.75GH	49.00C-H	61.25A-C	57.50A-D	51.75B-G	53.00A-F	51.87B
Cattle-2	58.50A-D	65.25A	63.00AB	55.50A-E	56.50A-E	65.50A	60.70A
Average	38.91b	53.83a	58.08a	49.66a	50.83a	53.50a	50.80

$LSD_{mixture}$: 5.403; $LSD_{fertilizer}$: 10.32 $LSD_{fertilizer\ X\ mixture}$: 13.23

According to Table 7, chicken manure (58.08%) had the highest statistical effect on the ratio of cereal plants in botanical composition. This was followed by cow (53.83%), without fertilizer (53.50%), chemical (50.83%), worm (49.66%), and sheep manure (38.91%) in descending order. However, except cow manure, other fertilizers are in the same group. The mixtures that make up the artificial meadow-pasture are divided into 3 groups and the mixture with the highest rate of legume in the botanical composition is the mixture of cattle-2 (*Astragalus cicer*, *Trifolium pratense*, *Medicago falcata*) with 60.70% ratio. This is followed by a mixture of cattle-1 (*Trifolium pratense*, *Medicago falcata*) with a ratio of 51.87% and a ratio of ovine-poultry (*Trifolium repens*) with a ratio of 39.83% in descending order. When we look at the fertilizer x mixture intreactions, the highest value was found in the parcel where cattle-2 mixture and without fertilizer was applied with 65.50%. The lowest botanical composition ratio was obtained in cattle-1 mixture with 38.75% and the sheep fertilizer.

Bayram (2005), in a study conducted on the effects of ventilation, organic and commercial fertilizer applications on the grass yield, quality and botanical composition of the secondary character of pasture in Bursa conditions, stated that organic fertilizers increased the ratio of grains compared to fertilizer-free conditions, but the increases here were less than commercial fertilizers. The researcher has determined the lowest grasses in fertilizer-free conditions. There are small differences between the study that the researcher has done and the study we have done. This difference may be due to the organic fertilizer types used in our study, the plants used in the mixture and their proportions and ecological conditions. In the same study, it is claimed that fertilizer applications generally decrease the rate of legumes, and the most decrease is in commercial fertilizer applications. According to the same researcher, the highest ratio of legumes was obtained in conditions without fertilizer. Chicken fertilize, on the other hand, gave results close to fertilizer-free conditions. This study of the researcher and our study show similarities. In addition, many researchers have identi fied data in their research that support the results we obtained in our study (Nuno et al 1988; Grzegorczyk et al 1990; Vintu 1993; Kuzuoğlu and Çelik 1999; Hatipoğlu et al 2001). Jeangros and Thoni (1994), on the other hand, stated that organic fertilizers increased legume species, especially *Trifolium repens*, in all regions and suggested organic fertilizer applications for desirable botanical composition.

4. Conclusion

Our meadow and pasture areas are decreasing for many different reasons, and climax vegetation is deteriorating in existing areas and the ratio of desired plant species in the botanical composition is gradually decreasing. Invasive plants cover the meadows and pastures. Breeding methods such as top seeding and fertilization are used for the improvement of meadows and pastures. This study is also important because it includes the issue of suitable plant mixtures according to the animal type to be grazed and the fertilizers that can be applied to these mixtures. According to the results of the study, the botanical composition of the grasses was obtained from the mixture prepared for ovine- poultry (*Lolium perenne*, *Festuca rubra*, *Poa pratensis*, *Trifolium repens)* and sheep manure. The composition of the highest legume plants was obtained from cattle-2 (*Festuca arundinecea*, *Dactylis glomerata*, *Astragalus cicer*, *Trifolium pratense*, *Medicago falcata*) mixture and chicken manure. In our country, the use of organic fertilizers is rather limited compared to commercial fertilizers in forage crop farming. However, excessive and long-term use of chemical fertilizers, especially nitrogenous fertilizers, causes salinization in the soil, heavy metal accumulation, nutrient imbalance, deterioration of microorganism activity, eutrophication and nitrate accumulation in surface and ground waters (Sönmez et al 2008). According to this study, the fact that sheep and chicken fertilizers are more effective in botanical composition reveals that sheep and poultry manure can be used in meadow-pasture areas. Thus, both fertilizers will be evaluated and the desired species in botanical composition will be increased.

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Application of Raw Rock Phosphate and Earthworm (*Lumbricus terrestris* L.) On The Development and Nutrient Content of Corn Plant

Emel ATMACA[*]

[*]Selçuk University, Faculty of Agriculture, Department of Soil Science and Plant Nutrition, Konya, Turkey

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ABSTRACT

Due to the fact that phosphate rock is water insoluble, the interaction of macro and micro organisms in the soil becomes important to increase its solubility. A study in the soil to investigate the effects of raw rock phosphate and earthworm castings application on the development and nutrient element content of corn plant was carried out in four frequency series as a greenhouse trial. To that end, 0-5-10-15-20-25-30-35 and 40 kg da^{-1} raw rock phosphate (15%) and earthworms (*Lumbricus terrestris* L.) were added to the soil in P_2O_5 application dose. Only the same does of raw rock phosphate was added to the other doses. Nutrient element content of the corn plant (N, P, K, Ca, Mg, Fe, Cu, Mn and Zn) in the pots with raw rock phosphate and earthworm castings application generally increased in comparison with the other pots which were not applied earthworm. According to the data obtained in the study, the effect of earthworm and different level of raw rock phosphate on the growth of corn plant was found statistically significant ($p<0.05$).

1. Introduction

Phosphorus castings are obtained by burning natural rock phosphate chemically or grinding finely. The use of phosphorus castings is increasing day by day because the amount of beneficial phosphorus for plants is low in the soil, so the phosphorus reserves used to produce phosphorus castings are gradually decreasing (Gahoonia et al. 1999). Raw phosphate or rock phosphate, known as phosphate rock, is the parent material of phosphorus castings. Rock phosphates are generally in apatite form in the nature and they are named as carbonate apatite, flourapatite, hydroxy apatite and sulphate apatite in terms of anion and cation in its content; the most commonly used one is flourapatite (Köleli and Kantar 2005).

Earthworms have ability to increase plant development by enhancing the physical characteristics (Baker, 1999) and chemical conditions (Tuffen et al. 2002; Sabrina et al. 2009a; 2011) of the soil, so they are important elements of rhizosphere ecosystem. Earthworms use the large part of organic wastes such as crop wastes, animal manure, biosolids and industrial wastes (Chan and Griffiths 1988; Hartenstein and Bisesi 1989; Edward 1998). Earthworms break up the wastes during nutrition period; they accelerate decomposition of the substances and the change of physico-chemical features of the materials (Orozco et al. 1996; Vinceslas-Akpa and Loquet 1997). Earthworms increase phosphorus availability from the soils to the plants when they are well entreated with manure (P) that has low solubility such as phosphate rock (Ouédraogo et al. 2005).

As a phosphate source, the application of triple superphosphate and rock phosphate to two different types of soils which were neutral and acidic; and the effects of avena with dry matter rate (*Avena sativa* L.) on P, Mn, Fe, Cu and Zn content in different incubation period were different in the plants grown in each soil but the difference was not found significant in general. Different results were obtained depending on incubation period, phosphate sources and the soil (Erdal et al. 1998).

Rock phosphate is the source of chemical phosphorous castings but its solubility is very low, so one of the solutions to increase its effectiveness is the application of the micro organisms that dissolve phosphate. In a greenhouse study, five levels of rock phosphate that contained optimum 16 mg kg^{-1} (0, 25, 50, 75 and 100%) were applied to three soils (low, moderate and high) in different phosphorous levels of 4 frequency and *Bacillus subtilis* and *Pseudomonas putida* were grafted. As a result of the study, it was discovered that it had the highest dry matter yield in soil P with maximum manure treatment of pseudomonas. The fact that the a bacterial treatments had the highest P uptake capacity was attributed to the secretion of toxic materials by bacteria (Hosseini et al. 2010).

* Corresponding author email: *ekaraarslan@selcuk.edu.tr*

A study was performed on the solubility of phosphate rock obtained from two different sources to research the effects of phosphorus solvent bacteria *Azospirillum brasilense* SP–245, *Bacillus subtilis* OSU–142, *Bacillus megaterium* M3, *Raoultella terrigena*, *Burkholderia cepacia* BA–7 in solution atmosphere. Research results show that bacteria applications caused a decrease in solution pH where both phosphorus sources were used but they caused an increase in electrical conductivity, phosphorus and Ca content (Güneş et al. 2013). Marie LB et al. (2018) conducted a pot-experiment with maize in a sandy loam soil with two fertilizer levels (0 and 100 mg P kg $^{-1)}$ and three biochars produced from soft wood (SW), rice husk (RH) and oil seed rape (OSR). They found that biochar effects on biological and chemical P processes in the rhizosphere were driven by biochar properties.

In a greenhouse study performed to search the effects of earthworm, mycorrhiza and rock phosphate applications on grass and phosphorus suitability in the soil, it was discovered that earthworm castings application increased dry matter rate and P accumulating of the grass considerably. When P, N, K, Ca and Mg concentration in grass was compared to the other treatments, it was seen that these values were significantly higher in the soil with earthworms and the increase in phosphorus use efficiency of the grass was attributed to earthworm, mycorrhiza and rock phosphate (Sabrina et al. 2013).

Although chemical fertilizers which are used for phosphorus sources have a productive effect in agriculture, they have an adverse impact on the sustainable use of soil. The importance of organic agriculture is increasing nowadays and the necessity of phosphate rock use is obvious. However, the low solubility of the phosphate sources applied to the soil has limited the use of them in agriculture. This study is intended to show the importance of the earthworms for the determination of the potential of phosphate rock to be used for phosphorus castings sources in agriculture and to determine the effects of the applications on the development and nutrient element content of the corn plant.

2. Materials and Methods

The study was carried out in the greenhouse of Selçuk University Faculty of Agriculture in the form of three frequency vase trial in randomized blocks, factorial experimental design. A mixture of clay soil, earthworms (*Lumbricus terrestris* L.) and raw rock phosphate (15%) were used as sample in the study. 10 kg of oven-dried soil were put in the pots and 0-5-10-15-20-25-30-35 and 40 kg da^{-1}, P_2O_5 application dose of raw rock phosphate was added. Testing vases were divided into two groups as with and without earthworms. Three earthworms were added to each vase containing earthworms. In the study, the seeds of 10 corns (*Zea mays* L.), a Pioneer corn type, were planted in the vases with 10 kg soil as a testing plant and this number was reduced to 6 after germination. Night and day temperature in the greenhouse was 28/20 ºC, 16 hours' light/8 hours' dark period; and relative humidity was between 40/60%. The plants were irrigated with distilled water and harvested by cutting from the soil surface after 50 days of development, and then some measurements and analyzes were made on the harvested plants. After the plant samples from the experiment were watered by tap water and diluted HCI solution, they were directed through pure water. Then they were dried in drying oven at 70ºC for 48 hours and ground, and then nitrogen analysis was performed in the extract obtained by means of method of wet decomposition (Bayraklı 1987) with sulphuric acid (Lindsay and Norwell 1978). P, K, Ca, Mg, Fe, Cu, Mn, Zn elements were analyzed with ICP-AES in extracts obtained from burned plant samples (Soltanpour and Workman 1981).

The analysis of the soil sample used in the test was performed according to texture: (Bouyocous 1951), pH: (Richards 1954), EC: (U.S. Salinity Lab. Staff 1954), organic matter: (Smith and Weldon 1941), $CaCO_3$: (Hızalan and Ünal 1966), total nitrogen: (Bremner 1965), phosphorus: (Olsen et al. 1954), changeable cations: (Knudsen et al. 1982), trace elements (Soltanpour and Workman 1981). Some physical and chemical characteristics of the soil used in the study were given in Table 1. Data were analyzed as a factorial experiment in a completely randomized manner with three replication using the JMP statistical software, version 5.1 (SAS Institute INc., Cary, NC, USA). Sources of variation were treatments, incubation day and their interaction. Means were compared by Student's t-test at a significance level of 0.05.

Table 1
Some physical and chemical properties of the trial soil

Properties	Value	Properties	Value	Properties	Value
Sand %	*21.28*	Org. Mat. (%)	0.11	Fe (mg kg^{-1})	2.25
Clay %	50.72	$CaCO_3$ (%)	21.48	Cu (mg kg^{-1})	0.31
Silt %	28.00	Total N (mg kg^{-1})	12.00	Mn (mg kg^{-1})	1.15
pH	8.15	P_2O_5 (mg kg^{-1})	6.30	Zn (mg kg^{-1})	0.37
EC (µS/cm)	625	K_2O (mg kg^{-1})	26.07		

3. Results and Discussion

3.1. Development of the plants

According to the data obtained from the test, the effect of earthworm and raw rock phosphate applied to the soil on the growth of corn plant was found to be statistically significant ($p<0.05$). An increase in the length of the plant was observed when plants with both worms and raw rock phosphate were compared with other no-worm applications. Plant lengths in worm and raw rock phosphate application were between 64.72 and 79.78 cm, whereas plants with raw rock phosphate were only between 52.06 and 68.52 cm. The highest plant length was obtained from the plant which was grown in the application dose of 20 kg P_2O_5 da^{-1} (79.78 cm). The lowest plant length (52.06 cm) was obtained form the control application without earthworm (Figure 1).

The effects of earthworm casting application and raw rock phosphate applied to soil in different doses on corn biome are given in Figure 2. As shown in the figure, the effects of the application on the biomass of the corn are different and these differences were significant when the application effect was examined in terms of dose and application x dose interaction ($p<0.05$). The biomass values of the corn varied between 78.26 and 31.66 g. The highest corn biomass value was obtained as 78.26 g from the plant where earthworms were added and the raw rock phosphate was applied as 20 kg P_2O_5 da^{-1}. The lowest biomass value was obtained (31.66 g) in the control application without earthworm (Figure 2).

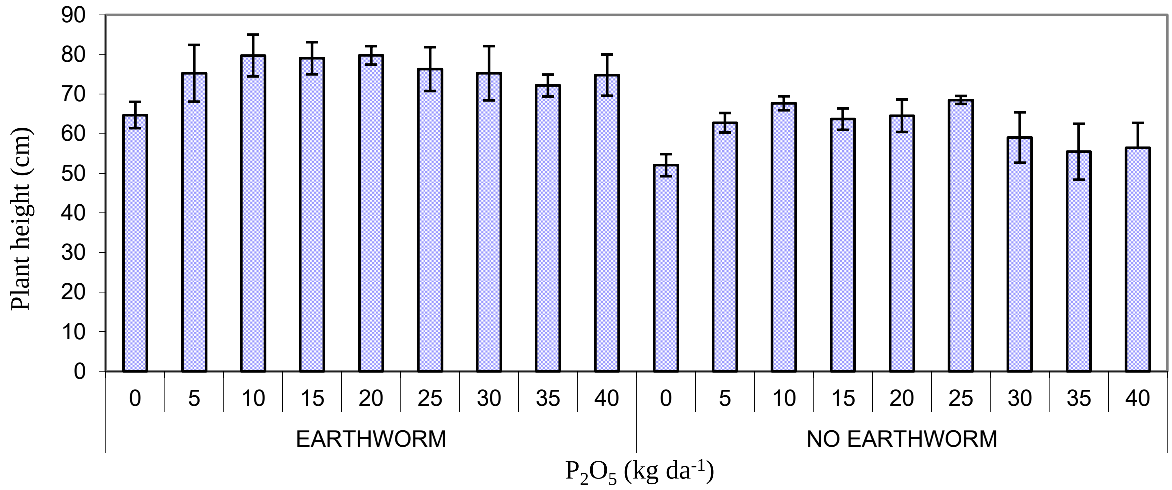

Figure 1
The effect of raw rock phosphate and earthworm application on the content of corn plant height.

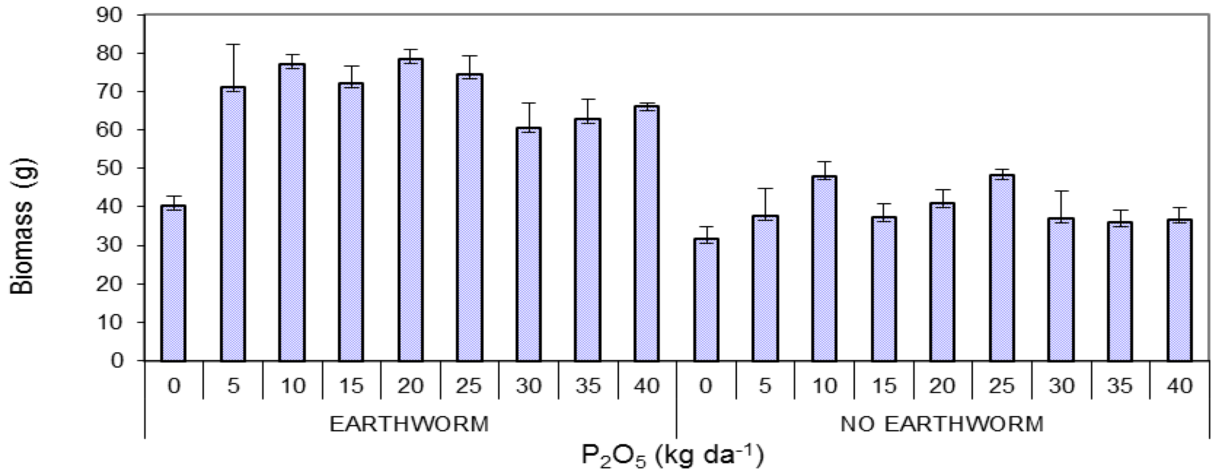

Figure 2
The effect of raw rock phosphate and earthworm application on the content of corn plant biomass.

3.2. Macro element contents of the plants

The effect of different levels of raw rock phosphate applications on the nitrogen content of corn is given in Table 2. The highest N content in corn was received from the plant with earthworms at 20 kg P_2O_5 da^{-1} application dose. Nitrogen content of the corn increased more than the control group and the difference between the applications (with and without earthworms) and raw rock phosphate doses was significant. The application x dose interaction to the nitrogen content of the relevant plant was statistically insignificant ($p<0.05$) (Table 2). Nitrogen content of the corn varied between 2.73 and 1.45% and the lowest nitrogen content was determined in the control application without earthworm. According to Jones et al. (1991), nitrogen contents of corn were at the fault level.

The effects of the application of different raw rock phosphate doses and earthworm castings on phosphorus content are given in Table 2. As seen in Table 2, P concentration content of corn generally increased depending on the increasing phosphorus doses. The effect of two different applications (with and without worm) and different doses of raw rock phosphate on the phosphorus content of maize was found significant ($p < 0.05$). According to Jones et al. 1991, phosphorus content of the plants is between 0.3- 0.5% of their dry weight. According to the research results, phosphorus content of corn is at the fault level. This rate is in minus position and it drops below 0.1%. Phosphorus content of corn changed between 0.18 and 0.38% and the highest phosphorus content was determined in 20 kg P_2O_5 da^{-1} application dose without earthworm (0.38%); the lowest phosphorus content was found in the control group without earthworm (0.18%). Phosphorus content of the test soil was quite low (0.001%). Phosphorus level of the soils generally varies between 0.02% and 0.15% and too little of it (1-2%) can be obtained by the plants. Phosphorus exists in the soil in two ways as organic and inorganic. The plants make use of inorganic orthophosphate that is melted in groundwater.

The effect of the applications with and without earthworm and different raw rock phosphate doses on potassium content of corn is given in Table 2. The highest (5.04 %) K content in corn was obtained from the plant with earthworm in 5 kg P_2O_5 da^{-1} application dose. Potassium content of corn increased compared to the control group and the difference between the applications (with and without earthworm) and raw rock phosphate doses was found significant. The effect of application of x dose interaction to the potassium content of the plant in question was found significant (Table 2). Potassium content of corn plant varied between 3.15 and 5.04% and the lowest potassium content (3.15 %) was determined in the control application without earthworm. According to the research results, potassium content of corn plant is usually sufficient and even higher (Jones et al. 1991).

The effect of different doses of raw rock phosphate and earthworm castings application on the calcium content of corn is given in Table 2. As seen in Table 2, Ca concentration of corn varied depending on increasing doses of phosphorus. The effect of two different applications (with and without earthworm) and different doses of raw rock phosphate on the calcium effect of corn was found significant ($p<0.05$). According to the research results, the calcium contents of corn are generally in sufficient level (Jones et al. 1991). The highest Ca content in corn was obtained from the plant with earthworms at the application dose of 5 kg P_2O_5 da^{-1}.

The effect of different doses of raw rock phosphate and earthworm castings application on the magnesium content of corn is given in Table 2. The highest Mg content (0.38%) in corn plant was obtained from the plant without earthworm at the application dose of 35 kg P_2O_5 da^{-1}. Magnesium content of corn increased more than the control and the difference between the applications (with and without earthworm) and raw rock phosphate doses was found significant. The effect of application x dose interaction on the magnesium content of the relevant plant was not significant (Table 2). The magnesium content of corn plant varied between 0.29 and 0.38% at a sufficient level (Jones et al., 1991), and the lowest magnesium content (0.29%) was found in the control application with earthworm. According to the research result, the magnesium content of corn plant was generally at a sufficient level (Jones et al. 1991).

3.3. Micro element contents of the plants

The effect of different doses of raw rock phosphate on the iron content of corn is given in Table 2. The highest Fe content in the corn (215.11 mg kg^{-1}) was obtained from the plant to which the earthworm castings were added at an application dose of 25 kg P_2O_5 da^{-1}. Fe content of corn increased in comparison with the control plant and the difference between the applications (with and without earthworm) and raw rock phosphate doses, and application x dose interaction was found statistically significant ($p<0.05$) (Table 2). Fe content of corn varied between 215.11 and 104.56 mg kg^{-1} and the lowest Fe content was determined in the control application with earthworm. According to Jones et al. (1991), Fe content of corn was at a sufficient level.

The effect of different doses of raw rock phosphate and earthworm castings application on the copper content of corn is given in Table 2. As seen in Table 2, Cu concentration of corn varies between 9.61 and 12.33 mg kg^{-1}. The effect of two different applications (with and without earthworm) and different doses of raw rock phosphate on copper content of corn was found significant ($p<0.05$). According to Jones et al. (1991), copper content of corn is at a sufficient level. The highest Cu content in corn was obtained from the plant (12.33 mg kg^{-1}) that the earthworm was added to at an application dose of 20 kg P_2O_5 da^{-1}.

The effect of the applications with and without earthworm and different doses of raw rock phosphate on the zinc content of corn is given in Table 2. The highest Zn content (55.67 mg kg^{-1}) in corn was obtained from the plant with earthworm at 20 kg P_2O_5 da^{-1} application dose. Zinc content of corn increased compared to the control and the difference between the applications (with and without earthworm) and raw rock phosphate doses was found significant ($p<0.05$). The effect of application x dose interaction on the zinc content of the plant in question was found significant ($p<0.05$) (Table 2). According to Jones et al. (1991), zinc contents of corn were at a sufficient level. Zinc content of corn varied between 31.44 and 55.67 mg kg^{-1} and the lowest zinc content was determined in the control application with earthworm (31.44 mg kg^{-1}).

The effect of the applications with and without earthworm and different doses of raw rock manganese on the zinc content of corn is given in Table 2.

As seen in Table 2, Mn concentration of corn varies depending on increasing doses of phosphorus. The effect of two different applications (with and without earthworm) and different doses of raw rock phosphate on manganese content of corn was found statistically significant in terms of application, dose and application x dose interaction ($p<0.05$). According to Jones et al. (1991), manganese content of corn is at a sufficient level in terms of these values. The highest Mn content in corn was obtained from the plant with earthworm at 20 kg P_2O_5 da^{-1} application dose (121.28 mg kg^{-1}). The lowest manganese content was obtained from the control application without earthworm (92.56 mg kg^{-1}).

Table 2
The effect of raw rock phosphate and earthworm application on the content of corn plant nutrient element.

	P_2O_5 (kg da^{-1})	%					mg kg^{-1}			
		N	P	K	Ca	Mg	Fe	Cu	Zn	Mn
Earthworm	0	1.83	0.20 fg	4.19 e-h	0.31 gh	0.29	104.56 f	9.67 e	31.44 ı	98.83 e-g
	5	2.44	0.25 cd	5.04 a	0.62 a	0.34	125.56 ef	11.39 a-c	47.22 b-d	100.11 e-g
	10	2.59	0.24 c-f	4.57 b-e	0.49 bc	0.36	158.67 cd	11.72 ab	52.56 ab	102.22 d-g
	15	2.26	0.24 c-e	4.62 bc	0.38 e-g	0.31	164.22 c	11.39 a-c	49.22 a-c	100.28 e-g
	20	2.73	0.26 cd	4.94 ab	0.45 b-d	0.34	186.67 bc	12.33 a	55.67 a	121.28 a
	25	2.46	0.23 c-f	4.66 bc	0.52 b	0.32	215.11 a	11.89 ab	45.00 c-e	116.94 ab
	30	2.00	0.30 b	4.48 c-e	0.40 d-f	0.36	173.33 bc	11.22 b-d	41.00 d-g	111.67 a-d
	35	2.36	0.25 cd	4.62 b-d	0.47 bc	0.36	179.89 bc	11.00 b-d	41.89 d-g	114.72 a-c
	40	2.34	0.27 a-c	4.22 d-h	0.36 fg	0.34	192.67 ab	11.61 ab	43.33 c-f	107.11 b-e
No Earthworm	0	1.45	0.18 g	3.15 j	0.25 h	0.31	110.89 ef	9.61 e	32.56 hı	92.56 g
	5	1.87	0.23 c-f	4.38 c-f	0.34 fg	0.29	127.56 ef	9.72 e	40.22 d-g	99.50 e-g
	10	1.75	0.25 cd	4.34 c-f	0.50 bc	0.38	158.56 cd	10.50 c-e	35.56 g-ı	106.22 c-f
	15	1.74	0.24 c-e	4.47 c-e	0.48 bc	0.37	127.56 ef	11.06 b-d	37.78 e-ı	103.61 b-e
	20	1.70	0.38 a	4.29 c-g	0.35 fg	0.36	134.67 de	11.39 a-c	48.44 bc	119.06 a
	25	1.79	0.19 fg	3.87 h	0.37 e-g	0.37	125.22 ef	11.17 b-d	38.89 e-h	95.33 fg
	30	1.60	0.23 d-g	3.92 gh	0.41 d-f	0.37	134.00 d-f	11.56 ab	33.78 g-ı	94.89 g
	35	1.80	0.25 c-e	4.06 f-h	0.44 c-e	0.38	127.78 ef	11.00 b-d	35.33 g-ı	99.06 e-g
	40	1.66	0.20 e-g	3.51 ı	0.36 e-g	0.37	124.11 ef	10.33 de	37.78 f-ı	96.11 e-g
	LSD (0.05)	ns	0.04	0.35	0.06	ns	25.40	0.89	6.32	9.44

Earthworm are known to accumulate heavy metals in their tissues. Different earthworm species accumulate heavy metals to different degrees; further, heavy metal accumulation in earthworms is also dependent on soil characteristics (including organic waste). The accumulations of Zinc and Copper in particular have higher rates of accumulation in earth worms (Domiguez et al. 2012; Lukhari et al. 2005).

The vermicomposting process results in the Potassium content being significantly increased. This is due to variations in Potassium distribution between the exchangeable and non-exchangeable forms. The total quantity of Potassium is however unchanged by earthworms – they however can change the form of Potassium in the soil which increases the nutrient content (Kumar 2005). The large part of phosphorus in the soil is in a formation that can't be made use of the plants. Phosphorus must be decomposed and turned into phosphate anions so that the plants can benefit from the phosphorus existing in organic or inorganic combinations of phosphorus.

The plants can benefit from free phosphate anions easily but it is hard for phosphate anions to be free in many kinds of soil. The plants can hardly make use of phosphorus especially in lime soil and in high pH soils and in too much acidic soil (Güneş et al. 2013).

When the development and nutrient element content of corn without earthworm are compared to the corn with earthworm, it was found that the inclusion of the earthworm increased the solubility of the phosphorus introduced into the soil and again increased the growth and nutrient content of the plant. In terms of qualitative and quantitative metabolic compositions, the properties of the rhizosphere differ from those of bulk soil, and their roles should be taken into account when investigating root exudates (Haichar et al. 2014; Mönchgesang et al. 2016; Coskun et al. 2017). Studies have shown that the inclusion of worm and raw rock phosphate significantly improves the growth and nutrient content of plants. (Erdal et al. 1998; Sabrina et al. 2013; Quédraogo et al. 2005; Hosseini et al. 2010; Güneş et al. 2013). There may be some reasons for increased phosphorus solubility, plant growth and nutrient content as a result of the earthworm inclusion. Earthworms are generally called as ecosystem engineers because of their abilites to modify the soils and plant communities (Lavelle et al. 1997; Edwards, 1998; Hale et al. 2005). Earthworms change the physical characteristics (Edwards and Shpitalo 1998), nutrition (Edwards and Bohlen 1996) and biological activities of the soil (Doube and Brown 1998) and surface plant communities (Piearce et al. 1994; Wurst et al. 2005) on account of mixing the surface, droppings, canalising and other activities. Zhu et al. (2016) also reported that the sugar content in corn root exudates increased especially as the N rate increased.

According to the results of this study, earthworm castings application and raw rock phosphate generally increased the development and nutrient element content of corn. Earthworm castings application and raw rock phosphate increased the development and nutrient content of the plants in other similar studies as well (Erdal et al. 1998; Sabrina et al. 2013). This contribution of the earthworms can be attributed to their digestion of organic matters in a good way. Accordingly, in a study performed in California it was discovered that surface litter was decomposed faster after *Lumbricus terrestris* was put in an apple garden that was irrigated and the soil became more fertile (Werner 1997). Plants need small quantities of trace elements (or Micronutrients) in the soil to thrive. If the quantity of Micronutrients is however to large, this can prevent plants from thriving or even be harmful (Khwairakpam and Bhargava 2009). Earthworms are helpful in this regard due to their ability to accumulate certain metals ingested or absorbed via their intenstive and skin. This can help regulate potentially harmful elements to plants in the soil (Sharma et al. 2005).

Phosphorus solubility has increased due to the earthworm casting applications being applied as an increasing factor for the current usefulness of phosphate sources. In worm and nonworm applications, the usefulness of phosphorus has increased more than control application (Table 2). Similar studies on this subject support this research (Ouédraogo et al. 2005; Hosseini et al. 2010).

The success of earthworms in how they can digest organic matter in the soil is evident in the excellence of their castings. Tutar (2013) stated that earthworm castings contained a large amount of bacteria (azotobacter) and mycorrhizal mushrooms that produce nitrogen fixation from symbiotic bacteria (Rhizobium) and asymbiotic microorganisms. He emphasized that secretion of the earthworms contained a large amount of and a great variety of enzymes. When vitamins, amino acids, growth hormone, and these secretions mixed with their feces, it allowed the plant to grow faster and made it more resistant to bad environmental conditions.

4. Conclusion

It is important to understand the interdependency between the soil, earthworms, metals and microorganisms in the soil and vermicomposts. Understanding these dependencies is key to creating high quality organic fertilizers. Microorganisms in the soil are a key food source for earthworms, but earthworms cannot digest some microorganism species; in such cases, their population can increase in the earthworm's gut and in their excrement. On the other hand, earthworms can kill some microorganism species during digestion.

This study was intended to be able to increase current resoluble phosphorus amount and the usability of raw rock phosphate in agriculture. The importance of organic agriculture is increasing nowadays and the necessity of phosphate rock use becomes obvious. Low solubility of these phosphate sources limits their uses in agriculture. Actually, the use of natural sources in natural ways without damaging the structure of the soil is imporant in agricultural sustainability. When this was taken into consideration, it was found out as a result of the study that the earthworms applied to increase the solubility of the existing phosphorus and raw rock phosphate in the soil made a contribution to the solubility considerably. Therefore, instead of giving more manure to lime soils to compensate for phosphorus deficiency due to fixing, the solubility of the currently applied fertilizer should be increased. In these applications, making use of earthworms, which are completely natural and biological fertilizers, not only contributes greatly to the sustainability of the soil but also prevents extra costs. If there is a production with manure application from the beginning, it would be wise to do this with phosphorus rock.

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Morphological and Physiological Effects of Drought Stress on Some Strawberry Cultivars

Mostafa Fraidoon Faaek FAAEK[1], Lütfi PIRLAK[2*]

[1]Selçuk University, Faculty of Agriculture, Department of Horticulture, Selçuklu, Konya, Turkey

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ABSTRACT

This study was carried out in the Selcuk University Faculty of Agriculture Department of Horticulture Research and practice greenhouse. In the study, Ata77, Bolverim77, Doruk77, Dorukhan77, Eren77, Erenoğlu77 and Hilal77 strawberry varieties obtained from Yalova Atatürk Horticultural Research Institute were used. Sewing 5-6 leaf stage seedlings strawberries made after the arrival of field capacity after the leaves of plants irrigation turgor until drought. After implementation of the varieties of drought with healing and drought period of watering again losses to determine. Leaf relative water content (LRWC) loss 15. by the end of the day up to Ata77 cultivar (51.51%) while the cultivar Dorukhan77 with at least lost 29.74%. Improvement of then 7. day also represents the maximum improvement in the kind of Dorukhan77 (% 5.38), while according to the day of check out lost 17.57% Ata77. Membrane permeability up to Ata77 cultivar (91.32%) while the lowest membrane radicals Doruk77 (71.46%). The drought is finally low stomatal conductivity Ata77 (10.70 mmol m-2 h-1) from the rubrics communicate the highest stomatal conductivity Doruk77 (106.76 mmol m-2 h-1) measured from. Measured in terms of the amount of chlorophyll in leaves, drought and recovery period maximum type of SPAD value from Eren77 (56.52 and 56.73) while Hilal77 the lowest values were obtained from (52.15 and 52.31). Body weight value of relative dry drought at the end of the implementation of the Doruk77 with the highest being obtained from 33.47 g minimum value has been obtained from Ata77 with 24.35 g. In terms of relative root dry weight, the highest value is being obtained from 24.79 g Doruk77 with the minimum value has been obtained from Dorukhan77 with 18.44 g. Leaf after leaf of the drought in the area measuring growth% 2.57 cultivar Dorukhan77 with, while the lowest leaf growth is cultivar has been Doruk77 0.26%.

1. Introduction

Strawberry is one of the important fruit species grown commercially in the world and in Turkey, and this importance is increasing. The commercially grown strawberry belongs to the Fragaria genus of the Rosaceae family and is included in the Fragaria X ananassa species, obtained by crossing Fragaria chiloensis and Fragaria virginiana species (Deuel and Plotto, 2004). Strawberry is a type of fruit that can easily adapt to different ecological conditions and climate types. As a matter of fact, it can be grown in different ecological conditions from Siberia to Ecuador, from places with high altitudes to places at sea level. Therefore, it can be grown in almost every region in Turkey. Strawberry production is mostly carried out in the Mediterranean and Aegean regions of Turkey, and over time, strawberries have been grown in other regions of Turkey. In the world, especially China, USA, Mexico, Turkey, Spain, Egypt are important strawberry producer countries (Anonymous, 2021).

Today, drought has reached social and economic dimensions that threaten the environment and countries with the increase in the world population, climate changes, deforestation and global warming. Drought is one of the natural disasters that cause the most damage to people and the environment and cause great losses. It is estimated that Turkey is among the countries with a high risk group in terms of the possible effects of global warming, and that especially the Mediterranean and Central Anatolia regions will be more affected by climate change in the future. Turkey has very different climatic zones and microclimate areas due to its geographical location and structure. Climate elements and especially the precipitation factor, which has the greatest impact on production, show great temporal and spatial changes. Although the annual precipitation average in Turkey is around 640 mm, water shortage

* Corresponding author email: *pirlak@selcuk.edu.tr*

**This work is part of first author’s PhD thesis and drought are experienced in many regions due to the irregularity of the precipitation distribution (Özcan et al., 2004). Among the main factors affecting drought in Turkey are atmospheric conditions, physical geography factors and climatic conditions (Anonymous, 2008). Drought stress caused by the lack of moisture necessary for the plant to grow normally and complete its life cycle; It is common in regions where rainfall is irregular and irrigation is weak (Sircelj et al., 2007). Drought is a meteorological phenomenon in general terms and is defined as the period when there is no precipitation until the water content of the soil and plant growth decreases significantly and the water shortage reaches the amount that will cause distress (Özcan et al., 2004). In drought conditions, the water potential of the soil and then the plant decreases. In the later stages, low turgor pressure, closure of stomata, decrease in leaf growth and decrease in photosynthesis rate occur. Plants exposed to drought stress have limited growth, lower dry matter production, increased susceptibility to diseases and pests, and decreased product quality and quantity (Monti, 1987).

Plants to drought stress; they respond with the change they show in morphological, biochemical and metabolic processes (Romo et al., 2001). As a result, plants exposed to water scarcity are more sensitive to other biotic and abiotic stresses (Coruso et al., 2008).

Global warming, which is seen as a potential threat to agricultural production in the future and whose impact we feel increasing day by day, will necessitate the determination of drought tolerance of existing cultivars and the cultivation of new drought-tolerant genotypes. For this purpose, in this study, the drought stress of 7 short-day strawberry cultivars, Bolverim77, Hilal77, Doruk77, Dorukhan77, Ata77, Eren77, Erenoğlu77, breeding in Yalova Atatürk Horticultural Central Research Institute.

2. Materials and Methods

2.1. Materials

This research was carried out in the greenhouse of the Department of Horticulture, Faculty of Agriculture, Selcuk University in 2016-2017. The plants were grown under sunlight, at an average temperature of 31/22 (day/night) and approximately relative humidity % 60-70 during the growing period. In the research, 7 strawberry cultivars, Bolverim77, Hilal77, Doruk77, Dorukhan77, Ata77, Eren77, Erenoğlu77, which were breeding in Yalova Atatürk Horticultural Central Research Institute, were used. Characteristics of the strawberry cultivars below.

ATA77: Tioga x Cruz hybrid. Its fruits are medium large, the outer color of the fruit is bright red, the fruit flesh is hard, the fruit is heart-shaped, the taste and smell are very good (Anonymous, 2017).

EREN77: Ottoman x Tufts hybrid. Its fruits are medium large, conical in shape, the outer color of the fruit is bright red, the taste and smell is very good, the fruit quality is good and the fruit flesh is hard (Anonymous, 2017).

HİLAL77: Ottoman x Tufts hybrid. Its fruits are medium-large, heart-shaped, the outer color of the fruit is bright red, the taste and smell is very good, the fruit quality is good and the fruit flesh is hard (Anonymous, 2017).

BOLVERİM77: Tioga x Yalova-104 hybrid. The fruits are large, the outer color of the fruit is bright light red, the hardness of the fruit is medium, the shape is flattened, the fruit taste is medium (Anonymous, 2017).

DORUK77: Tufts x Cruz hybrid. The fruits are small, the outer color of the fruit is bright red, the fruit flesh is quite hard. It is suitable for the food industry and can also be used as a table (Anonymous, 2017).

DORUKHAN77: Tufts x Cruz hybrid. The fruits are medium-large, the outer color of the fruit is bright red, the fruit flesh is hard. It is quite efficient. Although it is table quality, it is also suitable for the food industry (Anonymous, 2017).

ERENOĞLU77: Cruz x Tioga hybrid. The fruits are large, the outer color of the fruit is bright red, the fruit flesh is medium hard. Fruit quality is very good (Anonymous, 2017).

2.2. Methods

In the study, frigo strawberry seedlings were planted in 3-liter pots filled with peat. After the seedlings are planted, the flowers and branches are plucked until they reach the 5-6 leaf stage, and vegetative development of the plants is ensured. The seedlings used in the study were selected with equal vigor. The seedlings, whose development was completed, were irrigated at the field capacity level and no irrigation was applied until the first sign of drought (withering of the leaves). After the first sign of drought, the plants were started to be watered again and the recovery vitality was maintained.

The study was planned on 7 strawberry cultivars with a 15-day drought application followed by re-irrigation of the plants. In the study, there were 3 replications and 3 plants in each replication. In the study, morphological measurements of leaf area, plant fresh and dry weight, root fresh and dry weight were made. In addition, physiologically membrane permeability, leaf proportional water content, stomatal conductivity and chlorophyll content measurements were made.

The mature leaves from the plants were measured with the Winfolia leaf area meter program. Measurements were made on 10 leaves selected by chance from plants belonging to each application (İpek et al., 2014).

At the end of the research, the parts of the plants removed from the pots, except for the root parts, were first kept in an oven at 72°C for 48 hours after their wet weight, and their dry weight was determined by weighing them with precision scales (İpek et al., 2014).

At the end of the study, the roots, excluding the plant green parts of the plants removed from the pots, were first taken from the wet weight and kept in an oven at 72°C for 48 hours, and their dry weight was determined by weighing them with a precision balance (İpek et al., 2014).

For membrane permeability, 3 leaf discs, each 1 cm2 in size, were taken and passed through distilled water 3 times in glass tubes. After this process, 10 ml of water was added and shaken in closed vials at 25°C for 24 hours. Immediately afterwards, EC was measured (C1), the same samples were kept in an autoclave at 120°C for 20 minutes, then cooled down to 25°C and then EC was measured again (C2). Membrane permeability was determined by the following formula (Lutts et al., 1996).

Membrane Permeability = C1/C2×100

The leaf discs taken from the plants were weighed and their wet weight was determined, then they were kept in petri dishes filled with pure water in an airtight manner and weighed and their turgor weight was taken. Then, the leaf discs were kept in an oven at 72°C for 48 hours and their dry weight was weighed, and the relative water content was calculated according to the formula below (Kaya et al., 2003).

LRWC (%) = (WT-FW) / (WT-DW) ×100

LRWC = Leaf Relative Water Content

FW = Fresh Weight

DW = Dry Weight

WT = Weight in Turgor State

Gas exchange in the leaves was measured with the "Leaf Porometer" device from the middle part of the randomly selected leaves from the plants. These measurements were made during the drought phase and on the first day of the healing process (Kuşçu, 2006).

The present study used a completely randomized design, including three replicates per treatment and 5 plants per replicates. All data was subjected to one-way ANOVA. The Duncan's multiple range test was used to compare mean values at $p < 0.05$ by SPSS 23.0 software.

3. Results and Discussion

3.1. Results

Leaf area

With the effect of 15-day drought stress, there was almost no increase in the leaf area of the plants. The effects of drought stress on strawberry cultivars were found to be statistically significant. In 2016, the variety with the highest leaf area was Hilal77 and the lowest variety was Doruk77 in control, drought and recovery applications (Table 1.) In 2016, the highest leaf growth was in Eren77 during the drought and recovery period. Leaf area decreased between 0.97% and 3.28% compared to the control group in drought application. The highest decrease in leaf area occurred in Erenoğlu 77, the lowest decrease occurred in Ata77 cultivar.

The results of 2017 were generally similar to the results of 2016. This year, the most leaf area was determined in Hilal77 and the least in Doruk77 variety in control, drought and recovery applications (Table 1). During the drought and recovery period in 2017, the highest leaf growth occurred in Bolverim77 cultivar. Leaf area decreased between 2.33% and 4.25% in drought application compared to the control group. The highest decrease in leaf area occurred in Doruk 77, the lowest decrease occurred in Ata77 cultivar.

Table 1

Effects of drought stress on leaf area (cm^2) in strawberry cultivars

Cultivars	2016				2017			
	0. day	15. day control	15. day drought	7. day recovery	0. day	15. day control	15. day drought	7. day recovery
Doruk77	16.27 d	16.95 d	16.50 d	16.56 d	17.63 e	18.55 c	17.76 d	17.80 d
Dorukhan77	22.41 c	23.10 c	22.51 c	22.66 c	21.92 d	22.65 b	22.09 c	22.22 c
Hilal77	30.20 a	30.85 a	30.31 a	30.41 a	30.09 a	31.01 a	30.27 a	30.32 a
Bolverim77	27.58 b	28.65 b	27.97 b	28.05 b	28.75 bc	30.10 a	29.02 ab	29.20 ab
Eren77	27.43 b	28.30 b	27.82 b	27.95 b	27.57 c	29.21 a	27.82 b	27.88 b
Erenoğlu77	22.99 c	24.02 bc	23.23 c	23.33 c	23.06 d	24.12 b	23.23 c	23.27 c
Ata77	28.29 b	28.78 b	28.50 b	28.41 b	29.94 ab	30.90 a	30.18 a	30.27 a
LSD	1.90	4.81	1.94	1.87	1.90	3.99	1.91	1.93

*: There is no difference between the averages shown with the same letter in the same column

Plant fresh weight

At the end of the drought stress, there was a slight increase in plant fresh weight, and even a decrease in some cultivars. In the control application in 2016, the cultivars with the highest dry weight were Ata77 and Eren77, and the lowest cultivars were Doruk77 and Erenoğlu77. In drought application, the highest dry weight of the plant is Erenoğlu77 and the lowest is Doruk77. In the control application of 2017, the cultivars with the highest dry weight were found to be Ata77 and Eren77, and the lowest was Doruk77. In drought application, the highest dry weight of the plant is Erenoğlu77 and the lowest is Hilal77. In 2016, the highest decrease in plant fresh weights occurred in Bolverim 77, and the lowest decrease occurred in Erenoğlu 77 cultivar. In 2017, the highest decrease in plant fresh weights was detected in Eren 77, and the lowest decrease in Ata77 cultivar (Table 2).

Table 2
Effect of drought stress on plant fresh weight (g) in strawberry cultivars

Cultivars	2016			2017		
	0. day	15. day control	15. day drought	0. day	15. day control	15. day drought
Doruk77	39.35 d	44.25 e	42.11 g	35.99 d	40.12 d	37.57 f
Dorukhan77	45.16 c	54.23 d	51.74 f	38.15 bc	49.26 c	46.50 d
Hilal77	52.66 b	58.36 c	55.50 e	37.66 c	41.14 d	35.77 g
Bolverim77	51.67 b	68.53 a	61.16 b	39.67 b	55.24 b	49.04 b
Eren77	59.48 a	64.35 b	58.51 d	45.24 a	50.58 c	41.49 e
Erenoğlu77	40.20 d	63.87 b	61.83 a	31.93 e	60.05 a	52.10 a
Ata77	58.61 a	63.28 b	60.30 c	45.76 a	49.69 c	47.13 c
LSD	2.38	4.02	0.94	2.93	3.86	0.59

*: There is no difference between the averages shown with the same letter in the same column

Plant dry weight

It has been determined that the effects of drought stress differ according to the cultivars. In the control application in 2016, the highest dry weight of the plant was Doruk77 (19.53 g) and the lowest was Erenoğlu77 (13.32 g). In drought application, the highest dry weight of the plant is Ata77 (26.57 g), and the lowest is Eren77 (18.16 g). The highest decrease in plant dry weights was found in Doruk77, and the lowest decrease was in Eren77 cultivar. In the control application in 2017, the highest dry weight of the plant was determined as Doruk77 (21.68 g) and the lowest was Eren77 (13.77 g). In drought application, Erenoğlu77 (17.74 g) has the highest dry weight of the plant, and Hilal77 (13.65 g) has the lowest. The highest decrease in plant dry weights occurred in Eren 77, and the least decrease occurred in Dorukhan 77 cultivar (Table 3).

Table 3
Effect of drought stress on plant dry weight (g) in strawberry cultivars

Cultivars	2016			2017		
	0. day	15. day control	15. day drought	0. day	15. day control	15. day drought
Doruk77	19.53 a	27.56 b	25.34 b	21.68 a	23.52 a	17.35 ab
Dorukhan77	16.66 bc	28.45 ab	25.64 b	19.35 b	24.66 a	15.70 c
Hilal77	14.97 cd	23.45 d	20.17 e	14.39 d	17.10 c	13.65 e
Bolverim77	15.85 bc	26.89 bc	22.61 c	16.83 c	19.51 b	17.05 b
Eren77	16.99 b	23.44 d	18.16 f	13.77 d	16.53 c	14.46 d
Erenoğlu77	13.32 d	24.61 cd	21.36 d	13.87 d	20.30 b	17.74 a
Ata77	16.61 bc	29.47 a	26.57 a	17.50 bc	20.46 b	16.99 b
LSD	2.70	2.95	0.74	3.00	3.11	0.85

*: There is no difference between the averages shown with the same letter in the same column

Root fresh weight

Significant differences were determined in root fresh and dry weights of cultivars according to the applications (Table 4). In 2016, root wet weight was 15.30 g (Doruk77) and 23.71 g (Ata77); In drought application, it was found between 18.92 g (Doruk77) and 23.35 g (Hilal77). Root wet weights decreased between 18.90% and 8.10% compared to the control group in drought application. The highest decrease in root fresh weight was found in Hilal77, and the lowest decrease was found in Doruk77 cultivar. In 2017, root wet weight was 9.63 g (Doruk77) and 18.31 g (Hilal77); in drought application, it is between 12.33 g (Doruk77) and 17.01 g (Bolverim77). The highest decrease in root fresh weights was detected in Erenoğlu77, the lowest decrease in Eren77 cultivar (Table 4).

Table 4
The effect of drought stress on root fresh weight (g) in strawberry cultivars.

Cultivars	2016			2017		
	0. day	15. day control	15. day drought	0. day	15. day control	15. day drought
Doruk77	15.30 e	23.33 d	18.92 e	9.63 d	14.22 d	12.33 d
Dorukhan77	19.35 d	24.16 cd	21.87 d	12.61 c	17.40 c	15.06 c
Hilal77	20.68 c	25.41 bc	23.35 a	18.31 a	20.00 ab	16.21 ab
Bolverim77	19.91 cd	26.85 ab	22.62 bc	17.08 a	20.36 a	17.01 a
Eren77	22.66 b	27.45 a	22.88 ab	14.85 b	18.24 bc	14.96 c
Erenoğlu77	21.79 b	23.63 d	21.68 d	12.33 c	14.03 d	13.32 d
Ata77	23.71 a	25.10 bc	22.10 cd	12.47 c	17.09 c	15.41 bc
LSD	1.27	2.29	1.03	2.07	2.83	1.62

*: There is no difference between the averages shown with the same letter in the same column

Root dry weight

Significant differences were determined in root dry weights of cultivars according to the applications. In 2016, root dry weight was 5.86 g (Ata77) and 7.80 g (Dorukhan77); In drought application, it was found between 6.40 g (Erenoğlu77) and 8.75 g (Doruk77). In 2017, the root dry weight was 3.03 g (Eren77) and 5.96 g (Hilal77); in drought application, it is between 5.24 g (Ata77) and 7.42 g (Dorukhan77). In 2016, the highest decrease in root dry weights was Doruk77, the lowest decrease was Erenoğlu77; In 2017, the highest decrease occurred in Bolverim77, the lowest decrease occurred in Eren77 variety (Table 5).

Table 5
Effect of drought stress on root dry weight (g) in strawberry cultivars

Cultivars	2016			2017		
	0. day	15. day control	15. day drought	0. day	15. day control	15. day drought
Doruk77	7.30 ab	9.10 ab	8.75 a	4.35 bc	8.11 ab	7.30 a
Dorukhan77	7.80 a	9.24 ab	8.70 a	4.73 b	8.19 a	7.42 a
Hilal77	6.40 cd	9.04 a	8.46 ab	5.96 a	7.33 abc	6.45 b
Bolverim77	7.16 b	8.86 ab	8.29 bc	3.77 cd	7.19 c	6.71 b
Eren77	6.41 cd	8.75 ab	7.98 cd	3.03 d	6.46 abc	5.47 c
Erenoğlu77	6.78 bc	7.50 b	6.40 e	3.74 cd	6.23 bc	5.52 c
Ata77	5.86 d	8.36 ab	7.65 d	4.44 bc	6.14 c	5.24 c
LSD	0.80	3.05	0.54	1.19	2.95	0.74

*: There is no difference between the averages shown with the same letter in the same column

Membrane permeability

The results of membrane permeability in leaf samples of strawberry cultivars are given in Table 6. As the level of drought severity increases, it is seen that membrane damage increases with the increase in membrane permeability percentages. According to the data of 2016, the membrane damage differed in the cultivars, and the least damage occurred in Doruk77 (71.46%) and Ata77 (91.32%) the most in the drought period. In the recovery period, the least damage was detected in Doruk77 (35.73%), and the most in Ata77 (44.58%). The highest increase in membrane permeability occurred in Doruk77, the lowest increase in Hilal 77 variety. In 2017, the least damage occurred in Doruk77 (61.67%) variety, followed by Dorukhan77 (62.57%), and Ata77 (82.14%) variety was the most damaged. During the recovery period, the least damage was determined in Doruk77 with 22.07% and the highest damage was determined in Ata77 with 30.98%. The highest increase in membrane permeability was determined in Doruk 77, the lowest increase in Hilal 77 variety (Table 6)

Table 6
Effect of drought stress on membrane permeability (%) in strawberry cultivars

Cultivars	2016				2017			
	0. day	15. day control	15. day drought	7. day recovery	0. day	15. day control	15. day drought	7. day recovery
Doruk77	17.71 ab	21.10 a	71.46 e	35.73 d	17.52 cd	23.60 a	61.67 e	22.07 d
Dorukhan77	16.64 bc	18.36 bc	73.70 e	37.07 c	20.09 a	22.00 ab	62.57 e	27.48 bc
Hilal77	15.71 c	16.70 c	82.45 d	41.39 b	16.13 e	18.00 c	72.77 d	26.29 bc
Bolverim77	16.61 bc	18.00 bc	83.54 cd	41.83 b	17.92 bc	19.30 bc	73.54 cd	27.94 b
Eren77	17.75 ab	18.24 bc	84.91 c	42.43 b	16.50 de	18.45 bc	75.26 bc	26.00 c
Erenoğlu77	17.64 ab	18.35 bc	87.17 b	43.84 a	19.08 ab	19.87 bc	76.06 b	30.25 a
Ata77	18.10 a	19.14 ab	91.32 a	44.58 a	18.57 bc	20.35 abc	82.14 a	30.98 a
LSD	1.74	3.29	2.10	1.84	1.80	4.98	2.76	2.69

*: There is no difference between the averages shown with the same letter in the same column

Leaf relative water content

As a result of leaf relative water content measurements, it was found that the applications were statistically significant. In 2016, the highest LRWC value was observed in the cultivar Doruk77 (81.88%), followed by Dorukhan77 (80.40%), and the lowest value was determined in the cultivar Bolverim77 (78.27%). During the drought period, LRWC Doruk77 (68.77%) was the highest and the lowest was found in Ata77 (52.48%). Similarly, the highest LRWC Doruk77 (88.24%) and the lowest Ata77 (71.82%) variety were found during the recovery period. The highest decrease in leaf relative water content was determined in Doruk77, and the lowest decrease in Ata77 cultivar. In 2017, the highest LRWC Dorukhan77 (93.19%) was found in the control, and the lowest was found in Hilal77 variety. At the end of the 15-day drought application, the highest LRWC was found in Dorukhan77 variety, while the lowest value was determined in Ata77. In the recovery period after the drought, the highest value was again found in Dorukhan77 and the lowest in Ata77. The highest decrease in leaf relative water content was determined in Doruk77, and the lowest decrease in Ata77 (Table 7).

Table 7
Effect of drought stress on leaf relative water content (LRWC) (%) in strawberry cultivars

Cultivars	2016				2017			
	0. day	15. day control	15. day drought	7. day recovery	0. day	15. day control	15. day drought	7. day recovery
Doruk77	81.88 a	80.14 abc	68.77 a	88.24 a	86.85 b	80.36 c	74.19 a	87.17 b
Dorukhan77	80.40 b	82.65 a	62.66 b	83.50 b	93.19 a	90.01 a	74.20 a	96.48 a
Hilal77	78.53 de	79.63 d	60.39 c	75.28 c	74.58 d	75.10 d	58.40 bc	74.93 de
Bolverim77	78.27 e	80.00 abc	57.86 d	75.50 c	82.52 c	83.25 b	60.32 b	77.69 cd
Eren77	79.54 c	81.74 ab	57.48 d	73.41 d	84.62 bc	84.00 b	56.19 c	84.29 b
Erenoğlu77	78.69 de	79.96 cd	56.09 e	74.00 d	84.85 bc	85.63 b	57.22 c	78.21 c
Ata77	79.11 cd	81.38 ab	52.48 f	71.82 e	85.04 bc	84.52 b	50.50 d	72.65 e
LSD	1.06	2.92	0.83	1.11	4.51	2.91	3.45	4.51

*: There is no difference between the averages shown with the same letter in the same column

Stomatal conductivity

Drought application caused great decreases in stomatal conductivity in strawberry cultivars. While the highest decreases were found in Hilal77, Bolverim77, Eren77, Erenoğlu77 and Ata cultivars compared to control in 2016, the decreases were less in Doruk77 and Dorukhan77 cultivars compared to other cultivars. However, during the recovery period, the stomatal conductivities of the plants increased again to the control level. The results of 2017 are largely similar to the results of 2016 (Table 8).

Table 8
Effects of drought stress on stomatal conductivity in strawberry cultivars.

Cultivars	2016				2017			
	0. day	15. day control	15. day drought	7. day recovery	0. day	15. day control	15. day drought	7. day recovery
Doruk77	358.37 a	365.00 a	116.63 a	373.67 a	355.86 a	358.14 a	106.49 a	368.33 a
Dorukhan77	345.70 b	348.30 bc	112.44 b	366.07 c	343.76 b	340.15 d	103.03 b	355.96 b
Hilal77	339.26 c	350.87 bc	37.63 d	358.83 d	338.06 c	340.15 d	16.73 cd	364.65 a
Bolverim77	348.93 b	351.36 abc	39.49 c	368.20 b	344.30 b	344.90 c	17.19 c	370.51 a
Eren77	340.20 c	341.25 c	39.18 c	366.23 bc	338.20 c	340.52 d	16.81 cd	365.76 a
Erenoğlu77	328.43 d	328.70 d	38.97 cd	366.47 bc	325.43 d	328.40 e	16.07 d	367.50 a
Ata77	359.10 a	362.13 ab	23.34 e	353.90 e	356.83 a	350.36 b	10.77 e	351.36 b
LSD	4.98	2.45	2.05	2.79	5.61	2.98	1.40	9.62

*: There is no difference between the averages shown with the same letter in the same column

SPAD value

In 2016 and 2017, the SPAD value in strawberry leaves decreased a little as a result of drought application, but returned to the control level during the recovery period. Although the SPAD values of the cultivars are very close to each other, the highest values were determined in Eren77 cultivar in all periods (Table 9).

Table 9
Effect of drought stress on SPAD value in strawberry cultivars

Cultivars	2016				2017			
	0. day	15. day control	15. day drought	7. day recovery	0. day	15. day control	15. day drought	7. day recovery
Doruk77	55.06 bc	58.65 a	53.87 b	55.38 bc	55.00 cd	56.31 bc	52.94 bc	54.85 bc
Dorukhan77	55.73 abc	54.65 bc	54.88 ab	55.94 abc	54.58 cd	54.23 c	52.77 bc	54.49 bc
Hilal77	53.36 c	55.32 bc	53.16 b	53.44 c	55.03 bcd	56.85 ab	50.55 c	54.43 bc
Bolverim77	56.03 ab	55.52 bc	54.71 ab	56.16 ab	56.93 abc	55.36 bc	55.96 a	56.71 ab
Eren77	57.93 a	57.62 a	56.53 a	58.02 a	58.22 a	58.63 a	56.07 a	57.90 a
Erenoğlu77	56.80 ab	56.89 ab	55.32 ab	56.79 ab	57.43 ab	58.41 a	55.01 ab	57.18 a
Ata77	54.70 bc	54.20 c	53.11 b	54.53 bc	54.18 d	55.36 bc	53.54 ab	54.28 c
LSD	3.55	3.02	3.40	3.56	3.40	2.68	3.61	3.23

*: There is no difference between the averages shown with the same letter in the same column

Discussion

Drought; It occurs when the usable water in the soil decreases in plants and water is lost by transpiration or evaporation due to atmospheric conditions (Jaleel et al., 2009). Drought stress is one of the most important stresses affecting plant growth and yield, and it affects many physiological, biochemical and molecular properties in plants (Özfidan, 2010). Therefore, understanding the physiological and biochemical responses of plants in resistance to drought stress will be useful in identifying species and varieties that are resistant to drought conditions. In this context, in our study on newly bred strawberry cultivars, it was determined that the responses of cultivars to drought stress differ. During the 15 days of drought stress, the leaf area of the plants hardly increased. Reduction in leaf area due to drought also reduces dry matter production as it reduces plant fresh weight and photosynthesis activity due to sunlight intake (Sayyari and Ghanbari, 2012). In addition, dry matter accumulation in drought-stressed plants may result from changes in carbon and nitrogen metabolism as a result of aging and dying of leaves (Bertamini et al., 2006). Many plants provide resistance to dry conditions by accelerating the aging and shedding of their old leaves. This process is known as "leaf area arrangement" (Mahajan and Tuteja, 2005). In studies on the subject, Nigues and Baker (2000), olive, lavender and rosemary; Boutraa et al., (2010) in wheat; İpek (2015) on Myrobolan and Garnem rootstocks; Klamkowski and Treder (2008) determined that the leaf area decreased with drought stress in strawberry. The decrease in leaf area in the plant under drought stress is associated with the slowdown of photosynthesis. This slowdown in photosynthesis is due to chlorophyll content, water intake and insufficient nitrogen content. Nair et al., (2009) found a decrease in leaf area, water use efficiency, net assimilation rate and transpiration rate in okra with drought stress.

It was determined that plant fresh and dry weights of strawberry plants decreased under drought stress, while there was a slight increase in root fresh and dry weights. Leaf growth is more susceptible to drought stress than root development. The reduction in leaf expansion is beneficial for plants in water-deficient conditions. Because the decrease in the growth of leaf area increases the root development and volume by carrying the excess of energy and carbohydrates required for growth to the roots (Taiz and Zeiger, 2008). While water stress causes a decrease in growth due to the inability to supply the water required for cell division and growth, deficiencies in carbon and nitrogen metabolism also cause decreases in the fresh and dry weights of plants (Kluge, 1976; Bertamini et al., 2006). Our results, Rahman et al., (2002) tomato, Sivritepe et al., (2008) Gisela 5 cherry rootstock, Abbaspour et al., (2012) Pistachio, Karimi et al., (2012) on almond, Bolat et al., (2014) on apple and pear, and İpek (2015) on Myrobolan and Garnem rootstocks.

The maintenance of cell structure under stress conditions depends on the properties of membrane proteins and the structure of lipid compounds. Oxidative stress usually causes cell damage due to the deterioration in the structure of membrane proteins and lipids, depending on the concentration of active oxygen derivatives. For this reason, cell damage occurs at lower levels in genotypes that operate enzyme activities or perform osmotic regulation (Kuşvuran, 2010). In our study, drought stress caused significant increases in cell membrane permeability. These results are similar to the data obtained by Karimi et al., (2012) on 5 almond cultivars and GF 677 rootstock, Patel et al., (2011) on chickpea and İpek (2015) on Myrobolan and Garnem rootstocks in vitro conditions.

Decreased root activities in plants in arid conditions, resulting in the roots not getting enough water, decreases the water content of the leaves (Taiz and Zeiger, 2008). The water content of plants provides the protection of turgor and the uptake of mineral substances from the soil. When the relative water content decreases, the plant cells shrink by losing their turgor and try to control the preservation of cell volume by activating the protective mechanisms of the osmotic balance (Çırak and Esendal, 2006). In our study, it was determined that drought application decreased YOSI values and stomatal conductivity. Similar results were obtained in studies on the subject. Rahman et al., (2002) determined that there was a decrease in the relative water content of the leaves when the duration of water stress was prolonged in 2 tomato cultivars. Larbi and Mekliche (2004) determined that the relative water content of leaves decreased in two wheat cultivars under drought conditions. Ghaderi and Siosemardeh (2011) examined the effects of different irrigation regimes on two strawberry cultivars and found the highest leaf proportional water content in the control group.

In our study, some decreases were observed in chlorophyll content under drought stress in all cultivars. Water is one of the most important substances for chlorophyll synthesis, leaf water content must be high to maintain the maximum amount of chlorophyll (Goss, 1973). Efeoğlu (2009) determined in his study that the total amount of chlorophyll in the leaves of the corn plant under drought stress decreased, and the amount of chlorophyll increased with re-irrigation. Chlorophyll is one of the main pigments in the plant and a decrease in its concentration causes chlorosis, a decrease in growth and yield. Plants under stress give similar responses in terms of chlorophyll breakdown. Alisadeh et al. (2011) found that in apples and Zanjani et al (2012) in zucchini there was a decrease in the amount of chlorophyll with drought stress.

In the research that lasted for two years, the results related to the properties examined in general showed parallel. Differences between years in terms of some characteristics may be the result of climatic differences between years in uncontrolled greenhouse conditions.

4. Conclusions

Factors that inhibit plant growth are called stress. Stress caused by drought, salinity, high and low temperatures, and heavy metals are common in many agricultural parts of the world. In recent years, with the effect of global warming, the importance of water has started to be felt more and more with agricultural drought. Plants develop tolerance mechanisms to adapt to environmental conditions in the nature of physiological, biochemical and molecular responses to drought stress (İpek, 2105). All strawberry cultivars used in our study were affected by drought, but some cultivars were less affected than others. Doruk77 and Dorukhan77 cultivars were found to be superior to other cultivars in terms of both drought resistance and post-drought recovery. The high drought tolerance of these cultivars may depend on genetic characteristics. As a matter of fact, the parents of both varieties are the same (Tufts X Cruz). With the application of drought, leaf growth, decrease in LRWC and SPAD values in varieties; Membrane permeability and stomatal conductivity increased.

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An Economic Analysis of Plums Production: The Case of Gradacac, Bosnia And Herzegovina

Sumedina SPAHIC-VUKOJEVIC[1], Mithat DIREK[1]

[1]Selcuk University, Faculty of Agriculture, Department of Agricultural Economics, Konya, Turkey

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ABSTRACT

The production of plums has an important economic significance in BiH. By this product, Bosna Hersek is recognizable for a long time, since significant quantities of fresh and dried plum, besides for supply of domestic market, have been exported to the European and Global market. Municipality of Gradacac has a significant role in all of this, because takes the first place in the production of plums in BiH. This study investigates the economics of production of Plums in Gradacac. For this purpose, primary data were collected from plums farmers using a (multistage random sampling technique / stratified randomly sampling technique/simple random sampling technique). Date were analysed using economic analysis and descriptive statistical techniques. Results show that, the capital structure of the enterprises surveyed in the research area was classified according to their functions and the average active capital of the enterprises was calculated as 284.125,49 KM (Average 1$=1,67 KM in 2017). 91,76% of this is the farm capital and 8,44% is the fixed enterprise capital. The average of gross production value realized at the surveyed farms is 17366,41 KM, of which the value of the cattle production belongs to 19,75 %, while the plum's production value is 80,25 %.

1. Introduction

Plums are unusual in being independently domesticated on three different continents – Europe, Asia and North America. Most plums in commercial productions today are classified as European (hexaploid) or Japanese (diploid) types (Hui 2006).

Plum is orchard's culture that grows the most at the area of B&H. The production has based on a selection of Čačak's cultivation program and cultivator Stenley, with the gradual introduction of German's cultivators by the modernization of plum's production. Given that the biggest problem in the plum production is viral disease known as "šarka", more and more varieties are being introduced in production with a recommendation of resistance or tolerance to the same one (Kurtovic et al 2013).

The plum's production enables entry into new markets, by increasing employment and the degree of capacity use in the agriculture and the food industry, which encourages the development of entrepreneurship and the national economy (Prodanovic 2015). Therefore, it is important to emphasize the development of fruit's production and the application of modern technologies to achieve better economic effects (Blagojević and Božić 2012).

* Corresponding author email:*sumedina.spahic@hotmail.com*

Therefore, plum in Bosnia and Herzegovina takes the first place per sown areas and production. However, the low level of technics and technology in production of plum has reflected in relatively small and unstable yields per tree, as well as oscillations in annual production. There is a large number of old (oronulative) trees, as well as plum's trees, which have raised on inadequate land due to irregular yieldedness and poor productivity. The present production could be achieved from smaller surfaces than currently is case, thus releasing the surfaces for other cultures. The largest part of the produced plum in Bosnia and Herzegovina has exported. A large amount of produced plum goes to plum's brandy while the remaining has processed into dry plum and plum's jam.

The average annual production of plum in Bosnia and Herzegovina for the period 2008-2017 year was 133.887,60 tons. Production of plum varied over the years, with the highest number being recorded in 2013 year of 226.898 tones, and the lowest in 2014 year was 74,075 tones. Production in the last observed year (2017) was 74.398 tons, which is 84.181 tons lowest than in 2016 year when it amounted to 131.579 tons.

Due to favourable climatic conditions, Bosnia and Herzegovina belongs to the top of the European countries. Such climatic conditions are suitable for the cultivation of various fruit crops. This allows an export of a significant part of the total country's production of fruits to the European countries. The increase in export of the plum, results in an increase in income, for a country that is specialized in this type of production. The plum production has increased in the world as same as in our neighboring countries. Due to this fact, it is necessary to specialize our production of plum in order to be competitive with the other countries.

Gradacac is a traditional fruit-growing region. Thanks to the favorable agropedological properties of agricultural land and favorable climatic conditions, the Municipality of Gradačac takes the lead in the agricultural production of the Tuzla Canton, especially in the field of fruit growing (fruit production) (Spahic 2011).

Gradacac according to Kepen's climatic classification, belongs into the C climate zone (moderately warm and moody climate). Therefore, Gradacac has a moderate continental climate (Custovic 2013). According to the economic importance, production of plum, take the first place, among all fruit production. Plum (Prunus domestica) belongs to the Rose family (Rosaceae) and to the genus Prunus, which includes all stone fruit. Among all stone fruits which are growing in the area of Gradacac municipality, plum is the most important and the most demand fruit crop, therefore for the production of this culture, it gives a special importance (Kurtovic et al 2008).

The truth is that we are a country which, due to a poor agricultural structure, is not able to produce a large amount of plum, and in this way, surely we cannot be competitive with developed countries, where plum is produced on much larger agricultural plots. Therefore, quality is our best means, how to become competitive with the countries where plums are produced in much larger quantities. Plum production in the area of Gradacac municipality is characterized by a number of specificities. First of all, the initial investments were quite high, the capital flow was pretty slow, and therefore, the high of yields initially were not satisfactory. Due to the hard work of efforts of farmers, plum production has an intense character. However, due to inadequate political structure and unfinished adequate strategies for this fruit crop, we cannot say that the producers of plums in this area provide regular and high yields, and continuous quality of the plum which could result in a significant profit.

2. Materials and Methods

In order to realize the goals of this work in an adequate manner, appropriate methods will have to be applied, both for the collection of data and also for their processing. The methods that will be used in the preparation of this research are: survey method, method of interviewing and statistical method.

For the area of research, it was selected the Municipality of Gradacac. Gradadac area has been selected due to the purpose of sampling, according to the fact that this area constitutes 48.57% of the total plum production, easy transportation and limited financial funds. Sampling is the process of selecting of subset of individuals from the community, or sampling is the process of selecting single individual of the basic set. (Oğuz and Karakayacı, 2017).

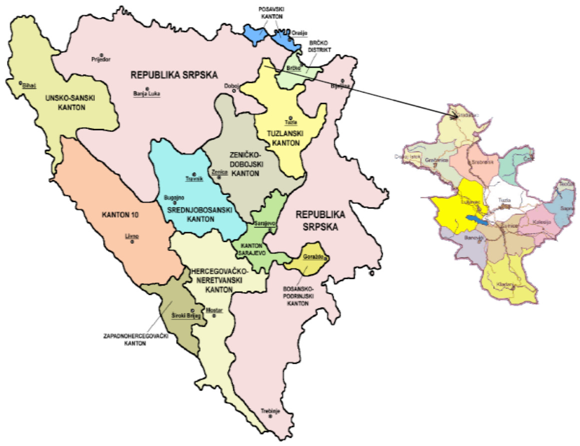

Figure 1
Administrative division of Bosnia and Herzegovina

Based on the results of the interviews in the Gradacac Municipality, it was determined that there is no definitive information regarding on the percentage of plum producers, and the information obtained from the authorities indicated that this rate was half. According to a simple random sampling method, the number of samples, which should be taken is calculated using the following formula. The formula used for this purpose is given below (Güneş and Arıkan 1988).

$$n=\frac{N(pq)}{(N-1)D^2+(pq)}$$

In this formula:

n: sample volume

d: allowable margin of error (accepted margin of error 10%)

t: The table value that corresponds to a 95% confidence level.

p - the ratio of the unit studied in the population to 0.50.

q - refers to the probability of occurrence of the incident (q = 1-p).

According to this study, a survey was conducted with a total of 65 plum producers.

2.1. Method used in socio-economic analysis of an enterprises

As the examined enterprises were taken as a whole, the distribution of capital according to their functions was applied (Açıl and Demirci 1984).

2.1.1. Elements of active and passive capital

Capital in agricultural farms is classified according to different criteria. The classification of capital according to liquidity is more appropriate for the analysis of capital (Erkuş et al 1995). In this study, the following classification is used according to the liquidity of capital.

I. Active capital

A. Agricultural capital

- land capital
- land melioration capital
- construction capital
- plant capital
- hunting and fishing capital

B. Capital of economy

1. Capital of permanent funds

- equity capital
- capital of tools and machines

Capital of working assets

- material capital
- money capital

II. Passive capital

- Foreign capital (debts)
- In the form of legal rights and short-term divisions

2.2. Socio-economic indicators

In the economic analysis of plums in the Gradacac region, the following methods were used.

2.2.1. Gross production value (GPV)

Gross production value, also called the gross value of production, the total value of production was realized in the accounting period (Çetin 2003). The value of agricultural products, produced on the farm, the value of plant and animal production estimated at farm prices, results in the total gross production value on the farm (Oğuz and Bayramoğlu 2018).

2.2.2. The total cost

The total costs examined for agricultural activities in the enterprises, will be calculated separately as variable and fixed costs (Oğuz and Bayramoğlu 2015).

Total Cost = Variable cost + Fixed cost

2.2.3. Pure profit

After the costs are found, the total costs from Gross revenue, the remaining part is called the interest of the active capital. Total production costs will be deducted from Gross revenue and the pure profit will be found (Çetin 2003).

Pure profit = Gross revenue – Total Cost

2.2.4. Gross profit

Gross profit is calculated by subtracting variable costs from gross production value. Gross profit is considered as an important measure for proving the competitiveness and success of the production activity (Erkuş et al 1995).

Gross profit = Gross production value – Variable costs

2.2.5. Agricultural income

Agricultural income is called the success criterion of the enterprises. The following equations are used in the calculation of agricultural income.

Agricultural income = Pur Profit – (Debt interest + Rents) + Family Labor Force Fee Return

2.2.6. Family Income

Income earned during the year by family members and agricultural producers. It covers the incomes both in and out of the enterprise and the non-agricultural income.

2.2.7. The financial and economic profitability of the enterprises surveyed

a) Rentability factor

The total income of the enterprise is Gross revenue and the income of capital is pure profit, the relation between these two measures is a factor of profitability (Oğuz and Bayramoğlu 2015).

Rantability factor (RF) = Pure Profit / Gross revenue

b) Economic rantability

It is calculated in order to measure the profitability of the enterprise. The total capital of the enterprise (active capital) and the resulting pure profit are proportioned.

*Economic Rantability = Pure Profit / Total Farms Capital*100*

c) Capital turnover rate

Another criterion of success that can be used to measure the success of a company (Oğuz and Bayramoğlu 2018).

*Capital turnover rate = The gross production value/Total farm capital*100*

3. Results and Discussion

The municipality of Gradacac is a suitable area for fruit production, especially when it comes to plum because it has high-quality resources (land, water, air) and experienced producers. The economy of plum's production has determined by many factors, and essential are as follow: choice of sorts, locations, application of agro and biotechnical measures, production costs and market prices.

3.1. Capital Structure in the farms

In agricultural enterprises, capital helps net revenues increase directly (Oğuz and Yener 2017). Active capital is classified as farm capital and enterprise capital. Farm capital consists of land, land improvement, building, plant, hunting and fish capital. The enterprise capital is divided into two groups as fixed enterprise capital and revolving enterprise capital. Fixed enterprise capital consists of livestock capital, tool and machine capital; and the revolving capital consists of material capital and money capital (Oğuz and Bayramoğlu, 2015)

The following table presents distribution (KM) and ratios (%) of active capital in the surveyed farms. The value of total active capital according to the size of the farm is different. 284125.49 KM of active capital has been identified per farms. 91.76 % of this is the farm capital and 8.44 % is the fixed enterprise capital. As the enterprise increases, active capital per enterprise increases. The highest value of total active capital is in the group of farms of 30 decare and more and amounted to 623995.63 KM, in the group of farms of 11-30 decare, the total value of capital was 297731.64 KM, while on farms 0-10 dunums 168305.28 KM.

Table 1
Distribution (KM) and ratios (%) of active capital in the surveyed farms

Capital groups		Farm Size Groups (da)						Average	
		0-10		11-30		31+			
		KM	%	KM	%	KM	%	KM	%
Farms capital	Land capital	15881.00	10.28	50667.00	18.49	208750.00	36.98	55673.80	21.40
	LIC	266.66	0.17	1508.33	0.55	1125.00	0.20	945.38	0.36
	Building capital	105574.08	68.31	130796.67	47.73	168287.50	29.81	124933.85	48.02
	Plant capital	32824.61	21.24	91061.30	33.23	186401.88	33.02	78604.90	30.21
	Total	154546.35	100.00 91.83	274033.30	100.00 92.04	564564.38	100.00 90.48	260157.93	100.00 91.76
Fixed enterprises capital	Livestock capital	3555.23	25.84	5798.34	24.47	7337.50	12.35	5056.02	21.10
	TM	10203.70	74.16	17900.00	75.53	52093.75	87.65	18911.54	78.90
	Total	1375893	100.00 8.17	23698.34	100.00 7.96	59431.25	100.00 9.52	23967.56	100.00 8.44
Total active capital		168305.28	100.00	297731.64	100.00	623995.63	100.00	284125.49	100.00

LIC: Land improve capital, TM: Tools machines, Resources; Calculated by the author according to research results.

As can be seen in the table, the share of the farm capital in the active capital is much more than the share that should be in a normal enterprise. Besides, the rates of plant, land improvement, livestock capital are very low. This formation of active capital is considered as a situation that affects business success negatively (Erkuş 1979). 91.76 % of the active capital in the enterprises surveyed is farm capital, 8.44 % is fixed enterprise capital. The largest share of active capital is obtained from building (43.97%). This is followed by plant capital (27.67 %), land capital (19.59%) and tool and machine capital (6.66 %).

3.2. Gross production value (GPV)

Under the term value of the stone fruit it is considered the market value of the products obtained. It is obtained by multiplying the amount of realized yields with the market price.

From the table, it can be stated that the average of gross production value of plum's at the surveyed farms is 13812.65 KM. As the size of plum's production has increased, the value of production is increasing.

The following table shows the gross production value of plum's at the surveyed farms by type of sales.

Table 2
Gross production value (GPV) of plum's

Farm Size Groups (da)	GPV (KM)
0-10	5853.34
11-30	14386.07
31+	38525.00
Average	13812.65

Table 3
Gross production value (GPV) of plum by type of sales at the surveyed farms

Farm Size Groups	Plum's production						Total
	Fresh plum	%	Dry plum	%	Brandy	%	
0-10	5707.04	97.50	74.07	1.27	72.22	1.23	5853.34
11-30	13116.07	91.17	833.33	5.79	436.67	3.04	14386.07
31+	38150.00	99.03	0.00	-	375.00	0.97	38525.00
Average	13119.57		415.38		277.69		13812.65
%	94.98		3.01		2.01		100.00

From the data in the table it can be stated that the largest quantity of plums at the surveyed farms sells in the fresh state (94.98%), dry plum has sold in very small quantities of only 3.01% while a small part of the plum has processed and sold in plum's brandy 2.01%.

The following table shows the gross production value of total production of plum at the surveyed farms.

Table 4
Gross production value (GPV) of total production of plum at the surveyed farms

Farm Size Groups	The gross production value of total production of plum (KM)		
	Sales Value	GPV of plums, which is consumed by the family and workers	Total
0-10	5853.34	129.63	5982.97
11-30	14386.07	150.60	14536.67
31+	38525.00	0.00	38525.00
Average	13812.65	123.35	13936.00
%	99.11	0.89	100.00

From the data in the table it can be estimated that the average of total gross production value produced by the examined farms was 13936.00 KM. In this study, \$1 = 1.67 Bosnia and Herzegovina convertible mark (BAM) calculated (approximately in October, 2017). 1 TRY = 0.44 Bosnia and Herzegovina convertible mark (BAM) calculated (approximately in October, 2017).

Thus, the highest value of produced slivers was achieved by selling 99.11%, while the value of the slurry was recovered and processed at the farm 0.89%. The following table shows the gross production value in livestock production achieved at the surveyed farms.

The following table shows the gross production value (GPV) achieved at the surveyed farms.

From the data in the Table 5, it can be seen that the average of gross production value realized at the surveyed farms is 17366.41 KM, of which the value of the cattle production belongs to 19.75 %, while the plum's production value is 80.25 %.

Table 5
Gross production value (GPV) realized at the surveyed farms

Farm Size Groups (da)	GPV-Livestock	GPV-Plum	Total GPV
0-10	2808.70	5982.97	8791.67
11-30	3238.21	14536.67	17774.88
31+	6249.38	38525.00	44774.38
Average	3430.40	13936.00	17366.41
%	19.75	80.25	100.00

3.3. Gross revenue

The following table shows the gross revenue by groups of the farm

Table 6
The gross revenue by groups of the farms (KM)

	Farm Size Groups							
	0-10		11-30		31+		Average	
	KM	%	KM	%	KM	%	KM	%
Gross production value	8791.67	73.52	17774.88	81.92	44774.38	89.87	17366.41	82.25
Housing rent	3167.22	26.48	3923.90	18.08	5048.63	10.13	3748.02	17.75
Gross revenue	11958.89	100.00	21698.78	100.00	49823.01	100.00	21114.42	100.00

It can be seen from the table that the value of the gross revenue per farms is 21114.42 KM.

3.4. Cost analysis on the farm

Cost analysis means testing the dynamics and structure of total cost of reproduction and their correlation with other categories or business results. Cost analysis is the basic and integral part of cost-effectiveness analysis. The purpose of cost analysis is to reveal the places and types of costs that can be reduced or avoided and thus achieve better results in the next business period (Gogic 2005).

The following table shows the average amount of total costs at the surveyed farms. From the table, it can be seen that the average amount of total costs are 17933.04 KM. In the enterprises surveyed, variable costs and fixed costs are estimated to be 7630.39 KM and 10302.65 KM, respectively. 44.22 % of total cost is variable costs and 55.78 % is due to fixed cost.

Table 7
Total cost

	Farm Size Groups (da)						Average	
	0-10		11-30		31+			
	KM	%	KM	%	KM	%	KM	%
Total Variable Cost	3150.54	35.93	7037.86	40.25	23434.20	55.78	7441.14	44.22
Total Fixed Cost	6117.54	64.07	11291.14	59.75	20720.58	44.22	10302.65	55.78
Total Cost	9268.08	100.00	18329.00	100.00	44154.78	100.00	17743.79	100.00

The following table shows a review of the total production cost.

14206.27 KM of total Production Cost is Intrest on active capital and 17743.79 KM is due to total cost (Table 8).

Table 8
The total production expenses

	Farm Size Groups (da)			Average
	0-10	11-30	31+	
	KM	KM	KM	KM
Interest on active capital	8415.26	14886.58	31199.78	14206.27
Total Cost	9268.08	18329.00	44154.78	17743.79
Total Production Cost	17683.34	33215.58	75354.56	31950.06

3.5. Pure profit

Pure profit in business analysis is defined as the best measure of success. (Oğuz and Bayramoğlu, 2018). The following table gives the determined indicators of the pure profit, i.e. the realized pure profit at the farms, and the average amount of pure profit.

From the Table 9, it can be seen that the average amount of pure profit is 3370.63 KM.

Table 9
Pure profit at the surveyed farms (KM)

	Farm Size Groups (da)							
	0-10		11-30		31+		Average	
	KM	%	KM	%	KM	%	KM	%
Gross revenue	11958.89	100.00	21698.78	100.00	49823.01	100.00	21114.42	100.00
Total Cost	9268.08	74.76	18329.00	77.72	44154.78	83.63	17743.79	78.80
Pure profit	2690.81	25.24	3369.78	22.28	5668.23	16.37	3370.63	21.20

3.6. Gross profit

Gross Profit is obtained by subtracting total variable costs from Gross Production Value (GPV) (Kıral et al 1999). The following table shows the gross profit at the surveyed farms. In the enterprises surveyed, enterprises-average gross profit was 9925.27 KM.

Table 10
Gross profit in the surveyed farms

	Farm Size Groups (da)							
	0-10		11-30		31-+		Average	
	KM	%	KM	%	KM	%	KM	%
GPV	8791.67	100.00	17774.88	100.00	44774.38	100.00	17366.41	100.00
Total variable costs	3150.54	35.84	7037.86	39.59	23434.20	52.34	7441.14	42.85
Gross profit	5641.13	64.16	10737.02	60.41	21340.18	47.66	9925.27	57.15

3.7. Agricultural income

Agricultural income is called a criterion of success of business (Oğuz and Bayramoğlu 2018). The table below shows the calculated agricultural income at the surveyed farms.

It can be seen from the table that the average profit realized at the surveyed farms is 5266.25 KM (Table 11).

Table 11
Agricultural profit in the surveyed farms

	Farm Size Groups (da)			Average
	0-10	11-30	31+	
Pure profit	2690.81	3369.78	5668.23	3370.63
Family Labor Force Fee Return	1069.44	2199.17	3545.63	1895.62
Agricultural income	3760.25	5568.95	9213.86	5266.25

3.8. Family income

The table below shows the calculated total family income. Thus, the total family profit per farm is 14696.51 KM.

Table 12
Total Family income

	Farm Size Groups (da)						Average	
	0-10		11-30		31+			
	KM	%	KM	%	KM	%	KM	%
Agricultural income	3760.25	30.15	5569.95	36.45	9213.86	46.04	5266.71	35.84
Non-agricultural income	8712.89	69.85	9709.63	63.55	10800.00	53.96	9429.80	64.16
Total Family income	12473.14	100.00	15279.58	100.00	20013.86	100.00	14696.51	100.00

3.9. Financial and Economical Profitability in the Surveyed farms

The profitability indicators determine the degree of economic efficiency of production, ie the effectiveness of invested production resources. The level of profitability shows how much of each invested 100 units of money earns pure profit or income (Ranogajec 2009).

Table 13
Rentability factor

	Farm Size Groups (da)			Average
	0-10	11-30	31+	
	KM	KM	KM	KM
Pure profit	2690.81	3369.78	5668.23	3370.63
Gross revenue	11958.89	21698.78	49823.01	21114.42
Rentability factor	22.50	15.53	11.38	15.96

Thus, the average renatability of production at farms is (15.96), which means that every 100 KM of production value has a profit of 15.96 KM. In the following table, has been given the economic rentability per groups of farms for 2017.

Table 14
Economic rentability (%)

	Farm Size Groups			Average
	0-10	11-30	31+	
Net profit	2690.81	3369.78	5668.23	3370.63
Total farm capital	168304.58	297806.64	623933.13	284160.57
Economic rentability	1.60	1.13	0.91	1.19

The average economy of the farms is 1.19 KM, which means that with each 1 KM the realized value of production was 1.19 KM.

The following table gives the capital turnover rate by farms.

Table 15
Capital turnover rate

	Farm groups			
	0-10	11-30	31+	Average
	KM	KM	KM	KM
The gross production value	8791.67	17774.88	44774.38	17366.41
Total farm capital	168304.58	297806.64	623933.13	284160.57
Capital turnover rate	5.22	5.97	7.18	6.11

The capital turnover rate is calculated within activity (efficiency) ratios. It is calculated by dividing the gross production value by the total enterprise capital. It demonstrates how effectively the enterprise assets can produce output. The higher the rate, the better. The capital turnover rate of dairy farming enterprises in the research area is 6.11 % in the average of the enterprises.

4. Conclusions

The capital structure of the enterprises surveyed in the research area was classified according to their functions and the average active capital of the enterprises was calculated as 284125.49 KM. 91.76% of this is the farm capital and 8.44% is the fixed enterprise capital.

One of the main factors of the production process is land. A land is a basic condition for performing agricultural production. The average value of the land capital is 55673.80 KM. The value of a dunum in the area of Gradacac municipality varies from location to location. So the production plots located near the suburban settlements have a fairly high price compared to plots located in rural areas.

The average of building capital at the surveyed farms is 124933.85 KM. The average value of plant capital at the surveyed farms is 78604.90 KM. The value of total active capital according to the size of the farm is different. 284125.49 KM of active capital has been identified per farms. 91.76% of this is the farm capital and 8.44% is the fixed enterprise capital. As can be seen in the table, the share of the farm capital in the active capital is much more than the share that should be in a normal enterprise. Besides, the rates of plant, land improvement, livestock capital are very low. The capital turnover rate, an important indicator in the success and comparison of the enterprises, is 6.11%.

The average of gross production value of plum’s at the surveyed farms is 13812.65 KM. that the largest quantity of plums at the surveyed farms sells in the fresh state (94.98%), dry plum has sold in very small quantities of only 3.01% while a small part of the plum has processed and sold in plum’s brandy 2.01%.

It`s necessary to know how to the plum, which is in the state of consumption, gives an added value, in which form should be sell to customers, how to find customers in order to finally achieve the mutual benefit. Without satisfied customers, i.e. consumers, successful production of the plum cannot be achieved. Therefore, it`s very important to develop a successful marketing strategy in order to achieve the efficiency and effectiveness of the production of this fruit crop. Since the consumer preferences, from the year to the year, are very fast change and that producers become more demanding when they buy a food, it is necessary to take a step forward and to consumers offer a new product, not just the one they are used to. Consequently, following the world trends in fruit production, producers could achieve very high success by offering consumers a value added product. Also, it`s known that the plum is a fruit crop which cannot store fresh on room temperature for a long time, unless it`s stored in cold storage for a shorter period of time. It`s necessary to process the plum and offer to consumer in some new shape, packing in order to production as well as consumption should be successful.

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Factors Affecting the Income of Farmers Participating In Traditional and Modern Livestock Markets: Case Study from Benin Republic

Oscar AKOUEGNONHOU[1,*], Nevin DEMİRBAŞ[2]

[1]Ege University, Institute of Science, Department of Agricultural Economics, İzmir, Turkey
[2]Ege University, Faculty of Agriculture, Department of Agricultural Economics, İzmir, Turkey

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ABSTRACT

Livestock markets in pastoral areas of Africa are institutions that facilitate the marketing of animals and animal products. The income of farmers participating in these livestock markets is influenced by various social and economic factors. These factors are generally not considered by farmers when making their decisions. Knowledge and control of these factors will enable farmers to make rational decisions in the production and sale of their animals, and thus improve their income. It is in this context that this study aimed to determine the factors affecting the income of rural households engaged in animal husbandry in the Republic of Benin. Livestock production system in Benin has been mostly traditional. However, the system has been gradually modernized. The farmers have marketed their livestock and livestock products in two types of self-managed livestock markets which are “Marché à Bétail Autogéré” (MBA) as modern market and “Marché à bétails Traditionnel (MT) as traditional livestock markets. The data of the research were obtained from face-to-face surveys conducted with 300 farmers in livestock markets. Multivariate regression model was used to analyze the factors affecting rural household income. Model results show that the variables of education level, experience in livestock farming, access to credit, number of cattle, number of sheep, pasture use, access to veterinary services, and membership to a livestock organization had a significant positive effect on the incomes of farmers preferring the MBA livestock market. While the variables of experience in livestock farming, number of cattle, pasture use, farmland ownership, and number of sheep had a significant positive effect on the incomes of farmers preferring the MT livestock market.

1. Introduction

The development of many African countries’ economy and life of the rural population in the south of the Sahara depends on the agricultural sector. Seventy to 80% of the active population was employed in the agricultural sector. The contribution of the agricultural sector to the Gross Domestic Product (GDP) of these countries ranged from 30% to 50%. The rural population in these countries has lived under low life standards and in economically unfavourable conditions (Diallo, 2004). In Benin Republic, economic activities were predominantly based on agriculture, and the agricultural sector contributes about 32.5% to GDP, 75% to exports, 15% to tax revenues and about 70% to employment (FAO, 2018). Agriculture is then seen as a sector with many potentials that should be seriously exploited to support national economic growth and thus contribute to the effective fight against poverty.

Livestock sub-sector occupies a significant place in agriculture and plays an important role in the economy of many African countries. Despite its traditional production system, it contributed 44% of the GDP of the Economic Community of West African States (ECOWAS) countries and ranked first in terms of trade in West Africa (Fabien, 2019).

The contribution of the livestock sub-sector to GDP of Benin was 5.82% and its share in the gross agricultural production value was 15.55% (FAO, 2016). It ranked second after crop production, and also contributes to agricultural services through fertilizer, traction and transport, especially in the cotton regions (ANOPER, 2014).

The animal species raised in Benin are conventional species (cattle, sheep, goats, pigs, poultry, etc.) as well as non-conventional species such as "Aulacode" (MAEP, 2001; ANOPER, 2014).

The animal production system is largely of the traditional nomadic and extensive type. This type of animal husbandry is based on the use of large areas, its main feature is the mobility of farmers and animals.

* Corresponding author email: *akbiggest@gmail.com*

This system is a way of effectively utilizing regional seasonal changes in feed and water resources, and these seasonal movements are sociologically important in some countries.

In West Africa countries, the poorest people depend on livestock as the main economic activity that provides them with food and cash. It is also the main insurance against risk for millions of poor people whose livelihoods depend on rain-fed agriculture. However, the region's potential for livestock production is poorly exploited (Roukayath, 2016; Fabien, 2019). Rural households do not fully benefit from the fruits of their activities and live on low incomes.

The income of the livestock farmers is mainly based on animal sale, which usually takes place in livestock markets. In the past, farmers in developing countries used to sell their animals in traditional markets when they need money in an emergency, but nowadays, most of them have moved into commercial production and also go to modern livestock markets. Some reasons for this change can be stated as improved animal prices and marketing margins in organized livestock markets, transaction flows in markets increase, etc. Animal markets constitute very important socio-economic units in the Sahara countries. Livestock markets in rural areas can ensure the economic development of regions, thus increasing the income of both the rural population and municipalities.

In Benin, farmers have marketed their livestock and livestock products in two types of self-managed livestock markets which are “Marché à Bétail Autogéré” (MBA) as modern market and “Marché à bétails Traditionnel (MT) as traditional livestock markets.

Considering the importance of animal husbandry in the rural economy and its contribution to the incomes of rural households, it is crucial to deepen the scientific research in this sector in order to increase the incomes of rural households and improve their living conditions. Indeed, the income level of rural communities is attributed to certain crucial factors, and understanding and controlling these factors may be the key to effective rural development policy formulation (Adebayo, 1985).

A closer look at the determinants of rural income would provide an in-depth knowledge into the factors that explain low income yield and poverty in rural regions (Olatona, 2007).

An overview of some studies showed that various factors affect the income of rural communities. Onibon, (2004) identified the farm distance to livestock market and the intermediaries between seller and buyer as factors affecting negatively the income of livestock households in Benin. Fadipe et al. (2014) found that the level of education of the household head, the farm size, the access to electricity and the gender of the household head are the major determinants of the rural household income in kwara state, Nigeria.

Household asset endowments, demographic factors, accessibility to rural towns, migration opportunities and perceptions on food security were found by Alobo and Bignebat, (2017) as the main determinants of the rural household income in Senegal and Kenya. Safa, (2005) examined the farmers' income to be influenced by education, land area, livestock ownership, family size, and coffee cultivation, but not by the age of the farmer in Yemen. Coetzee et al. (2005) found that poor market infra-structure, price variability, limited marketing support services and market information and credit services, absence of effective producer organizations at the grassroots and limited access to markets provide inad-equate opportunities for increased incomes of cattle keepers in the Eastern Cape Province of South Africa. Mabe et al. (2010) showed that the herd size, the number of female farmers involved in livestock enterprises and the educational level of the household head affect positively the farm income in livestock producing communities of North-West Province in South Africa. Ndiaye, (2017) examined the factors that influenced rural household income and found that the level of education of the household head, the fattening, the size of the cultivated area, as well as the cultivation of tomatoes and sweet potatoes, are the most important factors that determine household income in Senegal.

This study therefore provides a very useful insight into the various factors that affect the income of the livestock households in the Republic of Benin. This would be very useful for the farmers themselves and will draw the attention of policy makers to improve efficiently the right determinants of rural household income. The objective of this study was to determine the factors affecting the household income of farmers preferring MT and those preferring MBA and to compare the results of the two types of livestock markets.

2. Materials and Methods

The main material of this study was obtained from face-to-face surveys conducted with livestock farmers in MBA and MT livestock markets in the Republic of Benin. The number of animal farmers interviewed within the scope of the research was determined as 300. To better compare the results, the 300 livestock farmers surveyed were divided into two groups: 150 farmers who preferred the MBA livestock market and 150 farmers who preferred the MT livestock market. In the field, the full list of MBAs has been taken from the Department of Livestock Management of the Ministry of Agriculture. Six MBA were selected, based on the existence of at least two MT in the municipality where each MBA is located. These are MBA of Gogounou, Nikki, Bassila, Matéri, Savè and Iwoyé. The animal farmers surveyed were randomly selected in each livestock market. However, attention has been paid to the fact that they participate in only one of the two types of livestock markets of each municipality. Either MBA or MT.

The multivariate regression model was used to determine the factors affecting rural household income (Hartono et al., 2011; Hartono and Rohaeni, 2014;

Marwati et al., 2020). Rural household income is composed of farm income and off-farm income (Richard et al., 2016; Marwati et al., 2020).

The multivariate regression model is as follows:

$Y = \beta_o + \beta_1 X_1 + ... + \beta_n X_n + Ɛ$, (Şeref et al., 2016)

Y: Dependent variable

X_i: Independent variables

B_i: Parameters to forecast

Ɛ: Term of error

Table 1
Variables used in the model for MBA and MT livestock markets

Variables	Variable Description	Variable Type
Age	Age of the farm owner (years)	Continuous
Education level	Formal education period (years)	Continuous
Experience in livestock farming	Experience in raising animal (years)	Continuous
Access to credit	Farmer' access to credits (0: no, 1: yes)	Dummy
Number of cattle	Number of cattle owned (number)	Continuous
Number of sheep	Number of sheep owned (number)	Continuous
Pasture use	Use of grazing land (0: no, 1: yes)	Dummy
Access to veterinary services	Farmer's access to veterinary services (0: no, 1: yes)	Dummy
Membership to a livestock organization	Membership to a animal husbandry organization (0: no 1: yes)	Dummy
Number of family members	Number of individuals in the family (person)	Continuous
Distance to market	The farm distance to market (km)	Continuous
Agricultural land ownership	Agricultural lands owned by the famer (ha)	Continuous

$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + b_8X_8 + b_9X_9 + b_{10}X_{10} + e$

Y= Household income

X_1: Age

X_2: Education level

X_3: Experience in livestock farming

X_4: Access to credit

X_5: Number of cattle

X_6: Number of sheep

X_7: Pasture use

X_8: Access to veterinary services

X_9: Membership to a livestock organization

X_{10}: Number of family members

b_0: Intercept

b = 1, 2,…10: Regression coefficients associated with X_1, X_2, … X_{10}, respectively.

e: Term of error

The OLS is the estimation method used in the regression models created to determine the factors affecting the household income of livestock farmers preferring MBA and MT livestock markets.

The White test was used to detect the difference of variance problem in the model, and the Variance Inflation Factor (VIF) was used to detect the multicollinearity problem (Marwati et al., 2020). It has been found that there is no difference of variance and no multicollinearity problems in the multiple linear regression model selected.

3. Results and Discussion

General Characteristics of the Farms and Farmers in MBA and in MT Livestock Markets

Most of the farmers interviewed in this study (97.67%) in both markets were men and only 2.33% were women. Men are generally head of the households and owners of the herd; their sons are shepherds; their wife has the right to milk the herd and sell it. Of the farmers, 45.33% are between 41-60 years old, followed by those (43.34%) who are between 21-40 years old. The education level of the farmers is low. The largest group (76%) of the farmers in both markets had a primary education level. Farmers in MBA market had the highest education level. Most of the farmers have a farmland between 3-4 ha followed by those who have a farmland less or equal to 2 ha. The family size of 40% of the farmers is less than or equal to 3 members, followed by those (38.6%) who have a family size between 4-7 members. Of the farmers, 49.67% have more than 21 years of experience in livestock farming. Most of the farmers have been involved in animal husbandry since childhood (Table 2).

Livestock Farming System

Livestock farming system in Africa is mostly extensive (traditional). The intensive system is still not much developed. Most of the West African countries have a grazing system. Livestock production in Benin is conducted predominantly as family production system. It is applied with a minimum monetary investment. This livestock farming is currently evolving into a mixed crop-livestock system under the influence of cotton cultivation and the introduction of certain food products (Roukayath, 2016).

Factors Affecting the Household Income of Livestock Farmers

In the model for determining the factors affecting the rural household income, 10 variables for MBA livestock markets and 9 variables for MT livestock markets were considered as independent variables.

Table 2
Descriptive statisctics results for the livestocks farms

	MBA		MT		General			
	Number	%	Number	%	Number	%	$\chi2$	Sig
Gender								
Male	147	98.0	146	97.3	293	97.67	0.084	0.92
Female	3	2.0	4	2.7	7	2.33		
Total	150	100.0	150	100.0	300	100.0		
Age								
21-40	90	60.0	40	26.7	130	43.34	4.90	0.30
41-60	48	32.0	88	58.7	136	45.33		
>61	12	8.0	22	14.7	34	11.33		
Total	150	100.0	150	100.0	300	100.0		
Education (year)								
Uneducated (<1)	3	2	63	42	66	22	27.07	0.86
Primary school (1-6)	142	94.7	86	57.3	228	76		
College (7-10)	5	3.3	1	0.7	6	2		
Total	150	100.0	150	100.0	300	100		
Land size (ha)								
<2	63	42.0	18	12.0	81	27	11.56	0.24
3-4	60	40.0	30	20.0	90	30		
5-6	25	16.7	48	32.0	73	24.33		
>7	2	1.3	54	36.0	56	18.67		
Total	150	100.0	150	100.0	300	100		
Household Size								
≤3	94	62.7	26	17.3	120	40	8.30	0.22
4-7	44	29.3	72	48.0	116	38.67		
8-11	12	8.0	51	34.0	63	21		
≥12	-	-	1	0.7	1	0.33		
Total	150	100.0	150	100.0	300	100		
Experience (year)								
≤5	5	3.3	8	5.3	13	4.33	6.21	0.72
6-10	25	16.7	33	22.0	58	19.33		
11-20	41	27.3	39	26.0	80	26.67		
≥21	79	52.7	70	46.7	149	49.67		
Total	150	100.0	150	100.0	300	100		

The Self-Managed Livestock Market (MBA)

Based on the results of the multicollinearity test, it was found that there was no difference of variance (White Test: 0.994) and no multicollinearity problems in the model developed for determining the factors affecting the household income of livestock farmers preferring MBA livestock markets.

The VIF value in each variable is less than 10 and the tolerance value is greater than 0.10, then it can be said that the regression model is free from multicollinearity problems (Table 3).

Table 3
Multicollinearity Test Results

Variables	Tolerance	VIF
Constant		
Age	0.735	1.360
Education level	0.224	4.472
Experience in livestock farming	0.560	1.787
Access to credit	0.541	1.849
Number of cattle	0.749	1.335
Number of sheep	0.676	1.480
Pasture use	0.525	1.905
Access to veterinary services	0.748	1.336
Membership to a livestock organization	0.237	4.213
Number of family members	0.821	1.218

The F test was used to determine whether the independent variables in the model had a significant effect on the dependent variable simultaneously.

In Table 4, F and its signigicance were found as 107.964 and = 0.000, respectively. About ninety (0.901) percent of variance in the household income of the farmers can be explained by the explanatory variables included in the MBA model. The independent variables of age, education level, experience in livestock farming, access to credit, number of cattle, number of sheep, pasture use, access to veterinary services and membership to a livestock organization have statistically significant positive impact on the household income of the farmers preferring the MBA livestock markets.

The results showed that age of the household head and the number of family members have no statistically significant impact on the income of farmers participating in MBA. Eductaion level has a statistically significant positive impact on the rural household income of farmers. This result is similar to that obtained by Hartono and Rohaeni, 2014; Awan et al., 2015; Kabir et al., 2019; Marwati et al., 2020 who have shown in their studies that a higher level of education of the household head leads to an increase in farm income as it enables efficient decision making.

Experience in livestock farming has a statistically significant positive impact on the rural household income of farmers. This indicates that a high experience in livestock production might lead to a high household income. Farmers with a high experience would be more efficient in decision-making. This result is in line with previous studies conducted by Thys et al. (2005) in Ouagadougou in Burkina Faso and Ndiaye, (2017) in Senegal who have showed that a high farming experience would be related to a high household income.

Access to credit has a statistically significant positive impact on the income of farmers. Credit is a source of financing for agricultural activities.

Number of cattle has a statistically significant positive impact on the income of farmers. Cattle raising is the first choice of pastoralists. The size of the cattle herd determines the level of their household income. Safa, (2005) found in his study in Yemen that agroforestry farmers with livestock had high family income compared to those with less or no livestock. Number of sheep has a statistically significant positive impact on the income of farmers. Most of pastoralists of the sudy area associate cattle with small ruminant, mostly sheep. Sheep ranks second after cattle. It contributes significantly to the household income especially during festivals (Thys et al. 2005; Medenou, 1992).

Pasture use has a statistically significant positive effect on the income of farmers. The grazing lands used by most of farmers in pastoral areas are mostly natural, ungrown. This is costless for them. Pastoral livestock production is mainly derived from the use of natural resources - grassland and shrubs - grazed by animals on uncultivated lands mainly in arid and semi-arid areas (CEDEAO, 2008). This result is similar to that of Marandure et al. (2016) who stated that natural pasture feed resources reduce production costs, which subsequently improves the volume and quality of marketable livestock and therefore increases household income.

Access to veterinary services has a statistically significant positive impact on the income of farmers. Veterinary services are much useful for farmers to control the health of their husbandary by keeping them in a good state and protect them especially against Tripanosomia during rainy seanson.

Membership to a livestock organization has a significant positive impact on the income of farmers. To benefit from the advantages of livestock markets such as training, price information, loans, etc., most of farmers participating in MBA markets are part of existing livestock farmer organization in their area.

Table 4
Model results for determining the factors affecting the household income of the farmers preferred MBA

Variables	Coefficient	Standard error	t-statistic	p-value
Constant	0.859	0.854	1.005	0.317
Age	0.090	0.068	1.324	0.188
Education level	0.097	0.046	2.095	0.039**
Experience in livestock farming	0.109	0.058	1.867	0.065*
Access to credit	0.386	0.104	3.722	0.000***
Number of cattle	0.629	0.095	6.631	0.000***
Number of sheep	0.103	0.056	1.844	0.068*
Pasture use	0.482	0.082	5.852	0.000***
Access to veterinary services	0.555	0.124	4.489	0.000***
Membership to a livestock organization	0.616	0.094	6.574	0.000***
Number of family members	-0.072	0.094	-0.761	0.449
R^2 : 0.910	F value: 107.964			
Adjusted R^2 : 0.901	p-value: 0.000			

*, ** and *** mean that variable is significant at 10%, 5% and 1%, respectively.

Traditional Livestock Market (MT)

$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + b_8X_8 + b_9X_9 + e$

Y= Household income

X_1: Membership to a livestock organization

X_2: Experience in livestock farming

X_3: Number of cattle

X_4: Distance to market

X_5: Pasture use

X_6: Agricultural land ownership

X_7: Number of family members

X_8: Number of sheep

X_9: Age

b_0: Intercept

b = 1, 2, ...9: Regression coefficients associated with X_1, X_2, … X_9, respectively.

e: Term of errorBased on the results of the multicollinearity test, there was no difference of variance (White Test: 0.134) and no multicollinearity problems in the model developed for determining the factors affecting the household income of livestock farmers who preferred MT livestock markets.

Table 5 shows that the VIF value in each variable is less than 10 and the tolerance value is greater than

0.10, then it can be said that the regression model is free from multicollinearity problems.

Table 5
Multicollinearity Test

Variables	Tolerance	VIF
Constant		
Membership to a livestock organization	0.947	1.056
Experience in livestock farming	0.933	1.072
Number of cattle	0.837	1.195
Distance to market	0.737	1.357
Pasture use	0.276	3.623
Agricultural land ownership	0.313	3.198
Number of family members	0.950	1.053
Number of sheep	0.371	2.698
Age	0.273	3.666

The F test was used to determine whether the independent variables in the model had a significant effect on the dependent variable simultaneously.Table 6 shows that F and its significance were found 94.256 and 0.000, respectively. Explanatory variables explained 88% of variance in the income of livestock farms. Except membership to a livestock organization, distance to market, Number of family members, and age, the independent variables of experience in livestock farming, number of cattle, pasture use, agricultural land ownership and number of sheep significantly and positively affected the income of the farmers preferring the MT livestock markets.

Experience in livestock farming has a statistically significant positive impact on the rural household income of farmers in MT. This indicates that a high level of experience in livestock production leads to a high household income. Farmers with a high experience would be more efficient in decision-making. This result is in line with previous studies conducted by Thys et al. (2005) in Ouagadougou in Burkina Faso; Ndiaye, (2017) in Senegal.

Number of cattle has a statistically significant positive impact on the income of farmers. The size of the cattle herd determines the level of household income. Safa, (2005) stated in his study that agroforestry farmers with livestock had high family income compared to those with less or no livestock in Yemen.

Pasture use has a statistically significant positive effect on the income of farmers. The grazing lands used by most of farmers in the study areas are mostly natural, ungrown. This is costless for them. Pastoral livestock production is mainly derived from the use of natural resources - grassland and shrubs - grazed by animals on uncultivated land mainly in arid and semi-arid areas (CEDEAO, 2008). This result was also found by Marandure et al. (2016) who stated that natural pasture feed resources reduce production costs, which subsequently improves the volume and quality of marketable livestock and therefore increases household income.

Agricultural land ownership has a statistically significant positive impact on the income of farmers. The ownership of agricultural land procure many advantages to livestock farmers who live in deeper local areas. Safa, (2005) found that land size owned is significantly positively related to farmers' income in Yemen Ndiaye, (2017) showed that agricultural area has a positive and significant effect on the household income in Senegal. It is then assumed that if farm size increases, the share of income from the farm income source would also increase.

Number of sheep has a statistically significant positive impact on the income of farmers. Most of pastoralists of the sudy area associate cattle with small ruminant, mostly sheep. Sheep ranks second after cattle. It contributes significantly to the household income especially during festivals (Thys et al. 2005; Medenou, 1992).

Table 6
Model results for determining the factors affecting the household income of the farmers who prefer MT

Variables	Coefficient	Standard error	t-statistic	p-value
Constant	0.370	1.010	0.367	0.715
Membership to a livestock organization	0.307	0.240	1.281	0.203
Experience in livestock farming	1.435	0.377	3.811	0.000*
Number of cattle	0.110	0.045	2.446	0.016**
Distance to market	0.008	0.057	0.143	0.887
Pasture use	1.121	0.219	5.109	0.000*
Agricultural land ownership	0.838	0.095	8.850	0.000*
Number of family members	-0.004	0.050	-0.083	0.934
Number of sheep	0.778	0.156	4.983	0.000*
Age	-0.071	0.093	-0.766	0.346
R^2 : 0.890	F value: 94.256			
Adjusted R^2 : 0.880	p-value: 0.000			

* and ** mean that variable is significant at 1% and 5%, respectively.

4. Conclusion

In the monetary approach, the life standard indicator is household income. A household income derives from many activities (EMICoV, 2015). In most African countries, household income derives from agriculture and livestock sub-sector is a source of income for many rural households. In most of sub-Saharan Africa, it appears that livestock farming is practiced for subsistence, food, risk reduction, traction, fertilizer and cash income (Beverly et al., 2008).

The aim of this study was to determine the factors affecting the household income of farmers engaged in animal husbandry in the Republic of Benin. Two types of animal markets (MBA and MT) were considered in this study.

According to the results, many social and economic factors have a statistically significant positive impact on the household income of farmers participating in MBA and MT livestock markets. Experience in livestock farming, number of cattle, number of sheep, pasture use have a statistically significant positive impact on the household income in both MBA and MT livestock markets, while education level, access to credit, veterinary services, membership to a livestock organization have a statistically significant positive impact on only the household income of farmers participating in MBA and agricultural land ownership has a statistically significant positive impact on only the household income of farmers participating in MT.

Those factors, when they are improved efficiently, they can enable farmers to increase their household income and reduce the poverty in rural areas in the Republic of Benin. Income determinants should be carefully integrated in rural development policies in order to improve the rural household's purchasing power as well as the income distribution in the study area.

Enhancing access to credits, promoting rural education and road conditions and empowering rural households to make rational decision in selling their animals in a well-organized livestock market will reduce negative livestock income and consequently improve income of poor household in the rural areas, especially in the pastoral regions in Africa. In addition, priorities should be given to the development of large and modern livestock farming, and to modern livestock marketing system like Self-Managed Livestock Markets (MBA).

The government should therefore invest in the education and training of young people in the rural areas to encourage and provide them with the knowledge and skills necessary to improve their living conditions and alleviate poverty. Producers' easy access to farmland would allow them to increase their crop area and livestock, which would be a good policy for improving their household income.

The government should also encourage farmers' organizations that can promote their identity and represent their interests to the public authorities. Again, access to credit should be facilitated by the public administration to enable farmers to finance their activities.

In addition, women should be encouraged to participate more intensively in agricultural activities to reduce income inequality and poverty.

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Effects of Different Frequencies and Potassium Doses on Yield and Yield Components in Seed Sunflower

Mehmet ADALI [1,*], Mustafa ONDER[2]

[1]Selcuk University, Faculty of Agriculture, Department of Field Crops, Konya, Turkey
[2] Selcuk University, Institute of Sciences, Department of Field Crops, Konya, Turkey

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ABSTRACT

Field trials of the present study was realized in 3 isolation areas (3 different regions) as EK1102 variety in Eşrefli location, VE3060 variety in Aşağıpiri-beyli location and PS4042 variety in Doğanyurt location - TURKEY according to split plot in randomized complete block design with 3 replications. The main plots consisted from the plant density for the line control (PS4042: 6200 plant da^{-1}, VE3060: 5700 plant da^{-1}, EK1102: 6500 plant da^{-1}, 5000 plant da^{-1}, 6000 plant da^{-1}, 7000 plant da^{-1}) and 4 potassium doses (0, 3, 5, 7 kg/da K_2SO_4) applicated According to results the following ranges were detected; 109.67-307.00 kg da^{-1} for grain yield, 9.33-12.33 for days emergence period, 68.00-77.67 for days flowering period, 76.00-168.00 cm for plant height, 17.00-27.00 cm for diameter of the head, 7.33-8.72 gr for weight of one hundred grains, 4.17-7.15 mm for seed diameter, 11090.88-14519.33 pieces for kernel kg^{-1}. Consequently, results of the present research showed that, the lowest value was 11090 kernels kg^{-1}, PS4042 variety with 7 kg da^{-1} potassium dose application and 7000 plant da^{-1} sowing density while the highest value was 14519 kernel kg^{-1} and VE3060 variety with 5 kg da^{-1} potassium dose application and 5000 plant da^{-1} sowing density. It can be concluded that deep and various factors are needed to focus for more reliable data collection and adaptation to different ecologies.

1. Introduction

Fats are one of the basic foodstuffs that have vital value for our body and have an important place in our diet. Fats are as essential to our life as proteins and carbohydrates. Vegetable oils have a special importance in terms of their benefits for human health and their high nutritional value, especially with their low saturated fat content, containing free fatty acids necessary for cell structure, and dissolving fat-soluble vitamins such as A, D, E, and K in our body (Kolsarıcı et al., 2005; Kahraman, 2017). Humans need food to survive. A balanced diet, regular exercise, a good and quality sleep pattern bring a healthy life (Harmankaya et al., 2016). Cereals and legumes that are plant sources in addition to roots, leaves, shoots, flowers, fruits, bulbs of various plant parts are the basic foods for humans (Ceyhan et al., 2014). Change in the economic, social and cultural fields significantly affects the agriculture and food sector from production to consumption (Kahraman et al., 2015). Global agricultural policies increase the interest in the production of oilseeds and cereals and highlight monoculture in agricultural production. In addition to the change in income level and rapid urbanization add a different dimension to the demand for agricultural products, from nutritional habits to food supply (Ceyhan et al., 2011). All these developments significantly affect the production and consumption of legumes which are the main protein source of more than 2 billion people as well as the protection of soil and water resources that are main concepts of sustainability (Ozkan et al., 2017).

When the production of oilseed plants is considered, soybean takes the first place in the world and the production of oilseed plants in Turkey is listed as çigit, sunflower and soybean, respectively (Anonymous, 2008).

In the 2019/2020 marketing year in the world, sunflower was planted on 26.3 million hectares of land and 2-ton ha^{-1} yield was obtained. Compared to the previous marketing year, there was an increase of 2.2% in the planted area and 6.1% in the yield. In the same marketing year, production increased by 8.8% compared to the previous marketing year and totaled 54.9 million tons in the world (USDA, 2020).

While Turkey's oil sunflower cultivation areas were 560 thousand hectares in 2015, it increased by 21% in 2019 to 670 thousand hectares. On the other hand, sunflower production, which was 1.4 million tons in 2015, increased by 39% in 2019 and reached 1.95 million tons. According to TURKSTAT 2018/2019 marketing year data, the sufficiency rate of sunflower is 66.4%. While the average yield per decare was 264 kg in 2015, the yield per

* Corresponding author email: *mehmetadali123@gmail.com*

decare increased by 10% and reached 289 kg in 2019 (TUIK, 2019).

In 2019, seed production areas of companies producing seeds in Turkey, especially in Konya, Afyonkarahisar and Eskişehir, are approximately 20000 ha and the production was 28602-tons (BUGEM, 2020).

In the study conducted to determine the effects of different levels of nitrogen, phosphorus and potassium applications on yield and yield elements of sunflower under irrigated conditions, they observed that the increase in NPK level led to an increase in yield parameters in general. Accordingly, they reported that 80-50-50 kg/ha NPK fertilizers should be used per hectare to increase yield elements such as 100 grain weight, grain yield and the productivity of sunflower (Sadiq et al., 2000).

8 domestic and foreign hybrid sunflower varieties (AS 508, AS 615, AS 6310, Nantio F1, TR 6149, TR 3080, 64 A 83 and XF 4826) and 3 planting density (25 x 60, 35 x 60, 45 x 60). As a result of the research, the highest table diameter was from the variety AS6310 with 24 cm, the highest thousand-grain weight was from the TR 3080 variety with 76.66 g, the highest oil rate was from the Nantio variety with 39.78%, and the highest grain yield per decare was from the AS615 variety. determined (Şimşek and Sinan, 2001).

The effects of potassium fertilizer on sunflower yield and yield components in Tekirdağ region were investigated and it was determined that with 25 kg/ha K_2O, significant yield increases were achieved compared to the control block, plant height and head diameter were not affected, but the oil content per grain increased (Kacar et al., 2002).

As a result of a study conducted with Fedouk and Euroflor sunflower varieties; The highest seed yield and oil rate from both dense sowing (20 cm) and nitrogen levels of 100-140 kg/ha, the highest oil rate (43.5-44.2%) from Sakha-53 variety at 25 cm plant density and 70 kg. /ha nitrogen level was obtained. As a result, he recommended the use of frequent sowing (20 cm) and a nitrogen dose of 100 kg/ha to obtain the highest seed and oil yield under the environmental situation of the North Sinai Region (El-Sarag, 2007).

In the study on the research of soil tillage methods in second crop sunflower production in Tekirdag province, heavy disc harrow (DT), rotary tiller (ROT), heavy disc harrow+rotary tiller (DT+ROT), plow+heavy disc harrow (PUL+DT) was used as soil tillage methods., plow+heavy disc harrow+combicure (PUL+DT+KOM) and plow+rotatiller (PUL+ROT) methods were used. As a result, the results in terms of field emergence time, plant height, stem diameter and yield were found to be statistically significant. The highest plant height was in the tillage method with rotary tillers (ROT), while the lowest was in the plow+heavy disc harrow (PUL+DT) method. The highest efficiency was in the tillage methods made with plow+rotatiller (PUL+ROT) and rotary tiller (ROT), while the lowest efficiency was in the heavy disc harrow (DT) method (Akdağoğlu, 2015).

In an experiment established in 2016 to determine the oil sunflower varieties for Konya under Konya ecological conditions, it was found that Transol variety in Altınekin region, LG5580 and Bosfora in Obruk region, Transol and C70165 in Çumra region, Transol, Sanbro and C70165 varieties according to the average of three regions can be recommended for regional conditions. It was concluded that (Çetin, 2018).

In a trial conducted in Çukurova under dry conditions, the yield and yield components of sunflower (P64LC108) were examined after different fertilizer dosage applications (20.20.0 compound fertilizer, 0, 10, 15.20 kg/da); It was determined that plant height, head diameter, oil rate, seed yield and oil yield values increased as the fertilizer dose increased (Tunç, 2019).

In the experiment conducted in Adana conditions, in the field of Eastern Mediterranean Agricultural Research Institute in 2019, 3 different sunflowers (Zuhat, P64LC108 and Tunca) and 4 different in-row spacing (15-20-25-30 cm) were applied and 12 characteristics were examined (flowering time, physiological maturation time). As a result of the research, seed and oil yield, table diameter and hectoliter weight of different row spacings (self-fertilization rate, plant height, head diameter, seed kernel ratio, thousand grain weight, hectoliter weight, seed yield, protein ratio, oil ratio and oil yield) effect was detected. As a result of the experiment, the highest yield of 409.5 kg/da was obtained from the Tunca variety at a distance of 25 cm between the rows (Uçdağ, 2020).

In the 2-year study (2017-2018), which was conducted to determine root and root collar diseases in sunflower cultivation areas in Konya, Aksaray and Karaman and to investigate these and biological control possibilities, researches were conducted in the districts where the majority of oil sunflower production is made in these provinces, and plant samples showing disease symptoms were taken. Soil-borne fungi on isolated plants were diagnosed at the genus and species level by using macroscopic and microscopic methods. As a result of the isolations, Sclerotinia sclerotiorum was determined as the most common fungal agent. According to the symptomatological data, the disease rate of Sclerotinia sclerotiorum was 9.38% in Konya (Altınekin) and 4% in Aksaray (Center/Eskil) (Koçak, 2019)

Sarıkaya applied potassium at different doses (0-3-6-9-12 kg da^{-1}) in the sunflower experiment he established in Bursa under dry and irrigated conditions in 2012 and 2013, and 9 different characteristics were examined in the experiment (plant height, tabletop). diameter, grain yield, number of plants, number of grains, weight of bins, oil rate, inner bark rate and fresh weight), grain number, oil rate, inner bark rate, fresh weight and bin weight increased in dry conditions with potassium applications; in wet conditions; Thousand grain weight, wet weight and inner bark ratio statistically increased with potassium applications (Sarıkaya, 2016).

Seed sunflower production is one of the most developed sectors and has increasing export potential. In hybrid seed production, both at the certification stage and during seed production and sales, the processes are quite regular compared to other sectors. Especially in recent years, with the official introduction of special production zones, one of the biggest problems in the sector has been solved (Kaya, 2014).

Seed sunflower production in Turkey, especially in the Central Anatolian region, is increasing narrowly every year. While this production was 25 thousand tons in 2018, it increased to approximately 29 thousand tons in the next year (BUGEM, 2020). This research aims to contribute to the country's economy by increasing the yield and quality values of the sunflower plant, of which a large number of seed is produced in Turkey, and by increasing the quality values of these seed companies of foreign origin, increasing their satisfaction and profitability; was established to increase the production in Turkey every year.

2. Materials and Methods

Field studies of this research were carried out in Emirdağ-Afyonkarahisar, Paddy-Konya ecology. In 2018, the trial was established in 3 replications according to the split plot in randomized complete block design, and was conducted in 3 isolation zones (Eşrefli, Aşağıpiribeyli/Emirdağ and Doğanyurt/Çeltik villages. The trial: Witness, 5000 plant da^{-1}, 6000 plant da^{-1}, 7000 plant da^{-1} was formed from 3 main blocks 0-3-5-7 kg da^{-1} potassium sulphate (K_2SO_4) was installed with applications. Before planting, 15-15-15 fertilizer was applied and mixed into the soil with a rake. Frequency trials were placed on the main plots and potassium doses were placed on the subplot.

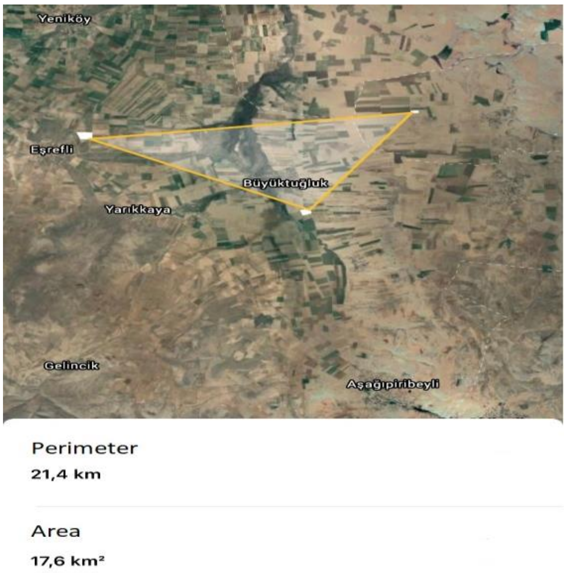

Figure 1
Location of Trial Fields

Considering the factors discussed in the research; A field trial consisting of 3 male sterile sunflower genotypes, each in a single isolation zone x 4 different frequency trials x 4 potassium doses x 3 replications, in total 48 x 3 = 144 plots was established. Seeds were planted in the first week of June, taking into account the regional conditions, while the soil prepared by the technique was in the tempering. Soil analysis results of the trial plots are given in Table 1.

Table 1
Some physical and chemical properties of trial fields

Soil parameters	Ashraf	Doganyurt	Asagipiribeyli
pH (1:2.5 h: w)	7.20	7.95	7.35
EC (mhos/cm)	1.05	0.91	1.1
$CaCo_3$ (%)	15.75	19.74	16.15
Organic matter (%)	2.05	1.16	1.9
P (%)	20.6	5.9	6.7
K (%)	68	65	72
Ca (%)	27.55	21.64	25.75
Mg (%)	1.80	3.37	2.23
Na (%)	60	56	65
Changeable % Na	1.29	1.1	1,2
B (%)	0.75	0.72	0.8
C (%)	0.62	1.18	3.34
Fe (%)	0.84	2.55	2.86
Zn (%)	1.52	1.3	1.72
Mn (%)	23.44	21.18	14.4
Textural class	loam	loam	loam

Each parcel has a total area of 21 m^2, 7 m wide x 3.0 m long. A gap of 2 m was left between the parcels and 2 m between the blocks. At harvest, all 2 rows on the sides of the parcel and 0.5 m long sections from both ends of the other rows will have an edge effect. During the research, no measurements or observations were made on the rows forming the edge effect. According to the results of soil analysis, suitable base fertilizer (15-15-15 50 kg da^{-1}) was given to the seedbed prepared by the technique and mixed with the soil with a rake before planting. In each plot, air seeder was planted in 10 rows at 28.6 cm, 23.8 cm, 20.4 cm and witness (22.5, 25.5, 20.5) cm in-row distances. In this research, as a source of potassium in field trials; Potassium Sulphate containing approximately 50% potassium and 46% sulfur was used as the water-soluble mass. Considering that the recommended fertilizer dose is 3-5 kg da^{-1}, once during the flowering period of the application; 4 different doses of 0, 3, 5, and 7 kg da^{-1} were applied to the plots with water. During the growing period, the cultural treatments (irrigation, fertilization, disease and pest control, hoeing) were carried out equally on all plots throughout the experiment. During the vegetation period, irrigation was done according to the need. The water needs of the plants were met by the drip irrigation system. After all the plants in the plots had matured, the parts except for the edge effect were harvested manually, and the seeds of these plants were used in the measurements and analyzes made afterwards. Considering that the recommended fertilizer dose is 3-5 kg da^{-1}, once during the flowering period of the application; 4 different doses of 0, 3, 5, and 7 kg da^{-1} were applied to the plots with water. During the growing period, the cultural treatments (irrigation, fertilization, disease and pest control, hoeing) were carried out equally on all plots throughout the experiment. During the vegetation period, irrigation was done according to the need. The water needs of the plants were met by the drip irrigation system. After all the plants in the plots had matured, the parts except for the edge effect were harvested manually, and the seeds of these plants were used in the measurements and analyzes made afterwards. Considering that the recommended fertilizer dose is 3-5 kg da^{-1}, once during the flowering period of the application; 4 different doses of 0, 3, 5, and 7 kg da^{-1} were applied to the plots with water. During the growing period, the cultural treatments (irrigation, fertilization, disease and pest control, hoeing) were carried out equally on all plots throughout the experiment. During the vegetation period, irrigation was done according to the need. The water needs of the plants were met by the drip irrigation system. After all the plants in the plots had matured, the parts except for the edge effect were harvested manually, and the seeds of these plants were used in the measurements and analyzes made afterwards. and 4 different doses of 7 kg da^{-1} were applied to the plots with water. During the growing period, the cultural treatments (irrigation, fertilization, disease and pest control, hoeing) were carried out equally on all plots throughout the experiment. During the vegetation period, irrigation was done according to the need. The water needs of the plants were met by the drip irrigation system. After all the plants in the plots had matured, the parts except for the edge effect were harvested manually, and the seeds of these plants were used in the measurements and analyzes made afterwards. and 4 different doses of 7 kg da^{-1} were applied to the plots with water. During the growing period, the cultural treatments (irrigation, fertilization, disease and pest control, hoeing) were carried out equally on all plots throughout the experiment. During the vegetation period, irrigation was done according to the need. The water needs of the plants were met by the drip irrigation system. After all the plants in the plots had matured, the parts except for the edge effect were harvested manually, and the seeds of these plants were used in the measurements and analyzes made afterward. During the vegetation period, irrigation was done according to the need. The water needs of the plants were met by the drip irrigation system. After all the plants in the plots had matured, the parts except for the edge effect were harvested manually, and the seeds of these plants were used in the measurements and analyzes made afterwards. During the vegetation period, irrigation was done according to the need. The water needs of the plants were met by the drip irrigation system. After all the plants in the plots had matured, the parts except for the edge effect were harvested manually, and the seeds of these plants were used in the measurements and analyzes made afterward.

The climate data of Emirdağ-Çeltik region, where the research was conducted, are given in Table 2.

Table 2
Climate data

Month	Rainfall (mm)		Main Air Temperature (°C)		Relative Air Humidity (%)	
	1970-2017	2018	1970-2017	2018	1970-2017	2018
April	41.4	42.9	15.6	15.46	64.1	64.4
May	47.3	47.9	23.4	22.97	50.1	50.5
June	42.6	42.9	27.1	27.17	46.4	47.7
July	30.1	30.5	27.5	28.09	45.1	45.2
August	20.1	19.4	28.9	29.32	48.1	47.7
September	32.5	34.6	26.4	26.1	53.4	55.4
October	46.3	46.9	22.3	22.51	55.4	55.9
Mean	37.2	37.9	24.6	24.5	51.8	52.4

To summarize the measurements, observations and analyzes discussed within the scope of the research; Emergence time (days), Flowering onset time (days) (Ergen and Sağlam, 2005), Head diameter, Plant height (cm), Grain yield (kg da^{-1}) (Yıldırım, 2018) will be determined.

In this context, the analyzes made in the laboratory can be summarized as follows: Hundred grain weight (g) - Diameter of the seed (mm) (Ergen and Sağlam, 2005), kernel kg^{-1}.

The values obtained in the research were subjected to statistical analyzes (variance analysis, grouping of means) with the computer-based package program named “JUMP” according to the “Divided Plots in Random Blocks Experimental Design” by accepting as factors (Sarıkaya, 2016).

3. Results and Discussion

The data obtained as a result of this research, which was carried out with the aim of determining the effects of different density and potassium applications on some agronomic characters in cytoplasmic male sterile parent sunflower lines used in seed production in Konya-Afyon ecological conditions mean squares values are given in Table 3.

Table 3
Analysis summary of the variance of the topics covered in the research

		Emergence time			Flowering time		
		Mean Square			Mean Square		
Source	DF	PS4042	VE3060	EK1102	PS4042	VE3060	EK1102
Total	47	-	-	-	-	-	-
Replication	2	1.98	1.58	0.58	10.14	0.40	0.19
Sowing Frequency (A)	3	1.28	0.35	0.14	1.30	1.02	4.91
Error-1	6	2.81	2.42	0.47	1.58	0.56	5.41
Fertilizer Dose (B)	3	0.11	0.02	0.75	6.08*	1.74	2.52
AxB	9	0.74	1.04	0.88	2.05	1.15	3.15
Error-2	24	0.63	1.01	0.56	1.31	1.55	2.08
		Hundred kernel weight			Head Diameter		
		Mean Square			Mean Square		
Source		PS4042	VE3060	EK1102	PS4042	VE3060	EK1102
Total		-	-	-	-	-	-
Recurrence		0.27	0.26	0.42	13.65	0.79	0.75
Sowing Frequency (A)		0.05	0.08	0.31	80.22**	21.90**	1.14
Error-1		0.06	0.10	0.14	4.44	3.04	0.97
Fertilizer Dose (B)		1.19**	1.02**	0.57**	15.33**	32.73**	3.14
AxB		0.01	0.02	0.00	1.92	15.19**	3.75
Error 2		0.01	0.02	0.00	0.94	6.83	1.89
		Plant Height			Kernel Kg^{-1}		
		Mean Square			Mean Square		
Source		PS4042	VE3060	EK1102	PS4042	VE3060	EK1102
Total		-	-	-	-	-	-
Recurrence		262.04	23.81	34.52	438601		1050321
Sowing Frequency (A)		4720.25**	2917.42**	1990.85**	626256	422282	724701
Error-1		271.43	48.65	13.85	732381	183156	204595
Fertilizer Dose (B)		953.04*	89.14*	50.08**	6435320**	168792	2728771**
AxB		487.04	38.03	7.58	90330	1.28e+7**	145643
Error 2		249.90	19.74	12.74	61764	82598.8	101961
		Grain Yield			Kernel diameter		
		Mean Square			Mean Square		
Source		PS4042	VE3060	EK1102	PS4042	VE3060	EK1102
Total		-	-	-	-	-	-
Recurrence		11.23	1660.75	35.15	0.14	0.71	0.01
Sowing Frequency (A)		2188.20**	7469.97**	6615.22**	0.69	0.54	0.08
Error-1		142.74	621.36	152.70	0.16	0.21	0.38
Fertilizer Dose (B)		27214.20**	34183.70**	23691.50**	5.28**	3.62**	3.98**
AxB		192.58	926.13*	270.32	0.14**	0.03	0.01
Error 2		140.92	319.76	124.67	0.04	0.03	0.01

In the study, grain yields varied in the range of 109.67-307 kg da^{-1} and these features are given in Table 4. As a result of the research, the values determined regarding the grain yields were determined by the results of the study, which states that the grain yields in sunflower vary between 120-360 kg da^{-1} (Simsek and Sinan, 2001; Ergen and Saglam, 2005; Kılıç, 2010; Evci et al., 2011; Kara and Başalma, 2011; Acar et al., 2012; Ali et al., 2013; Deviren, 2014; Erdemli, 2015; Fırat, 2015; Kıllı and Tekeli, 2016; Yıldırım, 2018; Can, 2019) showed parallelism with the studies, while grain yields in sunflower vary between 65-136 kg da^{-1} (Arslan et al., 2000; Karaaslan et al., 2002; Kaya et al., 2005; Tuncturk et al., 2005; Demirel, 2014) over their work.

The grain yield differences in the study may be caused by the genetic characteristics of the varieties, different soil structures and climatic reasons brought by the year.

Table 4
"Grain yield (kg da^{-1})" values and Lsd groups obtained according to different density and potassium doses

Lines (Location)	Plant density	Potassium doses (kg da^{-1}) 0	3	5	7	Average
PS4042	6200	126.33	150.67	183.33	217.67	169.50c
	5000	138.33	178.67	223.33	258.33	199.67a
	6000	122.00	161.67	210.33	243.00	184.25b
	7000	112.00	159.00	203.33	218.42	173.19bc
	Average	124.67d	162.50c	205.08b	234.35a	181.65
VE3060	5700	140.33gh	166.00fg	218.67cd	216.67d	185.42b
	5000	141.00gh	184.00ef	247.33bc	307.00a	219.83a
	6000	130.00h	155.67fgh	204.67	256.00b	186.58b
	7000	109.67i	133.67hi	169.00fg	223.33cd	158.92c
	Average	130.25d	159.83c	209.92b	250.75a	187.69
EK1102	6500	153.00hi	187.00fg	236.00cd	256.00b	208.00b
	5000	170.33gh	222.33	267.67b	292.33a	238.16a
	6000	157.67hi	180.67fg	216.00e	254.33bc	202.16b
	7000	143.33i	161.33hi	196.00f	224.67	181.33c
	Average	156.08	187.83	228.92	256.83	207.42

In the research, emergence times varied between 9.33-12.33 days and these features are given in Table 5. As a result of the research, the values determined regarding the emergence period are in parallel with the studies (Ergen and Saglam, 2005; Ali, 2011), which stated that the emergence period in sunflower varies between 9-16 days.

Table 5
"Emergence time (days)" values and Lsd groups obtained according to different density and potassium doses

Lines (Location)	Plant density	Potassium doses (kg da^{-1}) 0	3	5	7	Average
PS4042	6200	11.33	11:00	11.33	11:00	11.17
	5000	10.67	11.33	10.67	12.00	11.17
	6000	11.67	12.00	12.00	11.33	11.75
	7000	12.00	11:00	12.00	11.87	11.72
	Average	11.42	11.33	11.50	11.55	11.45
VE3060	5700	11.33	10.67	11.33	11:00	11.08
	5000	11:00	11.33	10.67	11.33	11.08
	6000	11:00	12.33	10.67	11.33	11.33
	7000	11.67	10.67	12.00	11.33	11.42
	Average	11.25	11.25	11.17	11.25	11.22
EK1102	6500	9.33	10.67	10.67	10.67	10.33
	5000	11:00	10.00	9.67	10.33	10.25
	6000	10.00	9.67	10.33	10.67	10.17
	7000	10.00	10.00	9.67	10.67	10.08
	Average	10.08	10.08	10.08	10.58	10.2

In the study, flowering periods were 68.00-77.67 days varied in the range and these features are given in Table 6. As a result of the research, the values determined regarding the flowering periods are in parallel with the studies (Ergen and Saglam, 2005; Çil et al., 2011; Demirel, 2014), which stated that the flowering period in sunflower varies between 60-75 days, while the flowering period in sunflowers varies between 59-72 days. (Acar et al., 2012; Erdemli, 2015; Can, 2019).

The differences in flowering periods in the study may be caused by genetic characteristics of varieties, different soil structures and climatic reasons brought by the year.

Table 6
"Flowering time (days)" values and Lsd groups obtained according to different density and potassium doses

Lines (Location)	Plant density	Potassium doses (kg da^{-1}) 0	3	5	7	Average
PS4042	6200	74.67	77.00	75.67	75.67	75.75
	5000	75.33	76.00	74.67	77.67	75.92
	6000	74.33	75.67	76.67	76.67	75.83
	7000	75.67	76.67	77.00	76.62	76.49
	Average	75.00b	76.33a	76.00a	76.66a	75.99
VE3060	5700	70.00	70.00	69.67	68.00	69.42
	5000	69.33	69.67	70.33	70.00	69.83
	6000	69.67	69.33	69.00	68.67	69.17
	7000	69.33	69.33	70.67	69.33	69.67
	Average	69.58	69.58	69.92	69.00	69.52
EK1102	6500	72.00	70.67	71.67	71.67	71.5
	5000	71.67	71.67	73.33	72.67	72.33
	6000	72.67	74.00	73.33	72.00	73.00
	7000	70.67	71.00	72.00	74.00	71.92
	Average	71.75	71.83	72.58	72.58	72.18

Plant height in the study 76.00-168.00 changed in cm and these features are given in Table 7. The values determined to plant height as a result of the research indicate that the plant height varies between 70-167 cm in sunflower (Atakişi, 1985; Göksoy, 1999; Karaaslan et al., 2002; Ergen and Saglam, 2005; Kaya et al., 2005; Evci, 2011; Karakaş 2012; Qatar 2012; Demirel, 2014; Deviren, 2014; Fırat, 2015; Kıllı and Tekeli, 2016; Memiş, 2018; Yıldırım, 2018), while the plant height in sunflower varies between 144-222 cm (Dilci, 1993; Ali et al., 2013; Can, 2019) remained under the works.

The differences in plant heights revealed in the study may be caused by the genetic characteristics of the varieties, different soil structures and climatic reasons brought by the year.

Table 7
"Plan Height (cm)" values and Lsd groups obtained according to different density and potassium doses

Lines (Location)	Plant density	Potassium doses (kg da^{-1}) 0	3	5	7	Average
PS4042	6200	105.33	113.67	112.67	118.33	112.50c
	5000	76.00	128.00	133.67	126.33	116.00bc
	6000	130.33	128.67	124.67	140.33	131.00b
	7000	152.67	155.00	158.00	161.53	156.80a
	Average	116.08b	131.33a	132.25a	136.63a	129.07
VE3060	5700	125.00	128.00	127.00	133.33	128.33c
	5000	123.00	126.67	123.33	130.33	125.83c
	6000	141.67	144.67	137.67	137.33	140.33b
	7000	155.33	157.33	159.33	168.00	160.00a
	Average	136.25b	139.17ab	136.83b	142.25a	138.62
EK1102	6500	119.67	118.00	122.67	124.67	121.25c
	5000	121.00	122.00	124.33	128.00	123.83c
	6000	139.00	137.33	138.33	138.33	138.25b
	7000	146.67	148.00	148.33	152.00	148.75a
	Average	131.58b	131.33b	133.42ab	135.75a	133.02

In the research, the diameter of the table varied between 17.00-27.00 cm and these features are given in Table 8. The values determined to the diameter of the tray as a result of the research, indicate that the diameter of the tray varies between 15-29 cm in sunflower (Atakişi, 1985; Oral and Kara, 1989; Kara, 1991; Şimşek and Sinan, 2001; Sefaoğlu, 2008; Ali et al., 2013; Deviren, 2014; Fırat, 2015; Yıldırım, 2019), indicating that the diameter of the tray varies between 8-19 cm in sunflower (Taşbölen, 1988; Sağlam and Ulger, 1992; Karaaslan et al., 2002; Ergen and Saglam, 2005; Kaya et al., 2005; Doğan and Sinan, 2010; Qatar, 2012; Erdemli, 2015) is on the works.

The differences in table diameter in the study may be caused by the genetic characteristics of the varieties, different soil structures and climatic reasons brought by the year.

Table 8
"Head Diameter (cm)" values and Lsd groups obtained according to different density and potassium doses

Lines (Location)	Plant density	Potassium doses (kg da^{-1})				Average
		0	3	5	7	
PS4042	6200	18.33	19.00	20.00	21.67	19.75b
	5000	24.00	24.33	25.00	27.00	25.08a
	6000	18.67	19.67	22.33	21.67	20.58b
	7000	18.67	20.00	20.00	19.63	19.57b
	Average	19.92c	20.75b	21.83a	22.49a	21.25
VE3060	5700	18.00f	19.33cd	19.00	19.00	18.83b
	5000	18.33ef	20.33b	20.33b	22.00a	20.25a
	6000	18.33ef	19.00	18.00f	20.00bc	18.83b
	7000	17.00g	17.67fg	19.33cd	20.00bc	18.50b
	Average	17.92c	19.08b	19.17b	20.25a	19.10
EK1102	6500	21.33	20.67	20.67	22.67	21.33
	5000	22.33	20.33	20.33	22.67	21.42
	6000	22.00	22.67	22.33	20.00	21.75
	7000	22.33	20.33	20.33	21.00	21.00
	Average	22.00	21.00	20.92	21.58	21.37

Hundred kernel weight 7.33-8.72 gvaried in the range and these features are given in Table 9. As a result of the research, the values determined to hundred kernel weights indicate that the hundred kernel weight in sunflower varies between 4.3-13.9 g (Oral and Kara, 1989; Karaaslan et al., 2002; Ergen and Saglam, 2005; Sefaoğlu, 2008; Ali et al., 2013; Fırat, 2015; Yıldırım, 2018; Can, 2019) studies, indicating that the hundred-seed weight of sunflower varies between 3.5-7.6 g (İncekara, 1972; Kara, 1991; Dilci, 1993; Arslan et al., 2000; Çil et al., 2011; Deviren, 2014; Erdemli, 2015; Kıllı and Tekeli, 2016) over the studies.

The hundred-kernel weight differences in the study may be caused by the genetic characteristics of the varieties, different soil structures and climatic reasons brought by the year.

Table 9
"Hundred kernel weight (gr)" values and Lsd groups obtained according to different density and potassium doses

Lines (Location)	Plant density	Potassium doses (kg da^{-1})				Average
		0	3	5	7	
PS4042	6200	7.87	8.18	8.39	8.49	8.23
	5000	7.78	8.06	8.33	8.40	8.14
	6000	7.71	8.06	8.33	8.45	8.13
	7000	7.80	8.11	8.42	8.72	8.26
	Average	7.79d	8.10c	8.37b	8.52a	8.19
VE3060	5700	7.42	7.93	8.21	8.33	7.97
	5000	7.75	7.97	8.17	8.37	8.06
	6000	7.74	7.95	8.16	8.29	8.03
	7000	7.56	7.81	8.00	8.17	7.88
	Average	7.61d	7.91c	8.13b	8.29a	7.99
EK1102	6500	7.56	7.71	7.88	8.03	7.80
	5000	7.72	7.89	8.09	8.20	7.98
	6000	7.60	7.78	7.91	8.17	7.87
	7000	7.33	7.53	7.65	7.86	7.59
	Average	7.56d	7.73c	7.88b	8.07a	7.81

The kernel diameter 4.17-7.15cm varied in the range and these features are given in Table 10. As a result of the research, the values determined regarding the seed diameter are Ergen and Saglam (2005), who stated that the seed diameter in sunflower varies between 4-6 cm; Mızrak (2006); It is in parallel with the studies of Karakaş (2012).

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Table 10
"Kernel Diameter (cm)" values and Lsd groups obtained according to different density and potassium doses

Lines (Location)	Plant density	Potassium doses (kg da^{-1}) 0	3	5	7	Average
PS4042	6200	5.03f	5.28ef	5.52e	6.11cd	5.49
	5000	5.12ef	5.53e	6.09d	6.52b	5.82
	6000	5.00f	5.55e	6.37bcd	6.63b	5.89
	7000	5.24ef	5.45e	6.42bc	7.15a	6.07
	Average	5.10d	5.45c	6.10b	6.61a	5.81
VE3060	5700	4.64	5.17	5.37	5.87	5.26
	5000	4.86	5.16	5.53	6.06	5.40
	6000	4.17	4.74	5.23	5.62	4.94
	7000	4.29	4.90	5.36	5.56	5.03
	Average	4.49d	4.99c	5.37b	5.78a	5.16
EK1102	6500	5.40	5.83	6.30	6.83	6.09
	5000	5.60	6.02	6.29	6.83	6.19
	6000	5.54	5.94	6.30	7.00	6.20
	7000	5.42	5.84	6.07	6.75	6.02
	Average	5.49d	5.91c	6.24b	6.85a	6.12

In the research, kernel kg^{-1} 11090.88-14519.33 pieces varied in the range and these features are given in Table 11.

Table 11
"Kernel kg^{-1} (numeral)" values and Lsd groups obtained according to different density and potassium doses

Lines (Location)	Plant density	Potassium doses (kg da^{-1}) 0	3	5	7	Average
PS4042	6200	12.479.67	11.960.00	11.748.33	11.238.67	11.856.67
	5000	13.253.00	12.379.33	11.993.67	11.509.00	12.283.75
	6000	13.483.00	12.477.00	12.099.00	11.470.67	12.382.42
	7000	13.185.00	12.393.00	11.936.33	11.090.88	12.151.30
	Average	13.100.17a	12.302.33b	11.944.33c	11.327.30d	12.168.53
VE3060	5700	13.896.00	12.795.67	12.566.33	11.419.67	12.669.42
	5000	14.519.33	13.124.00	12.436.67	11.729.00	12.952.25
	6000	13.907.33	12.838.33	12.360.67	11.769.67	12.719.00
	7000	14.160.33	12.945.33	12.344.67	11.730.67	12.795.25
	Average	14.120.75a	12.925.83b	12.427.08c	11.662.25d	12.783.98
EK1102	6500	12.997.67	12.779.00	12.552.00	12.259.00	12.646.92
	5000	13.243.67	12.791.00	12.814.00	12.428.33	12.819.25
	6000	14.088.00	13.155.67	12.938.33	12.237.00	13.104.75
	7000	13.787.00	13.162.00	13.200.00	12.537.33	13.171.58
	Average	13.529.08a	12.971.92b	12.876.08b	12.365.42c	12.935.63

As a result of the research, when the statistical analyzes given above are examined; The best grain yield is 219.22 kg da^{-1} in 5000 plant da^{-1} plant density and 247.75 kg da^{-1} and 7 kg da^{-1} application in terms of fertilizer dose and 7 kg da^{-1} Potassium application at 5000 plant density in comparison of planting frequency x fertilizer dose 285 We see that it is taken at 89 kg da^{-1} value

Considering the 100-grain weight characteristic, it was found valuable in terms of 7 kg da^{-1} potassium application and 8.28 g fertilizer dose application.

Considering the seed diameter feature, 7 kg da^{-1} potassium application and 6.41 cm fertilizer dose were found to be valuable in terms of application.

When we look at the number of grains per kilogram feature, they were found to be statistically significant with 12748 grains kg^{-1} in 7000 plants da^{-1} planting in terms of sowing frequency, and 13583 grains kg^{-1} with 0 kg da^{-1} potassium application in terms of fertilizer dose.

Considering that there are 150000 seeds in seed sunflower bags, 10,000 kernels kg^{-1} 15kg, 11,000 kernels kg^{-1} 13.6 kg, 12,000 kernels kg^{-1} 12.5 kg, 13,000 kernels kg^{-1} 11.5 kg, 14,000 kernels kg^{-1} 10.7 kg, 15,000 kernels kg^{-1} is 10 kg. Considering both the transportation and the area it covers and the absence of very small seeds, the ideal range for companies is 12,000-14,000.

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Determination of Effective and Specific Physical Features of Rice Varieties by Computer Vision In Exterior Quality Inspection

Ilkay CINAR[1,*], Murat KOKLU[1]

[1]Selçuk University, Faculty of Technology, Department of Computer Engineering, Konya, Turkey

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ABSTRACT

In this study, feature extraction processes were performed based on the image processing techniques using morphological, shape and color features for five different rice varieties of the same brand. A total of 75 thousand pieces of rice grain were obtained, including 15 thousand pieces of each variety of rice. Pre-processing operations were applied to the images and made available for feature extraction. A total of 106 features were inferred from the images; 12 morphological features and 4 shape features obtained using morphological features and 90 color features obtained from five different color spaces (RGB, HSV, L*a*b*, YCbCr, XYZ). In addition, for the 106 features obtained, features were selected by ANOVA, X2 and Gain Ratio tests and useful features were determined. In all tests, out of 106 features, the 5 most effective and specific features were obtained roundness, compactness, shape factor 3, aspect ratio and eccentricity. The color features were listed in different order following these features.

1. Introduction

Rice is the most important product after wheat and corn when the production values of grain products worldwide are considered. Rice is a grain product that is quite rich in carbohydrates and starch. In addition, it also has great significance in human nutrition due to its economical and nutritious value. In the same time, it is also widely used in many fields of industry (Juliano 1993).

There are different quality criteria for rice varieties produced in the world. These criteria include properties of rice such as cooking properties, physical appearance, aroma and taste properties as well as productivity. From the point of view of the ultimate consumer, the first criterion that comes to mind for rice varieties sold in packages on market shelves is physical appearance (Webb 1991, Hua, Xu et al. 2021). Therefore, more technological and effective methods are needed. It is especially inefficient and take excessive time to calibrate rice and separate them within various quality criteria during production especially one considers the high production volume.

Recent studies using image processing and machine learning methods have been studied in the literature. In one of these studies, in which the projection areas of some grain products such as wheat, barley, corn, chickpeas, lentils, beans, kidney beans and soy were determined by image processing technique, the projection areas of the products in three different locations were determined. With the UTHSCSA (University of Texas Health Science Center, San Antonio) image processing program, the relationships between the projection areas were analyzed by regression analysis by obtaining feature values such as length, width and thickness of the products used in the study. As a result of the research, it was concluded that the image processing technique is sufficient for the precise determination of the projection areas of small grain products. Morphological features of 13 different wheat varieties from bread and durum wheat type with image processing technique have been evaluated using the UTHSCSA Image Tool Version 3.0 program. As a result, it has been concluded that the results of measurements obtained by hand and image processing are close and that the image processing technique can be used to determine some of the morphological features of wheat grains (Demirbas and Dursun 2007). In another study using dried tobacco leaves, a system based on machine vision techniques was developed for automatic examination of the leaves. In this system, it is aimed to analyze tobacco leaves using color, size, shape and surface texture features. Based on experimental results, it is stated that this system is a suitable route for dried tobacco leaves. Besides, it is also stated that these features of tobacco leaves can be used for automatic classification as the purpose of the next studies (Zhang and Zhang 2008).

* Corresponding author email: *mkoklu@selcuk.edu.tr*

Aggarwal and Mohan analyzed the aspect ratio using the image processing technique for the grain quality of the rice. Rice samples from three different classes (full, semi-and broken) sold in grocery stores and priced according to their size were taken. It is aimed to examine the mixtures of these samples and determine the reference aspect ratio on the market (Aggarwal and Mohan 2010). Another study aimed to extract the morphological features of 5 pieces pasta wheat varieties called Showa, Altar 84, Altar 84-3, Dipper and Bushen with image processing technique. Five sets of features were used for linear discrimination analysis. 67.66% classification accuracy was obtained as the best result of the discrimination analysis using 11 morphological features (Farahani 2012). One of the studies was carried out using Gujarat-17 rice seeds with image analysis. It was aimed to perform quality analysis using the area, major axis length, minor axis length and eccentricity features on a certain number of samples. It is stated that the traditional quality assessment made by humans can be time consuming and expensive, and that quality analysis can be done without destruction with image analysis (Maheshwari, Jain et al. 2012). In a study on defining barley varieties, the effectiveness of determining the varieties based on the shape, color and texture features obtained from the seed image was evaluated. In the study, success rates ranging from 67% to 86% were achieved in linear distinctive analysis and artificial neural networks classifications. It has been stated that the classification results can be improved by standardizing seed images in terms of front and rear orientations and additional analyses that can be applied to wrinkled regions on the seed (Szczypiński, Klepaczko et al. 2015).

In another study on rice grains, a method for quality analysis using image processing techniques and geometric features of grains was proposed. Using MATLAB technology, the seven geometric features of rice grains (major axis length, minor axis length, eccentricity, area, orientation, perimeter, aspect ratio) were extracted from digital images and then grains belonging to certain varieties are divided into three different classes. The error ratio measuring different geometric features between the recommended method and the experimental analysis was achieved between -1.39% and 1.40% (Kaur and Singh 2015). Tin at all carried out using image processing techniques on 5 different varieties of rice specific to Myanmar, 5 morphological features were extracted for each variety. The study is stated to be realized out to develop computer-based systems in order to automatically classify rice varieties (Tin, Mon et al. 2018).

When the studies conducted in recent years are examined, it can be seen that image processing and machine vision systems are used on various grain products. In these studies, products were examined in terms of various morphological features such as quality, texture, color and size. In addition to morphological features, it also can be seen that various studies have been done using shape and color features.

2. Materials and Methods

In the study, a total of 75 thousand rice grain images were obtained, primarily 15 thousand for each variety (Available from: www.muratkoklu.com/datasets/Rice_Image_Dataset.rar). The resulting images have been prepared for the feature extraction phase by undergoing various pre-operations in MATLAB software. For images passed from pre-processing, 12 morphological features, 4 shape features obtained using morphological features, and with 90 color features obtained from five different color spaces, a total of 106 features were extracted (Available from: www.muratkoklu.com/datasets/Rice_MSC_Dateset.rar). Density distribution graphs of morphological and shape features were given and the distributions of rice varieties on features were examined. Finally, 106 features obtained to reduce the data size were feature selection made by ANOVA, X2 and Gain Ratio tests and the effective features were determined. The process stages of the study are given in Figure 1.

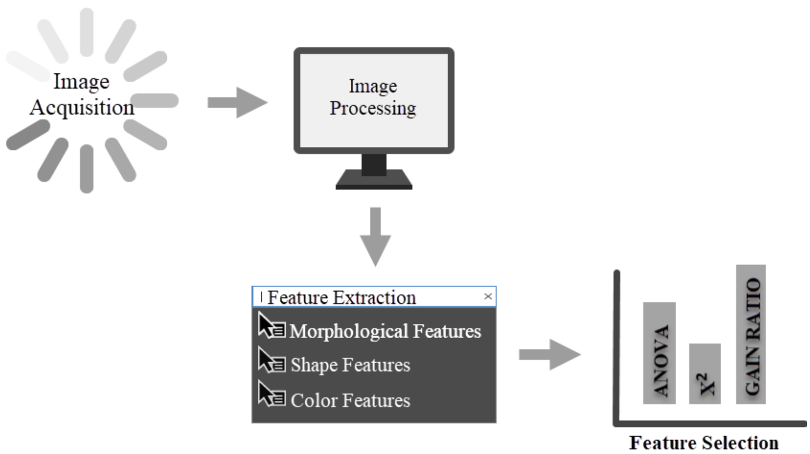


Figure 1
Process steps for the study

2.1. Image Acquisition

In image processing, firstly, the image is obtained with the help of sensors or cameras and digitization pro cess is performed. In Figure 2 shows the image capture and digitization processes.

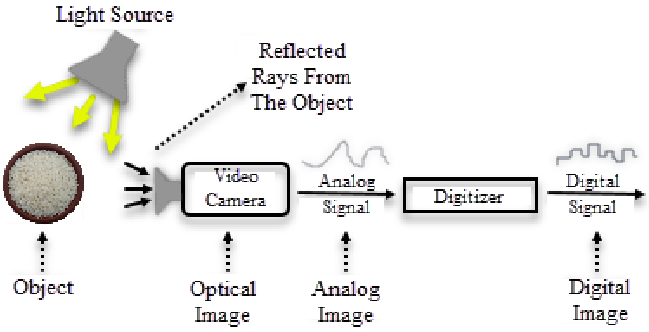


Figure 2
Capture and digitization of images

In Figure 2, reflected rays from the object illuminated by the light source are transferred to the camera. With the help of the camera, the object image is converted into analog form. The digitizer converts analog signals to digital signals, allowing the image to be processed and analyzed in a computer environment. In Figure 3, it is shown the post-digitization status of an image taken with the help of the camera.

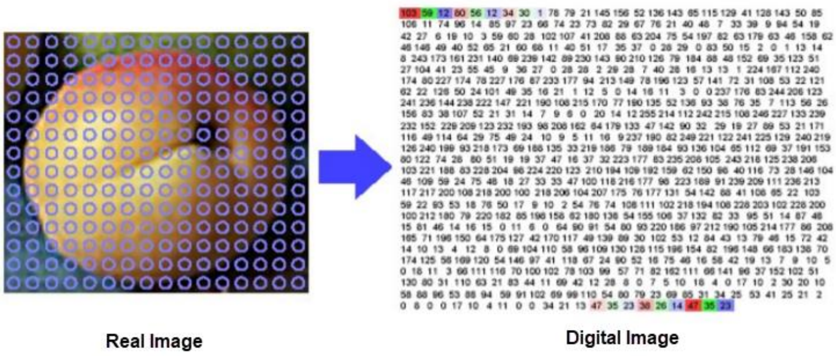


Figure 3
Real and digital image

In order to obtain images of rice varieties, the equipments given in Figure 4 was used. A camera with Ikegami brand CCD imaging sensor was used to acquire images. The camera has advanced sensitivity and high image quality. It displays at PAL resolution of 752(H) X582 (V). Features such as white balance and backlight correction are available. It is powered by 12V DC voltage and has a power consumption below 4.5W (Ikegami 2019).

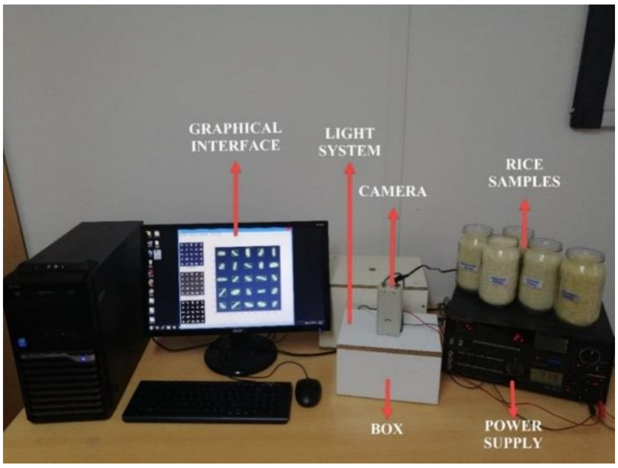


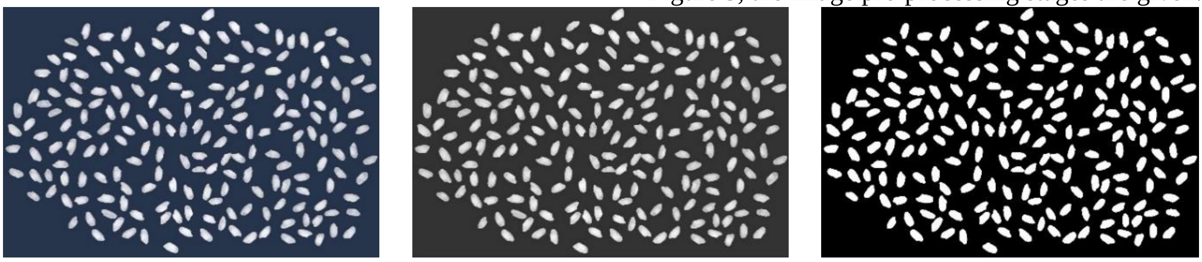
Figure 4
Equipment used to obtain images

The camera used in the study was placed on a closed box with a lighting mechanism in it and a structure to prevent taking light from the outside environment. The box floor background is chosen black for easy processing of the image. The box dimensions are designed so that an image can be taken from an area of 14 cm wide and 18 cm length. The height of the camera to the box floor is set to 15 cm. The images obtained from the camera were transferred to the computer and recorded (Cinar 2019).

2.2. Image Processing

Image processing is the process of transferring digitally acquired images to the computer environment and processing them and then transmitting them to the output unit (Kwan, Mora et al. 1999). In the image processing phase, pre-processes related to images are explained in order to perform feature extraction operations in the most accurate way.

Image processing was carried out with the help of MATLAB software. Images taken from the camera were primarily converted to grayscale images. Later, with the help of otsu method, the grayscale image was converted to a binary image using the global threshold level (Otsu 1979). Unwanted objects in the obtained binary images have been removed and prepared for the feature extraction stage by applying imopen process. In Figure 5, the image pre-processing stages are given.



a b c

Figure 5
Image pre-processing stages ((a) Color Image (b) Grayscale image (c) Post-preprocessing binary image)

2.3. Feature Extraction

Feature extraction is the process of obtaining characteristics such as shape, texture, color and contrast from images as numerical information (Shree and Kumar 2018). In the study, 12 morphological features were extracted and 4 shape features obtained by using these morphological features were extracted. In addition color images, from RGB (red, green, blue) color space to HSV (hue, saturation, value), L*a*b* (L*: lightness, a*: red/green value, b*: blue/yellow value.), YCbCr (y: luminance, cb: chroma blue, cr: chroma red) and XYZ color spaces by performing conversion operations, a total of 90 color features were extracted from five different color spaces (Cinar 2019). In Figure 6, the process stages of feature extraction are given.

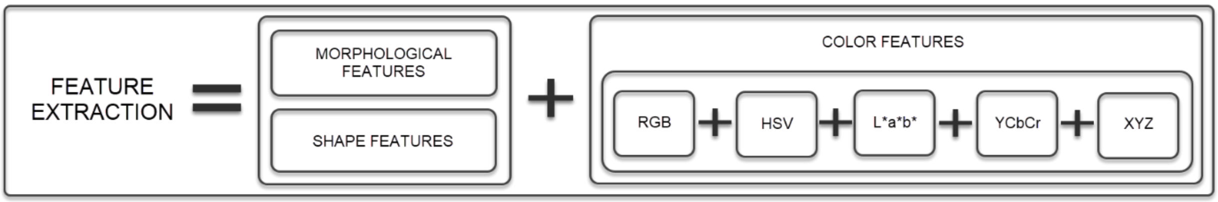


Figure 6
Process stages of feature extraction

2.3.1. Morphological and shape features

Morphological and shape features have been obtained using MATLAB regionprops function components (Buksh, Routh et al. 2014). The feature values obtained represent the number of pixels of each grain of rice. In Table 1, A list of morphological and shape features is given.

Table 1
List of morphological and shape features

Morphological Features						Shape Features	
1	Area	5	Eccentricity	9	Extent	1	Shape_Factor_1
2	Perimeter	6	Equivalent Diameter	10	Aspect Ratio	2	Shape_Factor_2
3	Major Axis Lenght	7	Solidity	11	Roundness	3	Shape_Factor_3
4	Minor Axis Lenght	8	Convex Area	12	Compactness	4	Shape_Factor_4

Explanations of morphological and shape features components are given below (Pazoki, Farokhi et al. 2014);

Area (A): It is the number of pixels within the boundaries of the rice grain area.

Perimeter (P): The rice grain gives the perimeter boundary length of.

Major Axis Lenght (L): It is the longest line that can be drawn on a grain of rice.

Minor Axis Lenght (l): It is the longest line on a grain of rice that can be drawn perpendicular to the major axis.

Eccentricity (Ec): Gives the eccentricity of the circle, which has the same moments as the region.

Equivalent Diameter (ED): It is the diameter of a circle with the same area as the area of the rice grain. The equivalent diameter was calculated according to Equation 1.

$$ED=\sqrt{\frac{4xA}{\pi}} \tag{1}$$

Solidity (S): It is the ratio of pixels in the convex stem to pixels in the rice grain region. Calculated according to Equation 2.

$$S=\frac{A}{CA} \tag{2}$$

Convex Area (CA): It is the number of pixels in the smallest convex Polygon that can accommodate the rice grain area.

Extent (Ex): Bounding is the ratio of pixels in the box to pixels in the rice grain region.

Aspect Ratio (AR): It is calculated by dividing the major axis length by the minor axis length. Calculated according to Equation 3.

$$AR=\frac{L}{l} \tag{3}$$

Roundness (Ro): It is calculated by making use of the area and the perimeter. The Roundness was calculated according to Equation 4.

$$Ro=\frac{4xAx\pi}{P^2} \tag{4}$$

Compactness (Co): It is calculated by dividing the equivalent diameter by the length of the major axis. Calculated according to Equation 5.

$$Co=\frac{ED}{L} \tag{5}$$

Shape Factor: Shape features are calculated using area, major axis and minor axis lengths from morphological features. Calculation formulas for shape factors are given below (Pazoki, Farokhi et al. 2014, Martínez, Gila et al. 2018).

Shape_Factor_1 (SF1): It is calculated by dividing the major axis length by the area. The calculation was made according to Equation 6.

$$SF1=\frac{L}{A} \tag{6}$$

Shape_Factor_2 (SF2): It is calculated by dividing the minor axis length by the area. Calculated according to Equation 7.

$$SF2=\frac{l}{A} \tag{7}$$

Shape_Factor_3 (SF3): The calculation was made according to Equation 8.

$$SF3=\frac{A}{\left(\frac{L}{2}\right)^2 x\ \pi} \tag{8}$$

Shape_Factor_4 (SF4): Calculated according to Equation 9.

$$SF4=\frac{A}{\frac{L}{2} x \frac{l}{2} x\ \pi} \tag{9}$$

2.3.2. Color features

Color images of rice grains used in the study were converted from RGB color space to HSV, L*a*b*, YCbCr and XYZ color spaces with the help of MATLAB software. Information about color spaces and conversion formulas is given below.

Color spaces: It is a mathematical representation used in defining color. Some color fields are formulated to allow people to choose colors, while others are formulated to facilitate the processing of data on machines. Color spaces are designed in three dimensions. Each pixel in the color image consists of 3 color channels (Wu and Sun 2013).

RGB Color space: RGB represents the primary colors red (R), green (G), and blue (B). All other colors are represented by a linear combination of these three main colors (Koschan and Abidi 2008). RGB color values are expressed in a range of values from 0 to 255. It is represented by black color values (0, 0, 0) and white color values (255, 255, 255). The values on the main diagonal represent the gray color values. Since RBG is considered the basic color model for image applications, it is possible to see the image on the screen without requiring any conversion (Ibraheem, Hasan et al. 2012).

HSV Color space: It consists of three parameters: hue (H), saturation (S), and value (V). The hue refers to the dominant wavelength of the color and takes a value between 0-360 degrees. Saturation refers to the vitality of color. A high saturation value causes colors to be vivid, while a low saturation value causes the color to approach tones of gray. The value refers to the brightness of the color, that is, the ratio of white in it. As the brightness value gets closer to zero, the color gets closer to black tones, and otherwise to white tones (García-Mateos, Hernández-Hernández et al. 2015).

RGB-HSV Conversion; RGB-HSV conversion formulas are given between Equation 10 and Equation 14 (Chaudhary, Chaudhari et al. 2012, Pazoki, Farokhi et al. 2014).

$$Max = Max(R,G,B) \tag{10}$$

$$Min = Min(R,G,B) \tag{11}$$

$$V = Max \tag{12}$$

$$S=\frac{Max - Min}{Max} \tag{13}$$

$$H = \begin{cases} \frac{1}{6}\frac{G - B}{Max - Min}, & V=R \\ \frac{1}{6}\frac{B - R}{Max - Min}+\frac{1}{3}, & V=G \\ \frac{1}{6}\frac{R - G}{Max - Min}+\frac{2}{3}, & V=B \\ \text{(Eğer } H<0 \rightarrow H = H+1) & \end{cases} \quad (14)$$

L*a*b* Color space: It is a color space defined by the CIE (International Commission on Illumination) and is also known as the CIELAB. It is often used for color control on objects. In this color space, colors are expressed as three values. The value L * refers to the paleness (0 Black, 100 white). a * value refers to red and green, b * value refers to yellow and blue, and axis values range from -128 to +128 (Beyaz, Ozturk et al. 2010, McGrath, Beck et al. 2017). While these values in L*a*b* space are being designed, it is designed to be perceived by the human eye (McGrath, Beck et al. 2017).

RGB-L*a*b* Conversion; RGB-L*a*b* conversion formulas are given between Equation 15 and Equation 17 (Chaudhary, Chaudhari et al. 2012, Pazoki, Farokhi et al. 2014).

$$L = 0.2126 \text{ x } R + 0.7152 \text{ x } G + 0.0722 \text{ x } B \quad (15)$$

$$A = 1.4749 \text{ x } (0.2213 \text{ x } R - 0.3390 \text{ x } G + 0.1177 \text{ x } B) + 128 \quad (16)$$

$$B = 0.6245 \text{ x } (0.1949 \text{ x } R + 0.6057 \text{ x } G - 0.8006 \text{ x } B) + 128 \quad (17)$$

YCbCr Color space: The YCbCr components are the brightness (Y), blue difference chroma (Cb), and red difference chroma (Cr) components (Ibraheem, Hasan et al. 2012). YCbCr distinguishes color space, color and brightness information. Brightness actually gives information about the amount of light on the image, and colorfulness gives information about the amount of hue ratio on the image (Chaudhary, Chaudhari et al. 2012, Pazoki, Farokhi et al. 2014).

RGB-YCbCr Conversion; RGB-YCbCr conversion formulas are given between Equation 18 and Equation 20 (Chaudhary, Chaudhari et al. 2012, Pazoki, Farokhi et al. 2014).

$$Y = 0.299 \text{ x } R + 0.587 \text{ x } G + 0.114 \text{ x } B \quad (18)$$

$$Cb = - 0.168 \text{ x } R - 0.331 \text{ x } G + 0.500 \text{ x } B \quad (19)$$

$$Cr = 0.500 \text{ x } R - 0.418 \text{ x } G - 0.081 \text{ x } B \quad (20)$$

XYZ Color space: It is the first color space defined by the CIE. Since the tristimulus values required to obtain color matching are in some cases negative, an artificial coordinate system has been developed to convert these values into positive. Thus, the tristimulus value and the Y color brightness value are chosen to be equivalent. XYZ consists of three components. X denotes red, Z denotes blue, and the Y component denotes brightness (Pratt 2001, Ibraheem, Hasan et al. 2012). The XYZ color space covers all the color values visible to humans (Mendoza, Dejmek et al. 2006).

RGB-XYZ Conversion; RGB-XYZ conversion formulas are given between Equation 21 and Equation 23 (Chaudhary, Chaudhari et al. 2012, Pazoki, Farokhi et al. 2014).

$$X = 0.4124 \text{ x } R + 0.3576 \text{ x } G + 0.1805 \text{ x } B \quad (21)$$

$$Y = 0.2126 \text{ x } R + 0.7152 \text{ x } G + 0.722 \text{ x } B \quad (22)$$

$$Z = 0.0193 \text{ x } R + 0.1192 \text{ x } G + 0.9505 \text{ x } B \quad (23)$$

After the conversion process, the features of these color spaces were replicated using the regionprops function in MATLAB with data from the MeanIntensity (mean intensity value of each an image) and PixelValue (number of pixels in the each an image region) components. Using RGB, HSV, L*a*b*, YCbCr and XYZ color spaces, a total of 90 color features were obtained with the components of average, standard deviation, skewness, roundness, entropy and wavelet decomposition for each color channel of the color features of rice images (Arefi, Motlagh et al. 2011). The list of color features is given in Table 2.

The components applied to the color features are described below, respectively (Arefi, Motlagh et al. 2011);

Mean (Me): It is the mean density value. (N variable vector, represents X input data). It is calculated according to Equation 24.

$$Me = \frac{1}{N}\sum_{i=1}^{N} Xi \quad (24)$$

Standard Deviation (SD): Returns the standard deviation of pixel values. The standard deviation is the square root of the variance (V). Calculation equations are given below.

$$V = \frac{1}{N\text{-}1}\sum_{i=1}^{N} (Xi - Me)^2 \quad (25)$$

$$SD = \sqrt{V} \quad (26)$$

Skewness (Skw): Returns the skewness value of pixel values. The calculation formula for Skewness is calculated according to Equation 27.

$$Skw = \frac{\frac{1}{N - 1}\sum_{i=1}^{N} (Xi - Me)^3}{SD^3} \quad (27)$$

Kurtosis (Ku): Returns the kurtosis value of pixel values. Kurtosis is calculated according to Equation 28.

$$Ku = \frac{\frac{1}{N - 1}\sum_{i=1}^{N} (Xi - Me)^4}{SD^4} - 3 \quad (28)$$

Entropy (E): Returns the entropy of the pixel values. Entropy is a statistical measurement used to characterize image texture. Given in Equation 29, pi represents the probability of the state i, while m represents the number of states.

$$E = - \sum_{i=1}^{m} p_i \log_2 p_i \quad (29)$$

Wavelet Decomposition: Returns the wavelet decomposition level of the matrix from pixel value using two-dimensional wavelet. Wavedec2 function was used and wavelet order db4 was selected.

Table 2
List of features obtained from color spaces

Color Space	Mean	Standard Deviation	Skewness	Kurtosis	Entropy	Wavelet Decomposition
RGB	Mean_RGB_R	StdDev_RGB_R	Skewness_RGB_R	Kurtosis_RGB_R	Entropy_RGB_R	Daub4_RGB_R
	Mean_RGB_G	StdDev_RGB_G	Skewness_RGB_G	Kurtosis_RGB_G	Entropy_RGB_G	Daub4_RGB_G
	Mean_RGB_B	StdDev_RGB_B	Skewness_RGB_B	Kurtosis_RGB_B	Entropy_RGB_B	Daub4_RGB_B
HSV	Mean_HSV_H	StdDev_HSV_H	Skewness_HSV_H	Kurtosis_HSV_H	Entropy_HSV_H	Daub4_HSV_H
	Mean_HSV_S	StdDev_HSV_S	Skewness_HSV_S	Kurtosis_HSV_S	Entropy_HSV_S	Daub4_HSV_S
	Mean_HSV_V	StdDev_HSV_V	Skewness_HSV_V	Kurtosis_HSV_V	Entropy_HSV_V	Daub4_HSV_V
L*a*b*	Mean_LAB_L	StdDev_LAB_L	Skewness_LAB_L	Kurtosis_LAB_L	Entropy_LAB_L	Daub4_LAB_L
	Mean_LAB_A	StdDev_LAB_A	Skewness_LAB_A	Kurtosis_LAB_A	Entropy_LAB_A	Daub4_LAB_A
	Mean_LAB_B	StdDev_LAB_B	Skewness_LAB_B	Kurtosis_LAB_B	Entropy_LAB_B	Daub4_LAB_B
YCbCr	Mean_ YCbCr_Y	StdDev_ YCbCr_Y	Skewness_ YCbCr_Y	Kurtosis_ YCbCr_Y	Entropy_ YCbCr_Y	Daub4_ YCbCr_Y
	Mean_YCbCr_Cb	StdDev_ YCbCr _Cb	Skewness_ YCbCr_Cb	Kurtosis_ YCbCr_Cb	Entropy_ YCbCr_Cb	Daub4_ YCbCr_Cb
	Mean_ YCbCr_Cr	StdDev_ YCbCr_Cr	Skewness_ YCbCr_Cr	Kurtosis_ YCbCr_Cr	Entropy_ YCbCr_Cr	Daub4_ YCbCr_Cr
XYZ	Mean_XYZ_X	StdDev_XYZ_X	Skewness_XYZ_X	Kurtosis_XYZ_X	Entropy_XYZ_X	Daub4_XYZ_X
	Mean_XYZ_Y	StdDev_XYZ_Y	Skewness_XYZ_Y	Kurtosis_XYZ_Y	Entropy_XYZ_Y	Daub4_XYZ_Y
	Mean_XYZ_Z	StdDev_XYZ_Z	Skewness_XYZ_Z	Kurtosis_XYZ_Z	Entropy_XYZ_Z	Daub4_XYZ_Z

2.4. Feature Selection

Feature selection is defined as the selection of the best subset that can represent the existing dataset. Feature selection is the process of selecting the best K pieces feature out of the N pieces features in the dataset by evaluating the features according to the method used (Forman 2003, Peralta, Del Río et al. 2015). In feature selection, ANOVA (Analysis of variance), X2 (Chi square) and Gain Ratio were used from commonly used tests.

ANOVA: It is a technique used to determine whether data from a different feature group has a common average. It is a feature selection technique used to determine whether differences in two or more sets of data are statistically significant (Gelman 2006, Beyaz and Ozturk 2016).

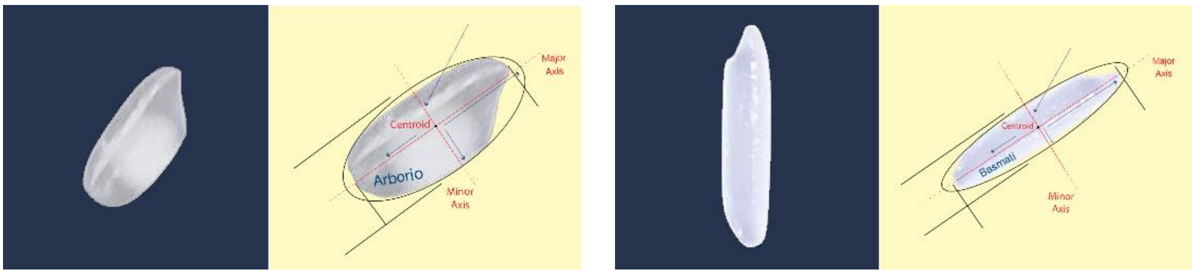
Chi square (X2): It is based on whether the difference between observed and expected frequencies is significant. It is used to test whether there is a relationship between features. As a result of the test, the features that are found to be unrelated are removed from the dataset (Liu and Setiono 1995).

Gain Ratio: The gain ratio is a non-symmetric criterion. Selects the highest rated features from among the features in the dataset with an average or better earnings (Quinlan 1986).

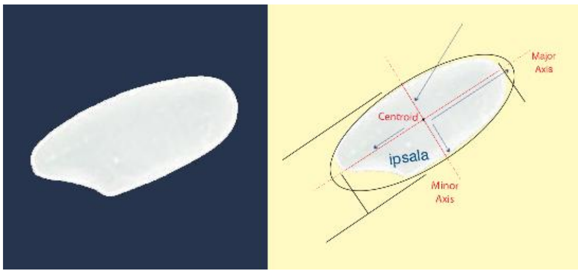
3. Results and Discussion

15 thousand pieces of rice grain image of each rice variety were obtained. In total, studies were carried out on the image of 75 thousand pieces rice grains. These images are pre-processed, free from unwanted substances that can be found on the image and prepared for feature extraction. Image examples of rice varieties are given in Figure 7.

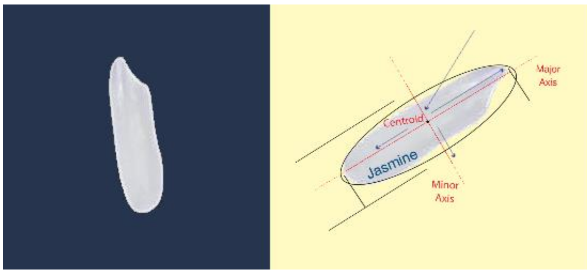
A total of 106 features, including 12 morphological features, 4 shape features and 90 color features obtained from 5 different color spaces were extracted on the pre-processed images. Morphological features have been obtained using regionprops components in MATLAB software. Shape features were also obtained using these morphological features. The statistical information of the morphological and shape features, where each rice variety is evaluated separately, is given in Table 3. The values given in Table 3 are expressed as the number of pixels. The density distribution graphs for the features used to extract morphological and shape features for rice varieties are given in Figure 8.



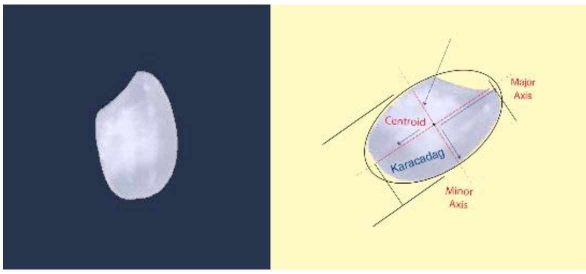
a) Arborio b) Basmati



c) Ipsala



d) Jasmine



e) Karacadag

Figure 7
Image examples of rice varieties

When the density distribution graphs obtained for the 16 features of morphological and shape features are examined, it is observed that Ipsala variety differs from other rice varieties in area, minor axis length, equivalent diameter, convex area and shape factor 1 features. In the density distribution graphs of major axis length, roundness, compactness, shape factor 2, and shape factor 3, it is seen that the Karacadag variety differs from other varieties. When we look at the graphics of solidity, extent, shape factor 4, it is seen that all varieties are mixed with each other. In addition, when the graphics of the area, perimeter, major axis length, minor axis length, equivalent diameter, convex area, shape factor 1, and shape factor 2 features are examined, it is seen that Jasmine variety is divided into two regions in terms of these features.

RGB, HSV, L*a*b, YCbCr and XYZ color spaces were used for color features. Conversion operations to other color spaces were performed by using pixel values for each RGB image. After the color conversion process, a total of 90 color features were obtained using 5 pieces color space data, mean, standard deviation, skewness, roundness, entropy and wavelet decomposition components.

In addition to the statistical information of morphological and shape features given for each of the rice varieties used in the study, the statistical information regarding the morphological, shape, and color features for a total of 75,000 rice grains for all varieties are given in Table 4.

Table 3
Statistical information about morphological and shape features for rice varieties

Rice Variety	Statistics	Area	Perimeter	Major Axis Lenght	Minor Axis Lenght	Eccentricity	Equivalent Diameter	Solidity	Convex Area	Extent	Aspect Ratio	Roundness	Compactness	Shape Factor_1	Shape Factor_2	Shape Factor_3	Shape Factor_4
Arborio	Minimum	4,666	269.03	97.8148	45.6124	0.6639	77.0775	0.9394	4,758	0.4628	1.3373	0.637	0.5551	0.0148	0.0077	0.3081	0.9585
	Mean	7,531.72	339.8524	137.5845	70.4594	0.8574	97.7905	0.9766	7,712.89	0.6833	1.9581	0.8177	0.7114	0.0184	0.0094	0.5066	0.9876
	Maximum	10,336	395.894	166.4845	86.7822	0.9494	114.7179	0.9912	10,537	0.8482	3.1827	0.9364	0.8559	0.0284	0.0135	0.7326	0.9987
	Standard Deviation	781.1792	18.4993	8.0226	4.6157	0.0214	5.1676	0.0068	807.1189	0.0609	0.1336	0.0261	0.0238	0.0013	0.0006	0.034	0.005
	Skewness	-0.4525	-0.5754	-0.5999	-0.6583	-0.9719	-0.631	-0.8178	-0.4404	0.4171	0.4896	-0.0553	0.103	1.2194	1.102	0.3006	-0.6146
	Kurtosis	0.3685	0.5491	0.8186	0.8279	4.8166	0.6368	0.5135	0.3354	-0.8458	2.6305	0.9233	1.9298	2.7985	2.4745	2.1372	0.7341
Basmati	Minimum	4,996	315.324	136.7606	34.673	0.9173	79.7565	0.8775	5,142	0.2788	2.5114	0.3925	0.4006	0.0203	0.0051	0.1605	0.8962
	Mean	7,563.94	426.9058	202.3362	48.4943	0.9702	97.9748	0.9701	7,797.52	0.5038	4.1942	0.5216	0.4853	0.0269	0.0065	0.2361	0.9808
	Maximum	10,835	515.519	255.6472	63.7871	0.9868	117.4545	0.9907	11,198	0.8888	6.1795	0.7253	0.625	0.0369	0.0095	0.3907	0.999
	Standard Deviation	862.1709	28.0444	14.8203	3.7793	0.0064	5.6257	0.0074	891.1227	0.1438	0.4117	0.036	0.0242	0.0021	0.0005	0.0239	0.0084
	Skewness	-0.0173	-0.2519	-0.3145	-0.0928	-1.3871	-0.1713	-1.5679	-0.0211	0.8361	0.0411	0.5374	0.6129	0.5254	0.8159	0.8458	-0.9985
	Kurtosis	-0.2244	-0.1373	0.0635	0.0478	4.6278	-0.1848	6.4033	-0.2273	-0.4332	0.586	1.384	1.4635	0.4738	1.2391	2.1578	2.8281
Ipsala	Minimum	8,277	361.258	150.1548	62.105	0.7882	102.6577	0.9391	8,422	0.4811	1.6249	0.6188	0.5481	0.0113	0.0052	0.3004	0.9528
	Mean	14,048.65	476.4978	197.0714	91.8166	0.8838	133.549	0.9775	14,373.35	0.6629	2.153	0.7757	0.6781	0.0141	0.0066	0.4603	0.9868
	Maximum	21,019	593.698	247.1038	113.4411	0.9537	163.5916	0.9911	21,633	0.8485	3.3246	0.8948	0.7786	0.0205	0.0085	0.6063	0.9987
	Standard Deviation	1,493.60	25.6224	11.1519	6.2955	0.0159	7.2079	0.0066	1,531.84	0.0747	0.148	0.0256	0.0221	0.001	0.0004	0.0296	0.005
	Skewness	-0.3	-0.3858	-0.2676	-0.6003	0.082	-0.4836	-0.4647	-0.2938	0.4447	1.0685	-0.5835	-0.5966	1.096	0.7094	-0.4498	-0.3798
	Kurtosis	0.2751	0.5899	0.5783	0.5467	1.0509	0.499	-0.0272	0.2712	-0.9838	2.6398	1.5165	1.355	2.009	1.2554	1.1494	0.5116
Jasmine	Minimum	3,929	261.04	106.0622	38.8685	0.8124	70.7288	0.9047	4,032	0.3628	1.715	0.5061	0.47	0.0165	0.0053	0.2209	0.9123
	Mean	6,267.31	347.7815	157.0765	50.9507	0.945	88.5446	0.9725	6,442.76	0.5898	3.0892	0.6419	0.565	0.0259	0.0084	0.3197	0.9813
	Maximum	12,43	523.891	243.8224	79.2672	0.9749	125.8029	0.9901	12,809	0.9017	4.4926	0.8725	0.7591	0.0329	0.0121	0.5762	0.9988
	Standard Deviation	1,800.34	49.1774	22.7591	6.849	0.0093	11.8175	0.0068	1,841.54	0.121	0.2519	0.034	0.023	0.003	0.001	0.0261	0.0069
	Skewness	1.4812	1.3798	1.3403	1.3173	-0.73	1.4185	-0.974	1.481	0.5599	0.3896	0.1278	0.1113	-0.9978	-1.0536	0.2801	-0.8945
	Kurtosis	0.5651	0.4025	0.5038	0.5542	3.7978	0.3484	2.6273	0.5717	-0.9152	0.8178	0.3963	0.718	-0.1046	-0.0962	1.0934	2.2343
Karacadag	Minimum	5,014	262.372	96.9683	54.0399	0.6277	79,9001	0,9474	5,11	0.5809	1.2845	0.7521	0.6513	0.0147	0.0087	0.4242	0.9675
	Mean	6,484.38	299.8098	114.9591	72.4257	0.7739	90,7974	0,9828	6,597.79	0.7263	1.5908	0.9056	0.7906	0.0178	0.0112	0.6256	0.9912
	Maximum	9,053	354.371	146.3295	87.4875	0.9041	107,3622	0,9921	9,188	0.8301	2.3401	0.98	0.8799	0.0236	0.0133	0.7743	0.9988
	Standard Deviation	495.5896	11.8513	5.5351	3.6547	0.0324	3,464	0,0055	500.7093	0.0365	0.103	0.023	0.0249	0.0009	0.0005	0.0392	0.0045
	Skewness	0.2597	0.2572	0.2885	-0.2869	-0.2001	0,1437	-1,3887	0.2635	0.2243	0.6858	-0.4829	-0.2903	0.6736	0.0292	-0.172	-0.9543
	Kurtosis	0.1275	0.0976	0.2136	0.6037	0.4063	0,0497	1,7242	0.1269	-0.5409	1.5149	0.58	0.6061	1.3193	-0.0139	0.4605	0.7453

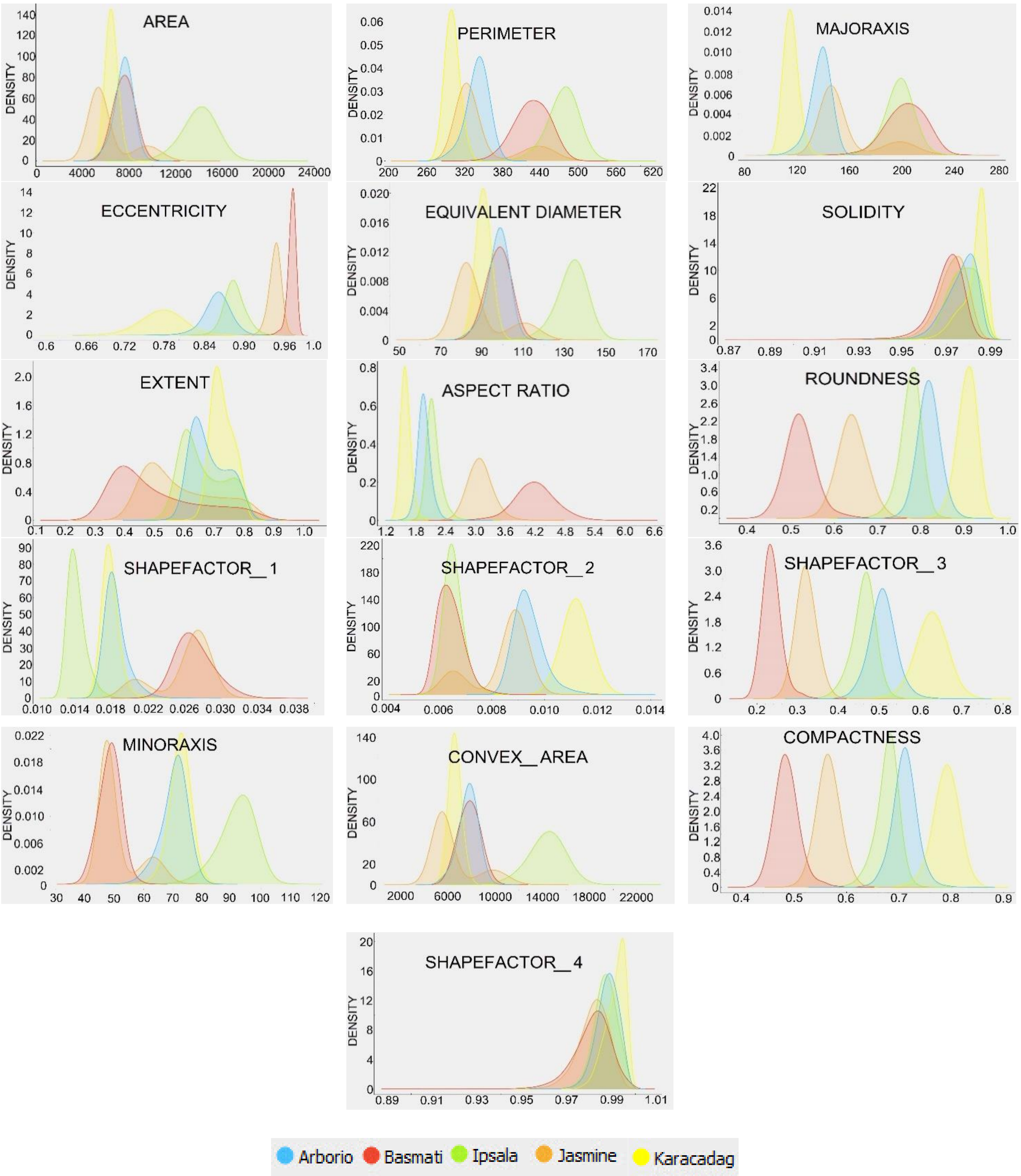


Figure 8
Density distribution graphs for morphological and shape features of rice varieties

Table 4
Statistical information on morphological, shape and color features for all varieties

	Feature	Minimum	Mean	Maximum	Standard Deviation	Skewness	Kurtosis	Feature	Minimum	Mean	Maximum	Standard Deviation	Skewness	Kurtosis
Morphological and Shape	Area	3,929	8,379.20	21,019	3,119.21	1.2189	0.2882	Extent	0.2788	0.6332	0.9017	0.1238	-0.6361	-0.4527
	Perimeter	261.04	378.1695	593.698	70.597	0.3784	-1.2991	Aspect Ratio	1.2845	2.5971	6.1795	0.969	0.8026	-0.5591
	Major Axis Lenght	96.9683	161.8055	255.6472	36.461	0.1279	-1.4311	Roundness	0.3925	0.7325	0.98	0.1386	-0.3623	-1.0926
	Minor Axis Lenght	34.673	66.8293	113.4411	16.6893	0.2691	-0.9539	Compactness	0.4006	0.6461	0.8799	0.1108	-0.1976	-1.1811
	Eccentricity	0.6277	0.8861	0.9868	0.0719	-0.5488	-0.636	Shape_Factor_1	0.0113	0.0206	0.0369	0.0053	0.3516	-1.2157
	Equivalent Diameter	70.7288	101.7313	163.5916	17.8741	1.0127	-0.0988	Shape_Factor_2	0.0051	0.0084	0.0135	0.0019	0.277	-1.2157
	Solidity	0.8775	0.9759	0.9921	0.008	-0.7854	1.8152	Shape_Factor_3	0.1605	0.4297	0.7743	0.1411	0.0087	-1.1657
	Convex Area	4,032	8,584.86	21,633	3,189.30	1.2145	0.2798	Shape_Factor_4	0.8962	0.9855	0.999	0.0073	-1.0799	2.7359
RGB	Mean_RGB_R	153.8	216.398	252.1837	13.3083	0.2342	-0.5234	Kurtosis_RGB_R	1.8413	11.9555	75.2016	7.4795	1.5759	2.9093
	Mean_RGB_G	157.2499	218.2058	252.3231	13.6464	0.2281	-0.6209	Kurtosis_RGB_G	1.8781	12.9443	89.3631	9.303	1.9358	4.5437
	Mean_RGB_B	160.1584	227.9184	252.1085	10.6825	-0.5402	0.2319	Kurtosis_RGB_B	1.8852	14.4673	71.9804	7.7546	1.299	2.6695
	StdDev_RGB_R	6.8171	15.3428	29.9674	3.4542	0.1086	-0.5677	Entropy_RGB_R	-1,36E+10	-4,43E+09	-1,47E+09	2,24E+09	-1.3145	0.3964
	StdDev_RGB_G	6.4117	15.4498	30.7654	3.5626	0.0513	-0.5205	Entropy_RGB_G	-1,38E+10	-4,51E+09	-1,55E+09	2,27E+09	-1.2476	0.2445
	StdDev_RGB_B	6.4175	15.4778	30.858	3.4686	0.0932	-0.3951	Entropy_RGB_B	-1,32E+10	-4,82E+09	-1,61E+09	1,99E+09	-1.1093	0.1689
	Skewness_RGB_R	-6.9388	-1.7785	0.9179	0.9487	-0.7312	0.4464	Daub4_RGB_R	76.8436	108.1788	126.1056	6.658	0.2351	-0.5238
	Skewness_RGB_G	-7.9118	-1.9385	0.7719	1.1119	-1.0563	1.0603	Daub4_RGB_G	78.5723	109.0821	126.1697	6.8276	0.2288	-0.6214
	Skewness_RGB_B	-6.9382	-2.3601	1.1624	0.951	-0.39	-0.0583	Daub4_RGB_B	80.0278	113.9363	126.0672	5.3433	-0.5392	0.229
HSV	Mean_HSV_H	0.0341	0.5477	0.8171	0.1856	-1.3173	0.0519	Kurtosis_HSV_H	1.0093	131.8412	5.504.56	261.9851	5.5243	46.9331
	Mean_HSV_S	0.0014	0.0606	0.2417	0.0367	0.4267	-0.7421	Kurtosis_HSV_S	1.2751	4.6014	76.7594	2.8191	4.1803	35.0858
	Mean_HSV_V	0.6281	0.8981	0.9906	0.0434	-0.5804	0.106	Kurtosis_HSV_V	1.885	15.4024	89.2129	9.05	1.5768	3.6972
	StdDev_HSV_H	0.0021	0.0642	0.4103	0.0614	2.078	5.1374	Entropy_HSV_H	262.2016	2,309.98	4,868.36	602.8766	-0.3309	0.4003
	StdDev_HSV_S	0.003	0.0191	0.0939	0.0105	1.0525	0.5996	Entropy_HSV_S	1.6196	184.7795	975.8339	159.4672	1.1109	0.9359
	StdDev_HSV_V	0.0251	0.0603	0.1184	0.0136	0.0581	-0.503	Entropy_HSV_V	137.2792	1,246.24	4,814.08	468.0433	0.662	0.5961
	Skewness_HSV_H	-70.8665	-4.7977	25.0218	7.1947	-1.3219	4.0856	Daub4_HSV_H	0.0172	0.2738	0.4087	0.0928	-1.3173	0.0518
	Skewness_HSV_S	-2.7134	0.0194	6.9277	1.0434	0.8717	0.8201	Daub4_HSV_S	0.0007	0.0303	0.1208	0.0183	0.4267	-0.7418
	Skewness_HSV_V	-7.9104	-2.4893	0.7774	1.0516	-0.5561	0.2247	Daub4_HSV_V	0.3139	0.449	0.4951	0.0217	-0.5788	0.1021

Table 4 (Continued)
Statistical information on morphological, shape and color features for all varieties

	Feature	Minimum	Mean	Maximum	Standard Deviation	Skewness	Kurtosis	Feature	Minimum	Mean	Maximum	Standard Deviation	Skewness	Kurtosis
LAB	Mean_LAB_L	164.7042	222.2155	252.5057	11.801	0.1584	-0.574	Kurtosis_LAB_L	1.9187	13.8507	89.816	9.3466	1.8296	4.0838
	Mean_LAB_A	118.2685	128.7591	134.9238	2.3522	-1.4086	3.4522	Kurtosis_LAB_A	1	4.2824	85.7886	2.3616	4.5529	65.7742
	Mean_LAB_B	107.3037	122.9208	140.5676	4.8736	0.0887	-0.8352	Kurtosis_LAB_B	0.9999	4.7306	73.882	2.9661	3.694	29.8098
	StdDev_LAB_L	5.8407	14.1272	27.4407	3.2473	0.0105	-0.5068	Entropy_LAB_L	-1,39E+10	-4,65E+09	-1,69E+09	2,25E+09	-12.554	0.2758
	StdDev_LAB_A	0.1061	0.9399	3.2582	0.396	0.7919	-0.06	Entropy_LAB_A	-3,27E+09	-1,34E+09	-6,29E+08	4,75E+08	-12.301	0.3996
	StdDev_LAB_B	0.0	2.2151	10.8211	1.327	1.0337	0.3072	Entropy_LAB_B	-3,47E+09	-1,25E+09	-5,47E+08	5,70E+08	-13.045	0.322
	Skewness_LAB_L	-7.9113	-2.0838	0.6713	1.0723	-0.9676	0.8708	Daub4_LAB_L	82.3006	111.0883	126.2651	5.9049	0.1592	-0.5748
	Skewness_LAB_A	-8.2952	0.1146	9.2085	0.9142	-0.0629	0.7586	Daub4_LAB_A	59.1379	64.3794	67.459	1.1756	-1.409	3.4536
	Skewness_LAB_B	-3.1682	0.5295	8.5405	0.9971	0.2693	0.895	Daub4_LAB_B	53.6538	61.4615	70.284	2.4356	0.0891	-0.8349
YCbCr	Mean_YCbCr_Y	150.4745	203.8867	232.55	10.8661	0.1382	-0.5441	Kurtosis_YCbCr_Y	1.8717	12.8945	83.3924	8.5364	1.7961	3.9484
	Mean_YCbCr_Cb	116.642	132.4831	146.8554	4.3203	-0.1078	-0.8464	Kurtosis_YCbCr_Cb	1	5.1287	14,559.16	58.3584	220.1377	52,636.73
	Mean_YCbCr_Cr	114.724	126.4034	133.0762	2.3508	-2.5254	7.2388	Kurtosis_YCbCr_Cr	0.9999	67.69	13,529.95	560.1777	11.444	145.0333
	StdDev_YCbCr_Y	5.5892	13.1638	25.4601	2.9794	0.0621	-0.4935	Entropy_YCbCr_Y	-1,15E+10	-3,86E+09	-1,38E+09	1,86E+09	-1.2598	0.2959
	StdDev_YCbCr_Cb	0.0	1.969	9.4741	1.1542	1.026	0.3329	Entropy_YCbCr_Cb	-3,22E+09	-1,41E+09	-6,65E+08	4,39E+08	-0.9979	0.0922
	StdDev_YCbCr_Cr	0.0	0.7544	4.1673	0.4073	1.2608	2.3222	Entropy_YCbCr_Cr	-3,29E+09	-1,30E+09	-6,00E+08	5,04E+08	-13.003	0.4479
	Skewness_YCbCr_Y	-7.5318	-1.9555	0.8661	1.0143	-0.9465	0.8552	Daub4_YCbCr_Y	75.1918	101.9254	116.2873	5.4369	0.1391	-0.5449
	Skewness_YCbCr_Cb	-7.5012	-0.4714	120.6575	1.2269	17.507	1,526.02	Daub4_YCbCr_Cb	58.3238	66.2405	73.4247	2.1591	-0.1081	-0.8461
	Skewness_YCbCr_Cr	-9.5813	1.7344	116.3182	7.8688	8.1093	7.25775	Daub4_YCbCr_Cr	57.3634	63.2021	66.5391	1.175	-2.5259	7.2413
XYZ	Mean_XYZ_X	0.3198	0.6841	0.9276	0.0838	0.1899	-0.5239	Kurtosis_XYZ_X	1.6937	8.2797	53.9629	5.2984	1.7544	3.8905
	Mean_XYZ_Y	0.3384	0.7144	0.977	0.0942	0.293	-0.5787	Kurtosis_XYZ_Y	1.698	8.3067	58.7763	5.7698	1.9101	4.5628
	Mean_XYZ_Z	0.3842	0.8427	1.0613	0.0863	-0.3714	-0.1616	Kurtosis_XYZ_Z	1.691	9.274	49.4251	5.1514	1.436	3.3613
	StdDev_XYZ_X	0.0483	0.0979	0.1949	0.0213	0.3779	-0.3846	Entropy_XYZ_X	764.2551	2,588.90	6,322.97	743.4779	1.309	1.3118
	StdDev_XYZ_Y	0.0497	0.1033	0.2119	0.0231	0.3855	-0.4311	Entropy_XYZ_Y	343.7069	2,367.18	5,835.09	596.1722	1.3253	2.5313
	StdDev_XYZ_Z	0.0533	0.1163	0.2262	0.0252	0.2634	-0.3409	Entropy_XYZ_Z	-2,074.59	1,489.69	5,615.51	828.0021	0.3848	1.1058
	Skewness_XYZ_X	-5.7217	-1.1577	1.6876	0.8228	-0.9473	1.1369	Daub4_XYZ_X	0.1597	0.3419	0.4639	0.0419	0.1908	-0.5244
	Skewness_XYZ_Y	-6.1703	-1.1312	1.6338	0.9002	-1.0683	1.3254	Daub4_XYZ_Y	0.169	0.3571	0.4886	0.0471	0.2937	-0.579
	Skewness_XYZ_Z	-5.9538	-1.504	1.8644	0.8295	-0.6169	0.57	Daub4_XYZ_Z	0.1918	0.4212	0.5302	0.0431	-0.3704	-0.1635

Finally, among a total of 106 features of morphological, shape, and color features, the importance order of the effective features was determined by selecting the features with ANOVA, X2, and Gain Ratio tests. The importance order of the effective features obtained from the tests is given in Table 5.

Table 5
Importance order of effective features obtained by ANOVA, X2 and Gain Ratio tests

Features	ANOVA	X^2	Gain Ratio	Features	ANOVA	X^2	Gain Ratio	Features	ANOVA	X^2	Gain Ratio	Features	ANOVA	X^2	Gain Ratio
Roundness	1	1	1	Entropy_ YCbCr_Cb	28	54	25	Daub4_RGB_G	55	57	50	Extent	82	92	72
Compactness	2	2	2	StdDev_HSV_V	29	15	27	Daub4_ YCbCr_Y	56	61	56	Entropy_XYZ_Y	83	93	78
Shape_Factor_3	3	3	3	StdDev_LAB_L	30	19	30	Mean_RGB_G	57	58	51	Skewness_XYZ_X	84	96	96
Aspect Ratio	4	4	4	StdDev_ YCbCr_Y	31	21	32	Mean_ YCbCr_Y	58	62	57	Skewness_ YCbCr_Cb	85	75	70
Eccentricity	5	5	5	StdDev_RGB_G	32	22	33	Daub4_XYZ_X	59	65	60	Daub4_XYZ_Z	86	84	90
Minor Axis Lenght	6	7	9	StdDev_RGB_B	33	20	34	Mean_XYZ_X	60	66	61	Mean_XYZ_Z	87	86	91
Entropy_LAB_B	7	31	13	StdDev_RGB_R	34	16	31	Kurtosis_HSV_V	61	25	42	Daub4_RGB_B	88	87	92
Entropy_RGB_R	8	30	24	StdDev_LAB_B	35	29	40	StdDev_XYZ_X	62	47	63	Mean_RGB_B	89	88	93
Entropy_ YCbCr_Cr	9	24	23	Entropy_XYZ_X	36	68	38	Skewness_RGB_G	63	69	75	Entropy_XYZ_Z	90	95	94
Shape_Factor_2	10	9	7	Kurtosis_RGB_R	37	35	55	StdDev_XYZ_Y	64	49	64	Solidity	91	97	100
Daub4_HSV_H	11	71	66	StdDev_ YCbCr _Cb	38	28	37	Skewness_LAB_L	65	72	76	Shape_Factor_4	92	99	102
Mean_HSV_H	12	70	65	Daub4_RGB_R	39	51	45	Skewness_LAB_A	66	56	69	Mean_ YCbCr_Cr	93	81	84
Shape_Factor_1	13	6	8	Mean_RGB_R	40	52	47	Skewness_RGB_R	67	80	79	Daub4_ YCbCr_Cr	94	82	85
Entropy_LAB_A	14	38	26	Kurtosis_RGB_G	41	26	41	Skewness_ YCbCr_Y	68	78	80	Skewness_XYZ_Z	95	94	98
Entropy_ YCbCr_Y	15	34	21	Kurtosis_LAB_L	42	32	46	Skewness_LAB_B	69	74	71	StdDev_ YCbCr_Cr	96	90	87
Entropy_LAB_L	16	36	20	Kurtosis_ YCbCr_Y	43	33	48	Skewness_HSV_V	70	67	73	Entropy_HSV_H	97	101	77
Entropy_RGB_G	17	37	19	Mean_HSV_S	44	18	36	Kurtosis_XYZ_Z	71	50	62	Skewness_HSV_H	98	102	99
Major Axis Lenght	18	8	6	Daub4_HSV_S	45	17	35	Kurtosis_RGB_B	72	53	68	Kurtosis_HSV_S	99	89	89
Area	19	45	17	Kurtosis_XYZ_Y	46	23	39	Skewness_HSV_S	73	73	74	Kurtosis_LAB_B	100	91	97
Convex Area	20	42	16	Kurtosis_XYZ_X	47	27	43	Skewness_XYZ_Y	74	85	88	StdDev_HSV_H	101	100	95
Equivalent Diameter	21	44	18	StdDev_HSV_S	48	48	44	Daub4_HSV_V	75	76	81	Kurtosis_LAB_A	102	103	103
Perimeter	22	12	10	StdDev_LAB_A	49	43	49	Mean_HSV_V	76	77	82	Kurtosis_HSV_H	103	104	105
Daub4_LAB_B	23	14	15	Daub4_LAB_L	50	59	52	Entropy_HSV_S	77	55	67	Skewness_YCbCr_Cr	104	105	104
Mean_LAB_B	24	13	14	Mean_LAB_L	51	60	53	Entropy_HSV_V	78	83	86	Kurtosis_YCbCr_Cr	105	106	106
Daub4_ YCbCr_Cb	25	11	12	Daub4_XYZ_Y	52	63	58	Mean_LAB_A	79	39	28	Kurtosis_YCbCr_Cb	106	98	101
Mean_YCbCr_Cb	26	10	11	Mean_XYZ_Y	53	64	59	Daub4_LAB_A	80	40	29				
Entropy_RGB_B	27	41	22	StdDev_XYZ_Z	54	46	54	Skewness_RGB_B	81	79	83				

The results from the ANOVA test show that morphological and shape features are the majority among the 10 most effective features. The color features contained within the first 30 features are components derived from L*a*b*, HSV, RGB, and YCbCr color spaces. It is also observed that components derived using the XYZ color space do not exist among the first 35 effective features.

In the X2 test, it is observed that all but one of the 10 most effective features are morphological and shape features. The color features contained within the first 30 features are components derived from L*a*b*, HSV, RGB, and YCbCr color spaces. Only two of the components derived using the XYZ color space are among the first 30 effective features.

When looking at the Gain Ratio test results, it is seen that all 10 most effective features consist of morphological and shape features. The color features contained within the first 30 features are components derived from L*a*b*, HSV, RGB, and YCbCr color spaces. Components derived using the XYZ color space are not included among the first 37 effective features.

Finally, when the ANOVA, X2 and Gain Ratio test results are evaluated together, it is observed that the ranking has not changed in terms of the top 5 effective features. In all tests, roundness, compactness, shape factor 3, aspect ratio and eccentricity features were obtained as the 5 most effective features.

4. Conclusions

A database can be created for the features of using the rice varieties mentioned in the paper. This database can be made available to the relevant sector in the field of agriculture. In addition, information such as the determination of rice varieties, morphological features etc. can be accessed instantly. Furthermore, by increasing the number of rice varieties, database can be extended.

Using the data obtained, an automated and moving image-capturing system can be designed to distinguish rice species, and a machine can be designed to perform operations such as calibration or separation of undesirable substances from varieties.

With the 106 features used in the study, feature extractions can be performed on other varieties of rice. Automatic classification processes of varieties can be performed by using these features. In addition, the effects of effective features on the success of classification can be compared with the ANOVA, X2 and Gain Ratio tests, where effective features are determined.

Classification studies can be done with artificial intelligence methods and new algorithms. The data obtained can be applied to other agricultural products that have not been studied in the literature. Furthermore, by increasing the number of features, a greater number of feature extractions can be realized.

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The Effects of Nitrogen Protoxide and Orizalin on Promotion of Polyploidy in Grapes

Zeki KARA[1,*], Mine ERBOĞA[2], Osman DOĞAN[1]

[1]Selçuk University, Faculty of Agriculture, Department of Horticulture, Konya, Turkey
[2]Selçuk University, Institute of Science, Department of Horticulture, Konya, Turkey

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ABSTRACT

The effort to reach higher yield and quality in grape production without losing the current quality has led researchers to induce polyploidy with chemical mutagens that cause less damage to the environment and researchers to obtain polyploid grape genotypes. The fact that the number of polyploid grape varieties and their production continue to increase creates synergy for research in this direction. In this study, Nitrous Protoxide, Oryzalin and their combined applications were tested to induce polyploidy in seeds and seedlings whose germination was exponentially induced of cvs. Ekşi Kara and Gök Üzüm (both *Vitis vinifera* L.). After 48-h, N_2O at 5 bar pressure was applied to seeds that germinated until root tips were visible, as well as 48-h and/or 96-h 0 (control), 25 µM and 100 µM oryzalin were applied to seedlings whose cotyledon leaves reached full size. Ploidy verification was made by flow cytometry (FC) analysis in selected seedlings by examining the effects of the treatments on the surviving seedling rate, stoma density and size, and the number of chloroplasts. While the morphological and cytological effects of all mutagen applications were found to be significant, only one seedling selected from 25 µM 48-h oryzalin application in Ekşi Kara cultivar was confirmed by FC analysis. Plant survival rate was lower and morphological differences were more pronounced in the combination of N_2O and oryzalin. In future studies, more polyploid induction can be tried with different dose and application time combinations of N_2O and oryzalin.

1. Introduction

In the grape marketing sector, it is important to develop high quality grape varieties with good market value. In grape breeding, it is aimed to develop varieties that can adapt well to different conditions, have high stress tolerance, good yield, and quality characteristics. Stimulated polyploidization technique is a widely used in plant breeding, as it provides various morphological differences in plant growth and development and generally strong environmental adaptation (Esmaeili et al 2020; Wang et al 2020). Although colchicine is effective in autopolyploid induction in vine, it has been sought for alternative mutagens due to its intensive labour requirement, dangerous and high price of higher concentrations (Kihara & Tsunewaki, 1960; Kitamura et al 2009), chimera regeneration, formation of aneuploids, abnormalities in plant development, and low seed productivity (Hassawi & Liang, 1991).

Compounds such as dinitroaniline and phosphonodiamidite have been used in polyploidization studies in recent years (Ramulu et al 1991; Tosca et al 1995; Hansen & Andersen, 1996; Väinölä, 2000; Simmonds et al 2001; Kermani et al 2003; Eeckhaut et al 2004; Pintos et al 2007; Touchell et al 2020). When colchicine, APM and different dinitroanilines (oryzalin, ethalfluralin, trifluralin, pendimethalin, benefin) were compared, a higher polyploidization potential was determined for all dinitroanilines compared to colchicine (Mitrofanova et al 2003).

Antimicrotubular herbicides were thought to be alternatives since they inhibit microtubule in a similar way to colchicine (Yemets & Blume, 2008). It has been reported in different species that nitrous oxide (N_2O) gas is effective in the doubling of the chromosome number in the cell and the formation of polyploid genotypes by preventing the formation of spindle fibbers and the retraction of chromosomes during the cell division process (Kihara & Tsunewaki, 1960; Kitamura et al 2009).

In this study, the effects of combined and separate applications of Nitrous Oxide (N_2O) and Oryzalin on ploidy promotion in cvs. Ekşi Kara and Gök Üzüm (both *Vitis vinifera* L.) were investigated at the morphological and cytological phase.

* Corresponding author email: *zkara@selcuk.edu.tr*

2. Materials and Methods

As the plant material, seeds of cvs. Ekşi Kara and Gök Üzüm which are the most important cultivars of vineyards in the Central Taurus Mountains, were germinated after 90 days of stratification at +4 °C and their root tips became visible. Tetraploid (4x) 'Kyoho' was used as control.

The application doses and durations of Nitrous oxide (N_2O) and Oryzalin as chemical mutagens are presented in Table 1.

In the experiment of induction of polyploidy with N_2O, germinated seeds applied 0, 48-h and 96-h N_2O under 5 bar pressures were sown in production pans in the greenhouse. In the trial of polyploidy induction with oryzalin, two application times (0 (control), 48-h and 96-h), two doses of oryzalin [0 (control), 25 µM and 100 µM] were applied to the seedlings that reached the cotyledon stage. Pure water was applied to control seedlings.

The experiment was set up in a randomized block design with 3 replications, and the number of plants in each replication was 12. In total, morphological, and cytological observations were made on 720 seedlings.

The rate of conversion to plant was calculated by dividing the number of shoot tips applied and viable to the total number of plants. Shoot length was measured with a tape measure at the end of vegetation. The width and length of the stoma were examined with a 40x magnification objective binocular microscope by peeling the lower epidermis of the leaf and placing it on the slide. In addition, chloroplasts were counted in all seedlings and compared with tetraploid (4x) 'Kyoho' grape variety. Flow cytometry (FC) analysis was performed on the selected material by determining the morphological difference. Data were subjected to analysis of variance (ANOVA), means were compared with Duncan multiple comparison test.

3. Results and Discussion

According to the results obtained from the multivariate analysis, the viability rate (%), shoot length (cm), stomatal density (number stoma mm^{-2}) and stomatal size (µm) of the examined traits in seedlings treated with N_2O and oryzalin were significantly higher than chemical mutagen applications ($p<0.01$). affected (Table 1). The shoot length difference between the two grape cultivars treated with mutagen was significant ($p<0.01$). Viability rates were affected by the increase in application time ($p<0.01$). Stoma densities (number stoma mm^{-2}) were significantly affected ($p<0.01$) according to cultivar, mutagen doses and application times (Table 1 and Table 2).

Table 1
Effects on morphological traits on mutagen treated seedlings

N_2O	Oryzalin	Duration	Seedling's mortality	Shoot length	Number of stomata	Stoma length	Stoma width	Number of chloroplasts
				cv. Ekşi Kara				
		Control	97.00±2.65 a	5.57±0.09 a	254.93±5.49 a	27.86±0.43 d	17.82±0.20 d	19.92±0.07 e
0 Bar	25 µM	48-h	83.17±1.65 b	3.02±0.09 de	213.61±1.85 cd	33.17±1.06 c	21.05±0.76 c	23.13±0.81 ab
		96-h	74.03±2.31 c	3.25±0.10 d	232.27±9.51 b	35.46±0.93 ac	22.58±0.67 ab	23.27±0.77 ab
	100 µM	48-h	66.63±5.25 d	2.83±0.10 f	232.64±11.20 b	37.70±0.71 ab	22.86±0.26 ab	24.05±0.47 a
		96-h	58.83±4.52 e	2.77±0.09 f	207.30±5.25 d	35.40±0.90 ac	22.00±0.65 b	22.45±0.22 bc
5 Bar	25 µM	48-h	76.00±1.56 c	4.76±0.25 b	227.24±12.76 bc	37.24±1.51 ab	22.87±0.25 ab	23.52±0.20 ab
		96-h	70.03±4.05 cd	4.83±0.27 b	209.08±7.87 d	38.28±2.82 a	23.06±0.65 a	21.19±0.96 d
	100 µM	48-h	66.07±4.31 d	3.98±0.24 c	212.61±10.60 cd	35.28±1.76 bc	22.59±0.47 ab	21.90±0.24 cd
		96-h	57.47±0.98 e	3.71±0.26 c	204.39±3.57 d	36.19±2.92 ab	22.38±0.35 ab	21.59±0.72 cd
LSD≤.005			6.16	0.29	14.84	2.60	0.91	1.00
				cv. Gök Üzüm				
		Control	100.00±0.00 a	5.71±0.28 a	251.01±5.40 a	31.25±0.42 d	20.37±0.52 c	20.48±0.17 d
0 Bar	25 µM	48-h	88.89±1.92 b	3.58±0.24 e	237.97±7.36 b	32.09±0.47 cd	18.62±0.30 e	20.60±0.53 d
		96-h	76.90±1.03 d	2.97±0.21 f	227.27±5.65 bc	31.83±0.35 d	19.26±0.33 de	21.93±0.46 bc
	100 µM	48-h	70.10±5.11 e	5.00±0.22bc	204.03±5.74 e	35.73±0.95 a	20.82±0.22 bc	22.62±0.56 b
		96-h	55.93±0.64 g	4.67±0.33 bd	223.67±7.07 cd	35.60±0.22 a	21.59±0.73 b	24.50±0.44 a
5 Bar	25 µM	48-h	82.96±5.13 c	5.17±0.26 b	214.86±8.05 de	35.76±0.22 a	23.78±0.28 a	22.33±0.61 bc
		96-h	69.26±1.28 ef	4.83±0.35 bd	227.00±6.14 bc	33.11±0.95 bc	22.82±0.71 a	20.63±0.13 d
	100 µM	48-h	64.45±3.85 f	4.38±0.26 d	208.10±1.66 e	35.89±0.63 a	19.98±0.73 cd	24.89±0.51 a
		96-h	46.67±4.41 h	4.62±0.22 cd	205.08±6.16 e	34.16±0.72 b	20.61±0.70 bc	21.41±0.90 cd
LSD≤.005			5.31	0.49	11.04	1.08	0.98	0.89

3.1. Vitality Rate (%)

The viability rate of the plants treated with oryzalin and/or N_2O decreased ($p<0.05$). In the Oryzalin study, increasing doses and application times decreased the surviving plant rate. The viability rate of seedlings treated with N_2O was higher than those treated with Oryzalin. In cv. Ekşi Kara, the highest rate of viability was obtained in the control (85 ± 1.73%), while the highest seedling death was in the application of 5 bar-48-h N_2O + 100 µM 96-h oryzalin (57.47 ± 0.98% survival).

The highest survival rate in cv. Gök Üzüm was determined in the control (90 ± 2%) and the lowest (46.67% ± 4.40) 5 bar 48-h N_2O + 100 µM 96-h oryzalin application (Table 1 and Table 2).

In a previous study using oryzalin in artificial induction of polyploidy in grapevine, the survival rates of autotetraploid plants ranged from 8.6 to 30%, depending on the variety (Bosco et al 2017). In another study of chromosomal folding in grapevine, while the linear effect of oryzalin on plant survival was determined, it was determined that increasing doses of oryzalin were more effective on plant regeneration than the application time (Sinski et al 2014). Similarly, 120 µM 24-s (33% of surviving explants were tetraploid) was reported to be the most effective of the in vitro applied oryzalin doses in *Watsonia lepida* (Ascough et al 2008). In addition, it has been suggested that the dose and application times that reduce the plant survival rate may provide an advantage by reducing the number of diploid and mixoploid plants. It was also reported that tetraploid plants obtained with high mutagen doses could show abnormalities such as a decrease in growth rate (Väinölä & Repo, 2000).

Table 2
The ANOVA of seedlings differences that treated with N_2O and oryzalin

SV	*df*	Seedling's mortality	Shoot length	Number of stomata	Stoma length	Stoma width	Number of chloroplasts
Cultivar	1	44.374^{ns}	4.647**	0.077^{ns}	0.053^{ns}	3.480*	1.188^{ns}
Dosage	3	1252.006**	2.411**	774.881**	29.165**	23.026*	3.442**
Duration	1	1109.673**	0.058^{ns}	56.587^{ns}	1.364^{ns}	0.551^{ns}	6.538**
Cul. x Dos.	1	24.160^{ns}	5.368**	374.270*	4.043^{ns}	4.076*	7.583**
Cul. x Dur.	1	31.924^{ns}	0.468*	91.650^{ns}	0.189^{ns}	0.204^{ns}	8.178**
Dos. x Dur.	3	7.357^{ns}	0.113^{ns}	78.300^{ns}	3.007^{ns}	1.245^{ns}	8.631**
Cul.xDos.xDur.	1	4.646^{ns}	0.125^{ns}	2072.711**	7.205^{ns}	2.388^{ns}	1.955^{ns}
Failure	40	16.062	0.313	162.343	6.414	4.207	4.792

ns: Not significant, *: Significance level 5%, **: Significance level 1%, Cul.: Cultivar, Dos.: Dosage, Dur.: Duration, SV: Source of variation, *df*: Degree of freedom

3.2. Shoot Length

The effects of mutagen treatments on shoot length were significant (p<0.05). Although less in N_2O applied plants; Increasing mutagen dose and application times caused a decrease in shoot length. While the shoot length was 5.57 ± 0.09 cm in cv. Ekşi Kara control seedling, the lowest shoot length was 2.77 ± 0.09 cm in 100 µM 96-h oryzalin treated seedlings. The shoot length was 5.71 ± 0.28 cm in the control seedlings of cv. Gök Üzüm, and the lowest shoot length was 2.96 ± 0.50 cm in those treated with 25 µM 96-h oryzalin (Table 1 and Table 2).

In previous studies of chromosome folding in grapevine in vitro, significant delays in growth and development of explants were reported (Xie et al 2015). Moreover, autotetraploid plants obtained from artificial polyploidy stimulation with in vitro oryzalin in grapevine had shorter internodes, thicker stems and more compact root systems (Sinski et al 2014).

3.3. Stoma Data

The effects of mutagen applications on stomatal length, width and density were significant (p<0.05). All applications increased the stoma length and width. In cv. Ekşi Kara, stomatal length was 27.86 ± 0.43 µm in control seedlings; It was measured as 38.28 ± 2.82 µm in the application of 5 bar N_2O + 25 µM 96-h oryzalin. The stomatal length was 31.24 ± 2.20 µm in the control seedlings of the cv. Gök Üzüm, while it was 36.55 ± 2.64 µm in those treated with 5 bar N_2O + 100 µM 48-h oryzalin. While the stomatal width of cv. Ekşi Kara control seedlings was 17.82 ± 0.20 µm; The largest stomata were 23.06 ± 1.14 µm with 5 bar N_2O + 25 µM 96-h oryzalin applied plants. While the stomatal width was measured as 20.36 ± 1.47 µm in the control seedlings of the cv. Gök Üzüm; The largest stomata were in seedlings treated with 23.78 ± 0.81 µm and 5 bar N_2O + 25 µM 48-h oryzalin (Table 1 and Table 2).

All mutagen applications reduced stoma density. In cv. Ekşi Kara, the densest stoma was 254.93 ± 14.81 mm^{-2} in the control, the least stoma was 204.39 ± 3.57 mm^{-2} in 5 bar N_2O + 100 µM 96-h oryzalin application. In cv. Gök Üzüm, the highest stomatal density was 251.008 ± 13.54 mm^{-2} in control seedlings, and the minimum 204.02 ± 5.73 mm^{-2} in 100 µM 48-h oryzalin application.

In a similar previous study, the stomatal length of tetraploid plants was one-third longer than diploids (Xie et al 2015). In another grapevine polyploidy study, researchers reported that the stomatal length and width values of the tetraploid plants they obtained showed a positive correlation with the chromosome numbers and a negative correlation with the stomatal density (Sinski et al 2014).

3.4. Chloroplast Count Data

Both mutagen treatments increased chloroplast numbers significantly (p<0.05) in seedlings of both grape cultivars. In cv. Ekşi Kara, 19.92 ± 0.07 chloroplasts per cell were determined in control seedlings, while the maximum number of chloroplasts was 24.05 ± 0.47 in 100 µM+48-h oryzalin applied seedlings. The number of chloroplasts per cell in cv. Gök Üzüm ranged from 20.48 ± 0.16 units in control seedlings to 24.88 ± 7.32 units in the application of 5 bar N_2O + 100 µM 48-h oryzalin (Table 1 and Table 2).

In a previous study, it was reported that the number of chloroplasts in stomatal guard cells was determined as 14.4±1.81 in diploids and 23.5±1.78 in tetraploids, as an effective and economic indicator for distinguishing tetraploids (Xie et al 2015). Other previous studies have suggested that stomatal size measurement and chloroplast count in stomatal guard cells are the most economical and efficient methods for detecting polyploidy (de Carvalho et al 2005; Yang et al 2006). In addition, it has been reported that chloroplast densities in stomatal guard cells are directly proportional to the number of chromosomes (Sinski et al 2014; Lan et al 2020). In the polyploid induction made in Alocasia plant, the best result was obtained with a 24-hour application of 0.01% oryzalin, with a rate of 15.4% tetraploid plant (Thao et al 2003).

3.5. Flow Cytometry (FC) Analysis

Morphological differences were determined by all observations, and seedlings suspected of being polyploid were selected and flow cytometry analysis was performed on them. Selected 1 Ekşi Kara seedling treated with 25 μM 48-h oryzalin was confirmed to be tetraploid (Figure 1).

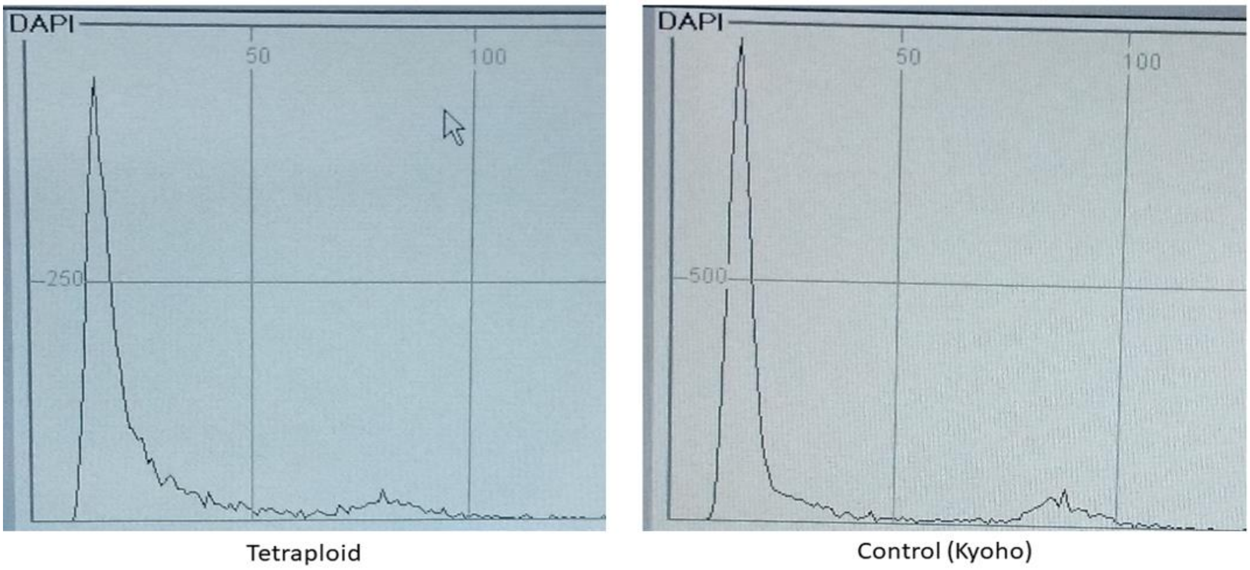

Figure 1
FC histograms of selected tetraploid cv. Ekşi Kara seedling (left) and tetraploid cv. Kyoho (right)

4. Conclusion

Our study is the first report in which N_2O and oryzalin were used together to obtain polyploidy in grapevine *in vivo*. By the N_2O and Oryzalin and combined mutagen applications, significant changes were recorded in morphological analyses in all the seedlings that survived and developed. In combination with N_2O + oryzalin, plant survival rate was lower and morphological differences were more pronounced. It was confirmed that changes in stomatal density and size, and changes in the number of chloroplasts could be used in the preselection of polyploidy prior to flow cytometry. In future studies, more polyploid induction can be tried with different dose and administration time combinations of N_2O and oryzalin. All surviving plants in our study are being preserved and monitored.

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Determination of Combining Ability in Sunflower Parents According to Line X Tester Analysis Method

Gülsüm KAYIŞOĞLU[1,*], Rahim ADA[2]

[1]Selçuk University, The Graduate School Of Natural And Applied Science, Department of Plant Breeding and Genetic, Konya, Turkey

[2] Selçuk University, Faculty of Agriculture, Department of Field Crops, Konya, Turkey

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ABSTRACT

In this research, which including two cytoplasmic male sterile female (CMS) lines and six recessives branching male tester parent (RfRf), 12 hybrids (F_1) were obtained by crossing the female and male lines in the Plant Breeding Greenhouse of Field Crops Department in 2018-19 winter period. Field trial was carried out in 2019 as four replications. Plant height (cm), head diameter (cm), 100 seed weight (g), seed yield (kg ha^{-1}), oil content (%) and oil yield (kg ha^{-1}) were investigated. Multiple sequence variance analysis, general and specific combining abilities, proportional relationships of some genetic parameters, heterosis and heterobeltiosis values, narrow and broad heritability were calculated. In conclusion, in this research; some of their agricultural characteristics and heritability were determined upon obtaining high yield sunflower lines. Considering the general combination abilities of parents for F1 generation, R31 was identified as appropriate parents for plant height; R02 for head diameter; R02 for 100 seed weight; R61 and R80 for yield seed yield and oil yield; and R61 for yield content. Considering the special combination abilities of hybrids in F1 generation, all hybrids were found to be significant and positive for plant height, 100 seed weight and oil content. RAM-1 X R80, RAM-19 X R61, RAM-1 X R31, RAM-19 X R71 and RAM-19 X R02 hybrids were found to be significant and positive for yield seed yield and oil yield.

1. Introduction

In Turkey, hybrid seeds are used in sunflower oil production, and hybrid varieties are preferred by producers due their features such as high yield performance, superior quality characteristics, uniform appearance, resistance to certain diseases and orobanche (Kaya et al., 2009). Therefore, breeding programs in sunflower in the world are generally directed towards hybrid breeding (Khan et al. 2004; Dagustu et al. 2012). In these breeding programs, the target is to obtain, to develop inbred lines with properties such as high seed yield and oil content, hence high oil yield, earliness, resistance to diseases and pests and so on, and to obtain hybrids with desired performance through them taking advantage of hybrid overgrowth (Vear, 2016). However, it is also very important that these bred lines maintain their superior performance under different environmental conditions. Therefore, knowing the factors affecting the oil yield, yield elements that play a decisive role and the relationships between, in the sunflower, which is an oil crop plant, will provide great benefit to the breeders in achieving the desired goals (Todorova, 1984; Kaya et al., 2009; Gontcharov, 2012).

By using heterosis effect in hybrid breeding, seed and oil yield is increased (Vranceanu 1998). In addition, hybrid sunflower is more stable than open pollinated varieties, highly auto-fertile and quite uniform in ripening. The high performance of hybrid combinations depends on the ability of the parents to combine. Breeders have been working on combining ability for many reasons. Some of these are: development of superior synthetics or hybrids, and planning of breeding programs by determining gene effects in terms of some properties of the material studied (Tan, 1993).

The Line x Tester analysis method provides breeders with a systematic approach to selection of parents for crossbreeding and enables them to crossbreed between superior parents to achieve the desired properties. At the same time, it can help breeders choose the most effective breeding method that can be used since it allows the estimation of different genetic parameters (Bozbek, 2006). It has been modified from the top crosses method proposed

* Corresponding author email: *glsm.kysgl@gmail.com*

by Kempthorne (1957) by Line x tester analysis and this method can be used as a suitable method in hybrid breeding where particularly cytoplasmic vicious and restorer lines play a role as parents (Singh and Chaudhary, 1977; Yildirim and Büyükbaykal, 1980; Yildirim and Cakir, 1986; Tan, 1993).

In the line x tester analysis, hybridizations are performed in all possible combinations with a group of tester parents which are used as males and parents which are used as female. The F_1 hybrid generations obtained are repeatedly assayed (Turgut, 2003). Singh and Chaudhary (1977) stated that this method could be applied in a trial plan including and excluding parents.

This study was carried out to determine the parent (broodstock) and hybrids having superior general and special combination ability in two main lines and six male testers and their 12 F_1 hybrids.

2. Materials and Methods

The research was carried out in Experimental Field of Selcuk University Faculty of Agriculture in Konya in 2019. 12 hybrids (F_1) to be used in the study were obtained using two cytoplasmic male sterile (CMS) main lines developed by Assoc. Prof. Dr. Rahim ADA (RAM-1 and RAM-19) and six recessives branching male (RfRf) testers (R02, R06, R31, R61, R71 and R80) by hybridization of female (CMS) and male (Restorer) lines in the Plant Breeding Greenhouse of Field Crops Department in 2018-19 winter period. The hybrids obtained were RAM-1xR02, RAM-1xR06, RAM-1xR31, RAM-1xR61, RAM-1xR71, RAM-1xR80, RAM-19xR02, RAM-19xR06, RAM-19xR31, RAM-19xR61, RAM19xR71 and RAM19xR80.

According to the Randomized Blocks Experimental Design, each row was accepted as one block in the field experiment established with four replications. The distance between blocks was 2 m, the width of rows was 25 cm and the length of the rows was 3 m; and each block is 2.1 m^2.

The soil of the trial area had a clay loam structure and its pH was slightly alkalic (7.70) and was low in organic matter (1.39%). These soils, having high lime content (691.5 kg ha^{-1}), had low phosphorus level (13.4 kg ha^{-1}) and no salinity problems.

The cultivation process for the trial was carried out on 24th April 2019. 400 kg ha^{-1} 15-15-15 compound fertilizer and 150 kg ha^{-1} urea (46% N), as top fertilizer, were given along with the cultivation. The field was hoed 3 times depending on the weed condition. Drip irrigation was done 4 times depending on the water needs of the plants. Harvesting was completed in the third week of September. Plant height (cm), head diameter (cm), 100-seed weight (g), seed yield (kg ha^{-1}), oil content (%) and oil yield (kg ha^{-1}) were investigated.

The data obtained from observation, measurement and analysis on F_1 plants in the research were subjected to preliminary variance analysis according to the Randomized Blocks Experimental Pattern in the "MSTAT-C Statistical Software" on PC. Multiple sequence (line x tester) analysis was performed on traits with a variation of 1% and 5% significance level between hybrids (Kempthorne, 1957; Sing and Chaudhary, 1979). Griffing (1956) was referred to in determining the effect and variance power of general and specific combining ability; Stansfield (1969), in determining the degree of inheritance; Fonseca and Pattersan (1968), in calculating the percentage values of heterosis and heterobeltiosis; Yurtsever (1984), in determining the relationships between traits.

Weather data of the experimental area

The weather data of the experimental area in 2019 with growing seasons for the sunflower with the long-term climatic data were depicted in Table 1. Data showed that the average temperature was 11,1ºC, 19,7ºC, 23,0ºC, 24,3ºC, 24,8ºC and 21,0ºC; whereas, the total amount of rainfall was 26,4 mm, 5,4 mm, 31,8 mm, 8,2 mm, 2,0 mm and 10,2 mm during the month of April, May, June, July, August and September, 2019 respectively (Table 1).

3. Results and Discussion

According to the average of the squares, the genotypes had a variation of 1% significance level for all traits examined. Parents also had a variation of 1% significance level except the oil yield. Plant height, seed yield and oil yield characteristics of hybrids were at 1% significance level, while the head diameter and 100 seed weight characteristics had a variation of 5% significance level. Parent x Hybrid Interaction, plant height (cm), head diameter (cm), 100 seed weight (g), seed yield (kg ha^{-1}), oil content (%) and oil yield (kg ha^{-1}) characteristics had a variation of 1% significance level. The lines had 1% significance level for seed yield and oil yield. The testers had a variation at %1 significance level for plant height, seed yield and oil yield, while head diameter and 100 seed weight had a variation at 5% significance level. Line x Testers Interaction had a variation at 1% significance level for seed yield and oil yield (Table 2).

Table 1
Weather data of the experimental areas (Konya)

The long-term*	April	May	June	July	August	September
Max. T. (ºC)	26,56	29,75	33,98	37,16	36,18	33,76
Min. T. (ºC)	2,12	6,82	11,18	15,6	15,64	9,94
Avg. T. (ºC)	13,2	17,22	21,45	25,68	25,22	20,94
T. Rain. (mm)	24,31	44,62	42,53	3,11	8,08	15,48
Humd. (%)	49,28	50,73	46,04	33,9	35,16	39,1
2019	April	May	June	July	August	September
Max. T. (ºC)	25,6	34,5	34,4	37,7	36,3	32,8
Min. T. (ºC)	0,5	6,9	14,5	14,1	15,4	8,2
Avg. T. (ºC)	11,1	19,7	23,0	24,3	24,8	21,0
T. Rain. (mm)	26,4	5,4	31,8	8,2	2,0	10,2
Humd. (%)	58,5	39,8	47,2	39,7	40,7	41,3

Anonymous,2020. General Directorate of Meteorology-Ankara. * 2010-2018.

Table 2
Sunflower F_1 hybrids examined for seed yield and some yield properties of the average number of squares calculated by multiple sequence analysis method

Source of Variations	DF	Plant Height	Head Diameter	100 Seed Weight
Replication	3	592.919	56.226	7.052
Genotypes	19	1098.474**	64.144**	16.152**
Parents	7	826.838**	11.468	5.990**
Crosses	11	255.547**	15.670*	3.221*
Parent x Cross Int.	1	12272.126**	966.084**	229.523**
Lines	1	83.240	0.043	5.434
Testers	5	457.888**	19.290*	5.014*
Line x Testers Int.	5	87.667	15.176	0.985
Error	57	94.386	6.663	1.535
Source of Variations	DF	Seed Yield	Oil Content	Oil Yield
Replication	3	1116.234	0.545	177.994
Genotypes	19	15050.549**	40.956**	2734.649**
Parents	7	3246.206**	32.233**	481.206*
Crosses	11	20108.185**	50.205**	3779.727**
Parent x Cross Int.	1	42046.955**	0.285	7012.890**
Lines	1	9600.920**	199.078**	5713.806**
Testers	5	9095.315**	39.401**	2200.790**
Line x Testers Int.	5	33222.508**	31.234**	4971.847**
Error	57	994.570	1.810	166.497

* : $p < 0.05$; ** : $p < 0.01$

Table 3
General combinations ability variance estimation (σ^2GKY), special combination ability variance estimation (σ^2ÖKY), additive variance (σ^2D), proportional relationships with dominance variance (σ^2H) for traits examined in Sunflower F1 hybrids

Specifications	σ^2GKY	σ^2ÖKY	σ^2GKY/ σ^2ÖKY	σ^2D	σ^2H	$(H/D)^{1/2}$
Plant Height	4.809	25.597	0.188	9.618	-1.680	0.418
Head Diameter	0.014	1.200	0.012	0.028	2.128	8.668
100 Seed Weight	0.064	0.526	0.122	0.128	-0.138	1.037
Yield	-375.671	4328.366	----	-751.341	8056.984	3.275
Oil Content	0.543	21.661	0.025	1.087	7.356	2.602
Oil Yield	-34.149	1055.012	----	-68.299	1201.337	4.194

3.1. Plant Height (cm)

In the research, it was observed that the average plant height of the parents ranged between 60.86 cm (R61) and 99.21 cm (R06), and the length of F_1 hybrids ranged between 87.74 cm (RAM-1 X R61) and 117 cm (RAM-1 X R31) (Table 4). It was found that the GCA variance for plant height was 4,809 and the SCA variance was 25,597 in F_1 hybrids (Head 2). In the study, when the plant height was examined for the plant height, RAM-1, RAM-19 and R61 varieties showed significant and negative ($p < 0.01$) GCA, R31 ($p<0.01$) varieties showed significant and positive, R80 ($p<0.05$) showed significant and positive GCA (Table 4). When the SCA effects of hybrids were examined in the F_1 generation, it was observed that all hybrids (p

<0.01) were genotypes with positive and significant SCA effect (Table 4). When Table 4 was analyzed, the average heterosis value determined in F_1 generation was 37.4% and the heterobeltiosis value was 24.40%. While none of the hybrids had statistically significant heterosis value in terms of this investigated feature, heterobeltiosis values of RAM-1 X R31, RAM-1 X R61, RAM-1 X R80, RAM-19 X R31, RAM-19 X R61 and RAM-19 X-R80 were statistically significant ($p<0.01$) and positive; and the values of RAM-1 X R02, RAM-19 X R02 and RAM-19 X R71 hybrids were significant ($p<0.05$) and positive (Table 4). Heterosis values ranged between 18.69% (RAM-19 X R06) and 62.41% (RAM-1 X R80), and heterobeltiosis values ranged between 5.84% (RAM-19 X R06) and 39.76% (RAM-19 X R80). In F_1 generation, the heritability level in the broad sense was 63.07 and the heritability level in the narrow sense was 30.50 for plant height. The high heritability level in a broad sense and the low heritability level in a narrow sense meant that the effect of environmental variance of this trait was high. It is in agreement with the findings of some researchers (Goksoy et al., 1999; Tan, 1993).

Table 4
Sunflower Parent and F_1 Hybrids of plant height, general combination ability (GCA), special combination ability (SCA), heterosis (Hs), heterobeltiosis (Hb) and heritability

Parents	Averages (cm)	GCA	SCA	Hs (%)	Hb (%)
RAM-1	65.05	-27.635**			
RAM-19	77.72	-25.660**			
R02	86.56	-3.714			
R06	99.21	-1.077			
R31	88.57	9.253**			
R61	60.86	-12.408**			
R71	98.54	3.786			
R80	73.95	4.161*			
Hybrids					
RAM-1 X R02	101.63		33.942**	34.06	17.40*
RAM-1 X R06	106.03		37.171**	29.09	6.87
RAM-1 X R31	117.00		41.471**	52.32	32.10**
RAM-1 X R61	87.74		24.119**	39.36	34.87**
RAM-1 X R71	106.38		32.775**	30.05	7.95
RAM-1 X R80	112.88		41.067**	62.41	52.64**
RAM-19 X R02	104.13		34.641**	26.76	20.29*
RAM-19 X R06	105.00		33.171**	18.69	5.84
RAM-19 X R31	114.69		35.757**	37.94	29.50**
RAM-19 X R61	100.63		38.669**	45.22	29.47**
RAM-19 X R71	114.38		40.808**	29.78	16.07*
RAM-19 X R80	108.63		32.766**	43.24	39.76**
LSD %1 : 18.342	mean Hs % : 37.41	h^2 :	30.50	Lines	3.435
LSD %5 : 13.808	mean Hb % : 24.40	H^2 :	63.07	SH Testers	1.983
				SH (SCA)	4.858

3.2. Head Diameter (cm)

In the research, it was observed that the average head diameter ranged between 8.03 cm (R61) and 12.97 cm (RAM-1) in the parents, and between 14.08 (RAM-1 X R61) and 19.68 cm (RAM-1 X R02) in F_1 hybrids (Table 5). It was found that the GCA variance for plant height was 4,809 and the SCA variance was 25,597 in F_1 hybrids (Table 3). The fact that ʋ2GCA/ʋ2SCA ratios were below 1 and (H/D) 1/2 ratios were over 1 in F_1 hybrids examined for head diameter showed that the non-additive dominant gene was effective on the heredity of this trait (Table 3). In the experiment, when the GCA was examined for the head diameter, RAM-1, RAM-19 and R06 varieties showed significant and negative ($p<0.01$), R31 ($p<0.05$) varieties showed significant and negative, R02 ($p <0.01$) varieties showed significant and positive GCA (Table 5). When the SCA effects of the hybrids were examined, RAM-19 X R06 and RAM-19 X R31 ($p<0.05$) had positive and significant SCA, and all other hybrids except for the RAM-1 X R61 hybrid were genotypes that had significant ($p<0.01$) and positive SCA effect. (Table 5). When Table 5 was analyzed, the average heterosis value determined in F_1 generation was 58.16% and the heterobeltiosis value was 38.65%.

In terms of this characteristic examined, the heterosis values of RAM-1 X R02, RAM-19 X R02 and RAM-19 X R61 hybrids were significant ($p<0.01$) and positive; those of RAM-1 X R06, RAM-1 X R31, RAM-1 X R80, RAM-19 X R71 and RAM-19 X R80 hybrids are significant ($p<0.05$) and positive, the heterobeltiosis values of RAM-1 X R02, RAM-1 X R31, RAM-19 X R02, RAM-19 X R61, RAM-19 X R71 and RAM-19 X R80 hybrids were statistically significant ($p<0.01$) and positive, and those of RAM-1 X R06, RAM-1 X R71 and RAM-1 X R80 hybrids were significant ($p<0.05$) and positive (Table 5). Heterosis values ranged between 32.25% (RAM-19 X R06) and 84.51% (RAM-19 X R61), and heterobeltiosis values, between 8.52% (RAM-1 X R61) and 63.02% (RAM-19 X R02). In F_1 generation, the heritability in the broad sense was 57.48 and the heritability in the narrow sense was 0.74 for head diameter. The high heritability level in a broad sense and the low heritability level in a narrow sense meant that the effect of environmental variance of this trait was high. These results contradict the findings of some other researchers working on the same subject (Hussain et al., 2017; Tan, 1993). These different results may be due to different genetic conditions and environmental conditions used.

Table 5
Sunflower Parent and F_1 Hybrids head diameter, general combination ability (GCA), special combination ability (SCA), heterosis (Hs), heterobeltiosis (Hb) and heritability

Parents	Averages (cm)	GCA	SCA	Hs (%)	Hb (%)
RAM-1	12.97	-4.322**			
RAM-19	11.89	-4.277**			
R02	10.29	2.328**			
R06	9.67	-1.653**			
R31	8.68	-1.287*			
R61	8.03	-0.972			
R71	10.58	0.948			
R80	8.72	0.636			
Hybrids					
RAM-1 X R02	19.68		6.738**	69.17**	51,70**
RAM-1 X R06	16.84		6.936**	48.77*	29,82*
RAM-1 X R31	17.50		7.453**	61.64*	34,93**
RAM-1 X R61	14.08		2.571	34.03	8,52
RAM-1 X R71	17.42		5.105**	47.88	34,27*
RAM-1 X R80	17.50		5.531**	61.36*	34,93*
RAM-19 X R02	19.38		6.279**	74.75**	63,02**
RAM-19 X R06	14.25		3.426*	32.25	19,90
RAM-19 X R31	14.32		3.154*	39.25	20,49
RAM-19 X R61	18.38		8.245**	84.51**	54,61**
RAM-19 X R71	18.88		6.992**	68.02*	58,81**
RAM-19 X R80	18.17		6.358**	76.32*	52,84**

LSD %1 :	4.874	mean Hs % :	58.16	h^2:	0,74	SH (Lines) :	0,913
LSD %5 :	3.669	Mean Hb %	38.65	H^2:	57,48	SH (Testers)	0,527
						SH (SCA) :	1,291

3.3. 100 Seed Weight (g)

In this study, values of 100 seed weights of parents and F_1 hybrids are given in Table 6. In the study, the average weight of 100 seeds of the parents ranged from 2.15 g (R31) to 5.36 g (RAM-1), whereas the values in F_1 hybrids ranged from 5.51 g (RAM-1 X R31) to 8.02 g (RAM-19 X R02) (Table 6). It is seen that the variance of the GCA is 0.064 and the variance of SCA is 0.526 for 100 seed weights of F_1 hybrids (Table 3). The fact that ʋ2GCA/ʋ2SCA ratios were below 1 and (H/D) 1/2 ratios were over 1 in F_1 hybrids examined for 100 seed weight showed that the non-additive dominant gene was effective on the heredity of this trait (Table 3).

In the experiment, when the GCA was examined for the 100 seed weight, RAM-1, RAM-19 and R31 varieties among testers were significant ($p<0.01$) and negative GCA, R02 variety showed significant ($p<0.05$) and negative GCA (Table 6). When the SCA effects of the hybrids were examined, RAM-1 X R61 and RAM-19 X R31 hybrids were positive and significant ($p<0.05$), and all other hybrids were significant ($p<0.01$) and positive in F_1 generation (Table 6). When Table 6 was analyzed, the average heterosis value determined in F_1 generation is 70.22% and the heterobeltiosis value was 29.07%. In terms of this characteristic examined, the heterosis value of RAM-1 X R31 was significant ($p<0.05$) and positive; all the other hybrids were significant ($p<0.01$) and positive, the heterobeltiosis values of RAM-1 X R02, RAM-1 X R31, RAM-19 X R02 and RAM-19 X R71 were significant ($p<0.01$) and positive; and the heterobeltiosis values of RAM-19 X R06 and RAM-19 X R61 were significant ($p<0.05$) and positive (Table 6). Heterosis values were between 45.97% (RAM-1 X R71) and 101.57% (RAM-19 X R02), and heterobeltiosis values were between 2.75% (RAM-1 X R31) and 53.98% (RAM-19 X R02). In F_1 generation, the heritability in the broad sense was 52.33 and the heritability in the narrow sense was 34.22 for 100 seed weight. The high heritability level in a broad sense and the low heritability level in a narrow sense meant that the effect of environmental variance of this trait was high. It is in agreement with the findings of some researchers (Chandra et al., 2011; Göksoy et al., 1999; Tan, 1993).

Table 6
Sunflower Parent and F_1 Hybrids 100 seed weight averages, general combining ability (GCA), special combination ability (SCA), heterosis (Hs), heterobeltiosis (Hb) and heritability

Parents		Averages (cm)	GCA		SCA	Hs (%)	Hb (%)
RAM-1		5.36	-1.957**				
RAM-19		5.21	-1.452**				
R02		2.75	1.134**				
R06		2.79	0.287				
R31		2.15	-1.301**				
R61		2.59	-0.161				
R71		3.17	0.172				
R80		2.85	-0.132				
Hybrids							
RAM-1 X R02		7.88			2.892**	94.27**	46.95**
RAM-1 X R06		6.95			2.503**	70.51**	29.65
RAM-1 X R31		5.51			2.167**	46.69*	2.75**
RAM-1 X R61		5.80			1.417*	45.97**	8.21
RAM-1 X R71		6.30			1.744**	47.57**	17.44
RAM-1 X R80		6.44			2.238**	56.83**	20.09
RAM-19 X R02		8.02			2.409**	101.57**	53.98**
RAM-19 X R06		7.26			2.233**	81.32**	39.25*
RAM-19 X R31		5.52			1.511*	50.07**	6.00
RAM-19 X R61		7.51			3.021**	92.63**	44.15*
RAM-19 X R71		7.68			2.915**	83.24**	47.41**
RAM-19 X R80		6.93			2.219**	71.96**	33.01
LSD %1 :	2.339	*mean* Hs % :	70.22	h^2	34.22	SH (*Lines)*	0.438
LSD %5 :	1.761	*Mean* Hb % :	29.07	H^2	52.33	SH (Testers)	0.253
						SH (SCA)	0.620

3.4. Seed Yield (kg ha^{-1})

In this study, values of yield seed yield of parents and F_1 hybrids are given in Table 7. In the research, it was observed that the average yield seed yield of the parents ranged between 1714.1 45 kg ha^{-1} (R31) and 2616.1 45 kg ha^{-1} (R06), and seed yield of F_1 hybrids ranged between 1684.5 kg ha^{-1} (RAM-1 X R71) and 4292.9 45 kg ha^{-1} (RAM-1 X R80) (Table 7). It was found that the GCA variance was -375.671 and the SCA variance was 4328.366 in F_1 hybrids for yield seed yield. The fact that ʋ2GCA/ʋ2SCA ratios were negative in F_1 hybrids examined for yield seed yield showed that the additive genes, i.e. dominant genes were effective on the heredity of this trait. (Table 3). In the experiment, when the GCA was examined for yield seed yield, RAM-1, RAM-19 and R31 varieties among testers showed significant (p<0.01) and negative GCA; R61 and R80 varieties showed significant (p<0.01) and negative GCA; and R31 variety showed significant (p<0.05) and negative GCA (Table 7). When the SCA effects of the hybrids were examined, it was found that all other hybrids except for RAM-1 X R61, RAM-1 X R71, RAM-19 X R31 and RAM-19 X R80 hybrids were genotypes that had significant (p<0.01) and positive SCA effect. (Table 7). When Table 7 was examined, it was found the average heterosis value determined in F_1 generation was 20.62%; the heterobeltiosis value was 13.99%. In terms of this trait, none of the hybrids had statistically significant heterosis values, whereas the heterobeltiosis values of RAM-1 X R31, RAM-1 X R80 and RAM-19 X R61 hybrids were positive and (p<0.01) significant, the value of RAM-1 X R71 hybrid was negative and significant (p<0.01); the value of RAM-19 X R02 was positive, and the value of RAM-19 X R31 was negative and significant (p<0.05). Heterosis values ranged between -28.25% (RAM-1 X R71) and 91.11% (RAM-1 X R80), and heterobeltiosis values, between -32.78% (RAM-1 X R71) and 74.05% (RAM-1 X R80). In F_1 generation, the heritability in the broad sense was 95.05 and the heritability in the narrow sense was 9.95 for yield seed yield (Table 7). The high heritability level in a broad sense and the low heritability level in a narrow sense meant that the effect of environmental variance of this trait was high. It is in agreement with the findings of some researchers (Gouri Shankar et al., 2007; Kang et al., 2013; Göksoy et al., 1999; Radić et al., 1977).

Table 7
Sunflower parent and F_1 hybrids Average seed yield, general combination ability (GCA), special combination ability (SCA), heterosis (Hs), heterobeltiosis (Hb) and heritability

Parents	Averages (kg ha^{-1})	GCA	SCA	Hs (%)	Hb (%)
RAM-1	2222	-58.124**			
RAM-19	2407	-79.338**			
R02	2171	4.962			
R06	2616	-3.513			
R31	1714	-16.075*			
R61	2147	22.206**			
R71	2506	-53.122**			
R80	2466	45.543**			
Hybrids					
RAM-1 X R02	2633		56.974**	19.84	18.45
RAM-1 X R06	2931		105.180**	21.13	12.02
RAM-1 X R31	3269		162.824**	66.06	47.07**
RAM-1 X R61	2535		26.729	16.04	14.06
RAM-1 X R71	1685		-11.352	-28.75	-32.78**
RAM-1 X R80	4293		237.781**	83.11	74.05**
RAM-19 X R02	2965		129.617**	29.53	23.16*
RAM-19 X R06	2498		75.761**	-0.56	-4.52
RAM-19 X R31	1908		9.743	-7.40	-20.73*
RAM-19 X R61	3408		171.358**	49.64	41.54**
RAM-19 X R71	3669		159.221**	12.01	9.81
RAM-19 X R80	2822		-24.136	-13.15	-14.19

LSD %1	59.541	mean Hs %	20.62	h^2	9.95	SH (Lines)	11.150
LSD %5	44.823	Mean Hb %	13.99	H^2	95.05	SH (Testers)	6.437
						SH (SCA)	15.768

3.5. Oil Content (%)

In this study, values of oil content of parents and F_1 hybrids are given in Table 8. In the research, it was observed that the average oil content of the parents ranged between 3518% (R06) and 42.20% (R80), and oil content of F_1 hybrids ranged between 36.07% (RAM-19 X R06) and 48.11%(RAM-1 X R61) (Table 8). It was found that the GCA variance for oil content was 0.543 and the SCA variance was 21.661 in F_1 hybrids (Table 3). The fact that ʋ2GCA/ʋ2SCA ratios were below 1 and (H/D) 1/2 ratios were over 1 in F_1 hybrids examined for oil content showed that the non-additive dominant gene was effective on the heredity of this trait (Table 3).

In the experiment, when the GCA was examined for the oil content, RAM-1, RAM-19 and R06 varieties showed significant (p <0.01) and negative GCA, R02 and R61 varieties showed significant (p<0.01) and negative GCA (Table 8). When the SCA effects of hybrids were examined in the F_1 generation, it was observed that all hybrids were genotypes with positive and significant (p <0.01) SCA effect (Table 8). When Table 8 was analyzed, the average heterosis value determined in F_1 generation was 2.10% and the heterobeltiosis value was -2.31%. In terms of this characteristic examined, the heterosis values of AM-1 X R02, RAM-1 X R61 and RAM-1 X R80 hybrids were significant (p<0.01) and negative; those of RAM-19 X R02 and RAM-19 X R06 hybrids were significant (p<0.05) and negative, the heterobeltiosis values of RAM-19 X R06, RAM-19 X R61, RAM-19 X R71 and RAM-19 X R80 hybrids were significant (p<0.01) and negative, those of RAM-1 X R31 and RAM-19 X R02 hybrids were significant (p<0.05) and negative, that of RAM-1 X R61 was significant (p<0.01) and positive; and that of RAM-1 X R71 hybrid was significant (p<0.05) and positive (Table 8). Heterosis values were between -11.66% (RAM-19 X R80) and 24.90% (RAM-1 X R61), and heterobeltiosis values were -%13.43 (RAM-19 X R80) and 15.52% (RAM-1 X R61). In F_1 generation, the heritability in the broad sense was 96.39 and the heritability in the narrow sense was 12.22 for oil content. The high heritability level in a broad sense and the low heritability level in a narrow sense meant that the effect of environmental variance of this trait was high. These results were also reported by Chandra et al., (2011) and Tan, (1993).

Table 8
Sunflower Parent and F_1 Hybrids average oil content, general combining ability (GCA), special combining ability (SCA), heterosis (Hs), heterobeltiosis (Hb) and heritability

Parents	Averages (%)	GCA	SCA	Hs (%)	Hb (%)
RAM-1	35.40	-8.443**			
RAM-19	40.50	-11.498**			
R02	41.28	0.793**			
R06	35.18	-3.722**			
R31	41.73	-0.126			
R61	41.65	3.167**			
R71	40.16	0.163			
R80	42.20	-0.275			
Hybrids					
RAM-1 X R02	42.35		13.747**	10.45**	2.58
RAM-1 X R06	36.26		10.142**	2.74	2.43
RAM-1 X R31	39.53		10.918**	2.52	-5.26*
RAM-1 X R61	48.11		19.064**	24.90**	15.52**
RAM-1 X R71	42.58		14.693**	12.72	6.03*
RAM-1 X R80	42.69		15.275**	10.04**	1.17
RAM-19 X R02	39.01		13.370**	-4.61*	-5.51*
RAM-19 X R06	36.07		13.966**	-4.69*	-10.95**
RAM-19 X R31	39.98		15.588**	-2.76	-4.18
RAM-19 X R61	37.99		9.636**	-7.52**	-8.79**
RAM-19 X R71	37.51		12.004**	-6.99**	-7.39**
RAM-19 X R80	36.53		11.131**	-11.66**	-13.43**

LSD %1	2.540	mean Hs %	2.10	h^2	12.22	SH (Lines)	0.476
LSD %5	1.912	mean Hb %	-2.31	H^2	96.39	SH (Testers)	0.275
						SH (SCA)	0.673

3.6. Oil Yield (kg ha^{-1})

In this study, values of oil yield of parents and F_1 hybrids are given in Table 9. In the research, it was observed that the average oil yield of the parents ranged between 716.2 45 kg ha^{-1} (R31) and 1042.7 45 kg ha^{-1} (R80), and the oil yield of F_1 hybrids ranged between 714.1 45 kg ha^{-1} (RAM-1 X R71) and 129.68 kg/da (RAM-19 X R61) (Table 9). It was found that the GCA variance for oil yield was -34.149 and the SCA variance was 1055.012 in F_1 hybrids (Table 3). The fact that ²GCA/²SCA ratios were negative in F_1 hybrids examined for oil yield showed that the additive genes, i.e. dominant genes were effective on the heredity of this trait. (Table 3). In the experiment, when the GCA was examined for oil yield, RAM-1, RAM-19, R06 and R71 varieties among testers showed significant ($p<0.01$) and negative GCA; R61 and R80 varieties showed significant ($p<0.01$) and negative GCA; and R31 variety showed significant ($p<0.05$) and negative GCA (Table 8). When the SCA effects of the hybrids were examined, it was found that RAM-19 x R80 had negative and significant ($p<0.05$) SCA effect, and all the other hybrids except for RAM-1 X R71 and RAM19 X R31 hybrids were genotypes that had significant ($p<0.01$) and positive SCA effect. (Table 9).

When Table 9 was examined, it was found the average heterosis value determined in F_1 generation was 23.48%; the heterobeltiosis value was 15.48%. In terms of this trait, none of the hybrids had statistically significant heterosis values, whereas the heterobeltiosis values of RAM-1 X R31, RAM-1 X R61, RAM-1 X R80 and RAM-19 X R61 hybrids were positive and ($p<0.01$) significant, the value of RAM-1 X R71 and RAM-19 X R80 hybrids were negative and significant ($p<0.01$); the value of RAM-1 X R02 was positive, and significant ($p<0.05$) and the value of RAM-19 X R31 was negative and significant ($p<0.05$). Heterosis values were between -23.21% (RAM-19 X R80) and 99.91% (RAM-1 X R80), and heterobeltiosis values were between -29.11% (RAM-1 X R71) and 75.40% (RAM-1 X R80). In F_1 generation, the heritability in the broad sense was 95.59 and the heritability in the narrow sense was 5.81 for oil yield (Table 9). The high heritability level in a broad sense and and the low heritability level in a narrow sense meant that the effect of environmental variance of this trait was high.

Table 9
Sunflower Parent and F_1 Hybrids average oil yield, general combination ability (GCA), special combination ability (SCA), heterosis (Hs), heterobeltiosis (Hb) and heritability

Parents	Averages (kg ha^{-1})	GCA	SCA	Hs (%)	Hb (%)
RAM-1	787.0	-19.218**			
RAM-19	973.6	-35.583**			
R02	896.1	3.805			
R06	922.0	-11.393**			
R31	716.2	-6.958*			
R61	894.1	16.259**			
R71	1007.4	-22.269**			
R80	1042.7	20.556**			
Hybrids					
RAM-1 X R02	1113.5		24.148**	32.31	24.26*
RAM-1 X R06	1061.9		32.470**	24.27	15.17
RAM-1 X R31	1291.8		58.684**	71.87	64.13**
RAM-1 X R61	1220.5		25.956**	45.19	36.50**
RAM-1 X R71	714.1		-3.029	-20.41	-29.11**
RAM-1 X R80	1829.0		102.795**	99.91	75.40**
RAM-19 X R02	1154.7		51.457**	23.51	18.59
RAM-19 X R06	902.3		33.003**	-4.81	-7.33
RAM-19 X R31	761.1		9.745	-9.92	-21.83*
RAM-19 X R61	1296.8		57.951**	38.86	33.19**
RAM-19 X R71	1032.5		61.250**	4.25	2.50
RAM-19 X R80	774.2		-16.024*	-23.21	-25.76**

LSD %1 :	24.361	mean Hs %	23.48	h^2	5.81	SH (Lines)	4.562
LSD %5 :	18.339	mean Hb %	15.48	H^2	95.59	SH (Testers)	2.634
						SH (SCA)	6.452

4. Conclusion

Considering the general combination abilities of parents for F_1 generation, R31 was identified as appropriate parents for plant height; R02 for head diameter; R02 for 100 seed weight; R61 and R80 for yield seed yield and oil yield; and R61 for yield content. Considering the special combination abilities of hybrids in F_1 generation, all hybrids were found to be significant and positive for plant height, 100 seed weight and oil content. All hybrids except for the RAM-1 X R61 were significant and positive for the head diameter. RAM-1 X R80, RAM-19 X R61, RAM-1 X R31, RAM-19 X R71 and RAM-19 X R02 hybrids were found to be significant and positive for yield seed yield and oil yield. As a result of the study, there is a sufficient genetic variation in the population addressed in terms of the agricultural features examined.

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Determination of Natural Flow Rates of Some Chickpea Varieties on Different Surfaces and Surface Angles

Yusuf ÇİFTCİ[1], Keziban YALÇIN DOKUMACI[1], Mehmet Hakan SONMETE[1*]

[1]Selçuk University, Faculty of Agriculture, Department of Agricultural Machinery and Technologies Engineering, Konya, Turkey

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ABSTRACT

In this study, some physical properties of Gökçe chickpea (registered variety) and Spanish chickpea (local population) variety cultivated in Konya Province were determined. Flow rates of chickpea varieties were detected at four different conveyor channel angles (24°, 28°, 32° and 36°) and on three different surfaces (galvanized sheet, painted sheet and steel sheet surfaces). Length, width, thickness, geometric mean diameter, sphericity, repose angle, thousand grain weight, bulk density values of Gökçe chickpeas at 8.90% moisture level are 10.09 mm, 7.34 mm, 7.74 mm and 8.30 mm, 0.82, 18.04°, 364.6 g and 746.82 kg m^{-3} and for Spanish variety at 10.40% moisture level are 12.16 mm, 8.22 mm, 9.01 mm, 9.65 mm, 0.79, 16.01°, 481.96 g, 690.21 kg m^{-3} were determined respectively. These varieties, the static friction coefficient values on galvanized sheet, painted sheet and steel sheet surfaces were found to be 0.335 and 0.351, 0.401 and 0.445, 0.388 and 0.435, respectively. Flow rates increased as the channel conveyor angle increased on galvanized sheet, painted sheet and steel sheet surfaces. The increase rates for Gökçe and Spanish chickpeas on these surfaces were 207% and 189%, 630% and 522%, 291% and 202%, respectively. When the surface averages are taken into account, average flow rates of 1.69 kg s^{-1} on the galvanized sheet surface, 1.24 kg s^{-1} on the painted sheet surface and 1.54 kg s^{-1} on the steel sheet surface were obtained and found to be statistically significant. The difference between the surfaces is due to the roughness values of the surfaces. The lowest average roughness value was found on the galvanized sheet surface (1.13 µm), and the highest on the painted surface (2.06 µm). According to the triple interaction results, the highest flow rate value was obtained on the galvanized sheet surface and the conveyor angle of 36° in both chickpea varieties, and the lowest flow values were obtained at the conveyor angle of 24° on the painted sheet surface.

1. Introduction

Chickpea (*Cicer arietinum L.*) is a plant cultivated and produced among the edible legumes in our country. It is generally produced in arid and semi-arid regions. In addition to this, it is the most resistant to salt among the edible legumes. With this aspect, chickpea is one of the legumes that can be preferred in crop rotation systems to be applied in places where salinity is a problem.

Chickpea is the most resistant to heat and drought among legumes. It can easily grow in soils with low organic matter, and it has an important place in reducing fallow areas by entering crop rotation in our arid regions where winter grain-fallow rotation is applied.

*Corresponding author email: *sonmete@selcuk.edu.tr*

Chickpeas are an important source of protein. Chickpea, which is also rich in carbohydrates, vitamins and minerals, has a versatile consumption area as edible, snack and animal feed. Chickpea seeds contain 29% protein, 3% fiber, 59% carbonhydrate, 5% oil and 4% ash. Although chickpea is deficient in the sulfur-containing amino acids cystine and methionine, it is a rich source of arginine and lysine (Iqbal et al. 2006).

Edible legumes have positive effects on soil fertility as well as their high protein content. They are taproot and form a symbiosis with *Rhizobium spp.* bacteria and bind the free nitrogen of the air to the soil (6.4-21.6 kg da^{-1} pure nitrogen). The fact that the C/N coefficient of plant residues remaining after the harvest of edible legumes is quite low increases the importance of these plants (Karakullukçu and Adak 2008).

The cultivation area, yield and production values of chickpea in dry agriculture in Turkey and Konya are given in Table 1. When the data of 2020 are examined, it is seen that chickpea is cultivated on an area of 5 115

607 da in Turkey and there is a total production of 630 000 tonnes. Chickpea cultivation area in Konya Region constitutes 7.17% of the cultivation area in our country and meets 7.95% of its production, and its yield value is approximately 111.4% higher than the average of Turkey.

Table 1
Cultivation area, yield and production values of dried chickpeas in Turkey and Konya (TÜİK 2021)

	Cultivated area (da)		Yield (kg da^{-1})		Production (tonnes)	
Years	Turkey	Konya	Turkey	Konya	Turkey	Konya
2016	3 595 289	213 707	129	151	455 000	32 139
2017	3 953 099	246 491	120	143	470 000	34 586
2018	5 144 159	351 518	123	139	630 000	48 845
2019	5 205 951	336 196	122	139	630 000	46 858
2020	5 115 607	366 721	123	137	630 000	50 112

Nowadays, more local varieties are grown and put on markets. These varieties are also used in breeding studies to develop new cultivars. Production of local cultivars does not be compatible organic farming principles as these are grown by using conventional farming systems.

Physico-mechanical properties of chickpea play a significant role in designment of storage structures and selection of storage material (Kashaninejad et al. 2006).

Physical properties and the orifice shape of the material influence the flow rate of the material. While the unit weight has an impact on compressibility and internal friction angle of grain, the shape of the grain and distribution are important in terms of flowability (Fitzpatrick et al. 2004).

In most studies, it has focused on the flow rate of material, the relationship between material properties and flow rate and regularity of flow in different orifices. For example, it has been investigated by Mohsenin (1986) that factors affecting grain flow such as silo geometry, orifice height diameter ratio and shape. And also, the equation describing the grain flow rate has been formed.

Turgut et al. (1994 and 1995) determined the flow smoothness of triple super phosphate and diammonium phosphate fertilizer in various orifices. They found that the flow smoothness of triple super phosphate fertilizer was significantly influenced by the shape and openness of the orifice. The most irregular output occurred in rectangular orifices and in the small voids. They concluded that the flow rate of diammonium phosphate fertilizers, in terms of orifice shape and the base angle was affected, and the height of the storage material has no effect on the flow rate.

Değirmencioğlu et al. (1998) developed a model for the flow of fertilizers and seeds through orifices of different sizes and shapes under the influence of gravity, by using dimensional analysis. Dimensionless terms were created in accordance with the Buckingham Pi-theorem and the estimation model was developed with multiple regression analysis and the estimation coefficient of the model was found to be 92.3%. The most important variable in the model was the angle of the orifice with the horizontal and it was determined that it could explain 61.5% of the variation in the obtained data.

Değirmencioğlu et al. (1999) measured the flow rate of granular fertilizers (urea, TSP and ammonium nitrate) and wheat and corn seeds from circular and sharp-edged (non-circular) orifices in laboratory conditions on a mass basis. They developed a new prediction model to estimate the flow rate from larger holes using stepwise regression analysis and determined the prediction coefficient of the model to be 94.7%.

Elaskar et al. (2001) obtained velocity profiles by recording images during the flow of sorghum through rough and smooth channels. They determined that the velocity increased by 113% when the surface of sliding slope angles increased from 18º to 38º. In addition, they reported that the maximum velocity occurred at an inclination angle of 37º, and the flow rate increased by 377% when the inclination angle increased from 30º to 37º.

Akar (2003) stated that natural flow rates of okra cultivars such as Amasya and Sultani depending on channel shape, flow angle and moisture content. In the study, it was determined that the increase in moisture content caused a decrease in the flow rate for both varieties, and the natural flow could not be achieved at a slope angle of 30º depending on the moisture content. It has also been reported that the highest natural flow was obtained in the experiment performed in the galvanized steel channel.

Karacabey et al. (2009) a model developed for the flow of fertilizers and seeds under the effect of gravity through orifices with different shapes and cross-sections was analyzed with the genetic algorithm approach, which is one of the solution methods, and they determined the measures that provide the highest material flow of trapezoidal orifices. As a result of the optimization, different sizes were determined in trapezoidal orifices with the same area, and 42-1280 kg h^{-1} increases were achieved in the flow of seed and fertilizer material for orifices with a cross-sectional area of 2000 mm^2, 7800 mm^2, 17600 mm^2 and 31400 mm^2 used in modeling.

Soliman et al. (2017) Jasmine (long) and Sakha (short) three different varieties of rice seeds in their study examined the flow properties depending on the variables in 3 groups. In the first group, three different diameter openings (6, 8 and 10 cm), in the second group three different openings and 4 different angles from the elbow (15°, 30°, 45° and 60°) and in the last group three different holes and five different slopes (0°, 15°, 30°, 45° and 60°) and three pipe lengths (0.5, 1 and 1.5 m) determined the natural flow properties of rice grains. The highest fluidity factor was obtained as 4.193 in White Sakha 103 variety with a surface friction coefficient of 0.30 µs, a spherical value of 0.540, and a thousand-grain weight of 21.80 g.

Arıkaymak and Hacıseferoğulları (2021) reported that the flow was seen on all surfaces and at all channel angles in the Horoz dry bean variety. Furthermore, in Sarıkız and Basara varieties, flow occurred on the painted sheet surface at 24° channel angle, while in Sarıkız variety, there was no flow on the flat sheet surface at 24° channel angle. Among the cultivars, the highest average flow rate (1.61 kg s^{-1}) occured in Horoz dry bean cultivar and such a flow rate was mostly achieved by surface profile and grain physical characteristics. The greatest flow rate was obtained from 360 conveyor channel angle (2.01 kg s^{-1}). Surface roughness affected flow rates and the greatest flow rate on galvanized sheet surface with the lowest surface roughness was measured as 1.66 kg s^{-1}. In line with these findings, it was revealed that the physical properties of the cultivars, the channel roughness and angle affected the flow rates.

In the present study, some physical properties of two chickpea varieties, which are Gökçe (registered variety) and Spanish (local population) chickpea varieties cultivated in Konya Province, were determined and natural flow rates of these chickpea varieties on different flow surfaces and angles were detected.

2. Materials and Methods

In the trials, Gökçe and Spanish chickpea varieties, all of which are cultivated in the Konya region, were used. The thousand grain weight of crops was measured on electronic balance (accuracy of ±0.001 g). In order to measure the thousand grain weight, 100 grains of each variety were randomly selected as three replications. Dimensional properties of grains were measured by using a micrometer with an accuracy of 0.01 mm. Sphericity (Φ) and geometric mean diameter (D_g) values were calculated using the following equations (Mohsenin, 1986).

$D_g = (LWT)^{1/3}$

$\Phi = D_g / L$

Where,

D_g : Geometric mean diameter (mm)

Φ : Sphericity (-)

L : Length of grain (mm)

W : Width of grain (mm)

T : Thickness of grain (mm)

The materials were slowly and freely poured on a flat surface to determine the angle of repose. The spilled materials formed a cone on the surface. The angles of repose were determined by calculating the tangent value (internal friction coefficient) of the horizontal angle of this cone.

Each crop was poured into a one-liter glass vessel with a velocity of 12 seconds per liter. After shedding the excess crop up to the vessel, the remaining crop was weighed. The bulk density was determined by dividing the weight of grain by the volume of the vessel.

The coefficient of static friction was measured on painted sheet, steel sheet and galvanized sheet surfaces. In this measurement, one end of the friction surface was connected to the endless screw and the chickpea grain was placed on the surface and gradually raised with the screw. During the sliding movement of the chickpea grain on the surface, the horizontal and vertical height values were read from the ruler and recorded. Afterwards, the static friction coefficient was calculated by using the tangent value of the angle found. Baryeh (2001) and Gezer et al. (2003) have used similar methods in their researches.

The experimental test unit used in this research was designed specifically and the flow rate values were determined using it. This test unit consists of a cylindrical feeding hopper cone-shaped with a capacity of five liters, it has a discharge slide valve that can be opened easily at the bottom of the hopper and a conveyor channel. The channel conveyors which have three different surfaces such as steel sheet, galvanized steel sheet and painted steel sheet and have a 0.5 m length were used in the experiment. Inside radius and overall inside depth of the channel conveyor are 53 mm and 78 mm, respectively. A special structure is made to support the channel and hopper. A schematic view of this experimental test unit was shown in Figure 1.

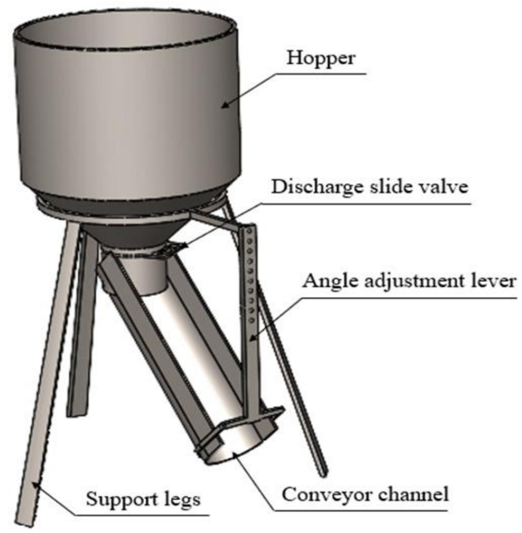

Figure 1
A schematic view of natural flow test unit

During the trials, after a cone-shaped hopper was filled with material, the discharge slide valve cover at the bottom of the storage was opened, and the digital chronometer was operated simultaneously. When all material passed to the channel conveyor, the chronometer was stopped and the elapsed time was determined.

These values were divided by the mass of the material, and the natural flow rates were determined as three replications.

There are three values to define surface roughness: R_z (the measured roughness value), R_a (the mathematical average roughness value), and R_{max} (the biggest surface roughness). R_z, R_a and R_{max} values were measured by using profilmeter device (measurement range of 0-150 µm, Marsurf brand) repeated three times (Figure 2).

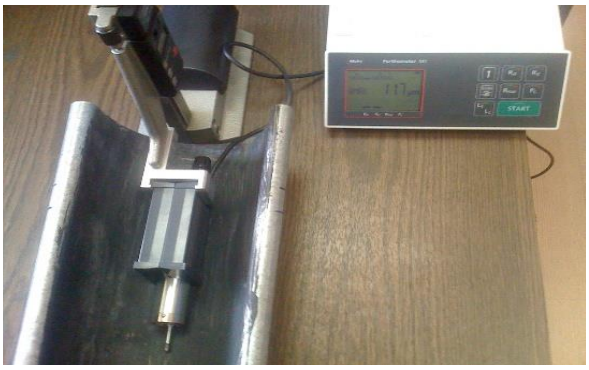

Figure 2
Profilmeter device measuring roughness on painted sheet surface

In the statistical analysis of the data obtained, variance analysis was applied using the MINITAB 16 program, and LSD analysis was performed by using the MSTAT-C package program to determine the different groups.

3. Results and Discussion

The mathematical mean roughness values (R_a) of the galvanized sheet surface, the steel sheet surface, and the painted sheet surface were found to be 1.13, 1.20 and 2.06 respectively. Some physical properties of dry chickpea cultivars used in the study are given in Table 2. The length, width, thickness, geometric mean diameter and thousand-grain mass values of the grain were found to highest in the Spanish chickpea cultivar as 12.06 mm, 8.22 mm, 9.01 mm, 9.65 mm and 481.96 g, respectively.

In the same chickpea cultivar, sphericity, natural repose angle and bulk density values were determined to be the lowest at 0.82, 18.04º and 746.82 kg m^{-3}. The coefficient of static friction values for the galvanized sheet, the painted sheet, and the steel sheet surfaces varied from 0.335 to 0.445. The lowest values of coefficient of static friction were obtained from the galvanized sheet surface, and the highest values of coefficient of static friction were obtained from the painted sheet surface.

When the results of the research are compared with the other studies carried out with chickpea varieties in Turkey, it is seen that the sphericity value of the Koçbaşı variety is higher (87.58%) at the moisture value of 5.2% (d.b), and the length (9.34 mm) and width (7.72 mm) value is lower than Gökçe and Spanish (Konak et al. 2002).

Length, width, thickness, thousand-grain weight of Black Kabuli chickpea seeds were reported 6.85 mm, 5.08 mm, 4.72 mm and 100.18 g respectively, static friction coefficient values were also reported 0.172 for stainless steel and 0.282 galvanized iron surfaces. These values were lower than Spanish and Gökçe chickpea varieties (Gürhan et al. 2009)

It was determined that the sphericity and bulk density values of Ilc-482 and Diyar-95 chickpea cultivars were higher as 86.2% to 795 kg m^{-3} and 89.8% to 792 kg m^{-3}, respectively (Gürsoy and Güzel 2010).

The natural flow rate values for different surfaces and channel conveyor angles were shown in Table 3. By increasing the channel conveyor angles, the natural flow rate values increased on all surfaces. It is seen that the flow rate is low in both chickpea varieties at a channel angle of 24º on the painted sheet surface. The reason for this is that the static friction coefficient value on the painted sheet surface is more. The less of the natural repose angle of the Spanish variety chickpea was effective in obtaining higher flow rates at all surface and transmission angles. The angle of repose of the granular material is important in the design of transmission machines.

Table 2
Some physical properties of chickpeas

Properties	Gökçe chickpea	Spanish chickpea
Moisture (%)	8.90	10.40
Length (mm)	10.09±0.07	12.16±0.09
Width (mm	7.34±0.07	8.22±0.07
Thickness (mm)	7.74±0.06	9.01±0.08
Geometric mean diameter (mm)	8.30±0.056	9.65±0.069
Sphericity (-)	0.82±0.005	0.79±0.004
Angle of repose (º)	18.04±1.06	16.01±0.78
Thousand grain weight (g)	364.6±0.73	481.96±6.36
Bulk density (kg m^{-3})	746.82±5.83	690.21±16.29
Coefficient of static friction		
Galvanized sheet surface	0.335±0.014	0.351±0.010
Painted sheet surface	0.401±0.015	0.445±0.015
Steel sheet surface	0.388±0.010	0.435±0.012

It is shown that the different channel angles of different dry chickpea cultivars and the natural flow rates obtained on the transmission surface in Table 3. According to the variance analysis results applied to these values, a statistically significant relationship was determined between the triple ($p<0.10$) and all other parameters and their interactions ($p<0.01$).

When the averages of chickpea cultivars were examined, the highest flow rate was 1.55 kg s^{-1} in Spanish chickpea cultivar and 1.43 kg s^{-1} in Gökçe chickpea cultivar, and the difference between them was statistically significant ($F=88.11$). Low repose angle and grain surface profile were effective in obtaining high flow rate in Spanish chickpea variety.

Flow rates increased as the channel conveyor angle increased on galvanized sheet, painted and sheet metal surfaces. The increase rates for Gökçe and Spanish chickpeas on these surfaces were 207% and 189%, 630% and 522%, 291% and 202%, respectively. Considering the surface averages, mean of flow rates of 1.69 kg s^{-1} on the galvanized sheet surface, 1.24 kg s^{-1} on the painted sheet surface and 1.54 kg s^{-1} on the steel sheet surface were obtained and found to be statistically significant ($F=444.43$). The difference between the surfaces is due to the roughness values of the surfaces. The lowest mean of roughness value was found on the galvanized sheet surface (1.13 μm), and the highest on the painted sheet surface (2.06 μm).

Table 3
Natural flow rate values of chickpeas for different surfaces and channel conveyor angles (kg s^{-1})

	Channel conveyor angles			
	24 º	28 º	32 º	36 º
Galvanized sheet surface				
Gökçe chickpea	$1.01\pm0.01_{\imath}$	$1.51\pm0.01_{f}$	$1.89\pm0.02_{c}$	$2.09\pm0.11_{a}$
Spanish chickpea	$1.13\pm0.01_{h}$	$1.74\pm0.03_{d}$	$1.98\pm0.02_{b}$	$2.14\pm0.04_{a}$
Painted sheet surface				
Gökçe chickpea	$0.30\pm0.01_{k}$	$1.11\pm0.01_{h}$	$1.59\pm0.02_{e}$	$1.89\pm0.02_{c}$
Spanish chickpea	$0.37\pm0.01_{k}$	$1.13\pm0.01_{h}$	$1.61\pm0.01_{e}$	$1.93\pm0.02_{bc}$
Steel sheet surface				
Gökçe chickpea	$0.66\pm0.04_{j}$	$1.40\pm0.01_{g}$	$1.79\pm0.01_{d}$	$1.92\pm0.02_{bc}$
Spanish chickpea	$0.98\pm0.00_{\imath}$	$1.65\pm0.01_{e}$	$1.93\pm0.04_{bc}$	$1.98\pm0.02_{b}$
LSD=0.07221				

When the averages of the angle values are evaluated, the flow rate value is determined as 0.74 kg s^{-1} at the 24º channel angle and as 1.99 kg s^{-1} at the 36º channel angle ($F=1968.13$). The high slope angle caused an increase in the flow rate of the material and a decrease in the flow depth of the material. Elaskar et al. (2001) reported that the velocity of the sorghum grain and the maximum depth of steady flow show an approximately linear relationship with the slope of the channel.

According to the triple interaction results ($F=2.27$), the highest flow rate value was obtained on the galvanized sheet surface and the conveyor angle of 36º in both chickpea varieties, and the lowest flow values were obtained at the conveyor angle of 24º on the painted sheet surface.

4. Conclusions

Differences were found between the physical properties of the local population Spanish variety and the registered variety Gökçe chickpea seeds produced in the Konya region. In order for the flow to be smooth in both chickpea varieties, the channel angle must be higher than the static friction coefficient value of the grain on the relevant surface. This situation is especialy important on surfaces with high roughness values. As a result of the trials, we can state that the periodic cleaning of the channel surface has a positive effect on the flow rate. In this research, experimental observations are given regardless of a theory. In future studies, velocity profiles of the grain should be revealed and flow characteristics should be determined.

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An Application of Fuzzy Pearson Correlation Methods in Animal Sciences

Derviş TOPUZ [1*], İsmail KESKİN [2]

[1]Niğde Ömer Halisdemir University, Niğde Zübeyde Hanım Vocational School of Health Services, Department of Health Services Science, Niğde, Turkey

[2] Selcuk University, Faculty of Agriculture, Department of Animal Science, Konya, Turkey

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ABSTRACT

How to evaluate an appropriate correlation to find the fuzzy relationship between variables is an important topic in the lactation milk yield and reproduction characteristics measurement. Especially when the data illustrate uncertain, inconsistent and incomplete type, fuzzy statistical technique has some theoric features that help resolving unclear thinking in human logic and the source of uncertainties in the natural structure of the data. Traditionally, we use Pearson's Correlation Coefficient to measure the correlation between data with real value. However, when the data are composed of fuzzy numbers, it is not feasible to use such a traditional approach to determine the fuzzy correlation coefficient. This study proposes the calculation of fuzzy correlation with triangular of fuzzy data. Using Matlab application, fuzzy Pearson correlation coefficients and their membership degrees which belong to Holstein Friesian cows for the relationship between lactation milk yield, the age of the animal at lactation, number of days milked, service period and first calving age were calculated (-0.0056; 0.95), (0.1419; 0.98), (-0.272;1.0) and (-0.2543; 0.90) respectively. The membership degrees of the calculated fuzzy Pearson coefficient values are more reliable and a consistent coefficient since it determines the size of the relationship between the sets, which belong to variables.

As a result of the study, the fuzzy Pearson correlation coefficient analysis may be preferred to calculate the degree of uncertainty and membership degrees between variables that should be used in studies to increase lactation milk yield.

1. Introduction

In recent years, fuzzy logic and fuzzy logic based applications have become an important subject in many fields of science and contributed to the development of alternative statistical methods. Increased knowledge and rapid developments in the field of technology lead to radical and continuous changes in human life. It has been the aim of all societies to keep up with this change and not to be left behind, or to solve problems from inaccurate thoughts or ambiguities in terms of information about the event or the case, which contains many uncertainties. The information obtained is not sufficient, reliable, in all cases, so that an event can be fully understood and interpreted, it is often necessary to reach the result through knowledge and thinking. Instead of being unstable where the integrity of the available information cannot be achieved, researchers obtain accurate and reliable results by adding experiences and thoughts to the process (Şentürk & Aşan 2007). However, since most of the information used in real life has a generally fuzzy structure, it is obvious that everything is facing a grading problem.

Fuzzy logic theory actually mimics man-specific behavior. Naturally, an uncertainty can be easily recognized when expressing information that can be verified based on any scientific data (Paksoy et al 2013). For example, while a person engaged in animal husbandry uses "cold", "normal", "hot" etc, compound fuzzy expressions consist of linguistic variables such as "too cold", "normal", "too hot". In order to solve many uncertainties in the natural structure of this kind of data, it has been shown that in almost every field today, new alternative statistical approaches can be obtained with more reliable and consistent results (Xie & Wu 2012). In this study, the calculation of fuzzy Pearson's correlation coefficient with triangular fuzzy data was demonstrated.

This study was conducted to determine the relationships between lactation milk yield and reproductive characteristics using fuzzy Pearson correlation analysis.

2. Materials and Methods

* Corresponding author email: *topuz@ohu.edu.tr*

Material

The material of the study was composed of 138 cows of Holstein Friesian cows reared in a private enterprise in Develi, Kayseri. The relationships between lactation milk yield and service period, gestation period and first calving age of these cows were calculated by using fuzzy Pearson correlation coefficient. Calculation method and the mean fuzzy correlation coefficient value for each coefficient were compared by creating confidence intervals. Also fuzzy standard error values, such as fuzzy statistics values are calculated for 138 head Holstein Friesian cows. Data collection with the animal care and breeding practices from the enterprise were used in this study in compatible with animal welfare rules stated in Article 9 in government law of Turkey (No.5996).

For analyses EXCEL 2016, Matlab R2013a and SPSS for WINDOWS Version 24.0 were used.

Method

Classic and Fuzzy Cluster

It is a set of clusters that is developed on the logic of any set of elements belonging to the properties that are examined on classic clusters or which is not the element of the cluster. This type of cluster requires characteristic functions to reveal the shape of the distribution of random variables. So classic clusters, $f_B(x)$ are defined with characteristic functions (Tanaka & Guo 1999).

Using the characteristic function, each element examined is assigned only one of the values 0 and 1 (Zadeh 1965). It is possible to define the characteristic function of the B as;

$$f_B(x) = \begin{Bmatrix} 1, & x \in B & \text{if} \\ 0, & x \notin B & \text{if} \end{Bmatrix} \quad (1)$$

Here $f_B(x): E \to \{0,1\} \to R$ (set of real numbers is the characteristic (membership) function of cluster B, which is a subset of the universal cluster (Zadeh 1965; Ross 2004; Tansu 2012; Bede 2013; Trillas & Eciolaza 2015).

Each element in the cluster either belongs to a cluster or not. Partial membership is never allowed, hence the classic set theory identifies the boundaries of the clusters and the properties of the elements of the cluster. However, the limits of any set to be formed in practice and the general characteristics of the elements that will form this cluster cannot always be determined precisely. In such cases, it is clear that the basic knowledge of classical set theory is insufficient to classify some uncertainties in our daily lives.

To solve such situations, there is a need for different scientific methods with basic knowledge that can measure the linguistic uncertainty of words or groups of words used in a very complex or unambiguously defined language of life. Membership functions that use fuzzy numbers objectively are created to examine the uncertainty of scientific methods needed. With these membership functions, many ambiguities can be expressed mathematically and the values of the variables can be evaluated numerically (Zadeh 1978).

Fuzzy sets membership functions with expressed $\mu_{\tilde{B}}(x_i)$ is the cluster type and they form the basis of fuzzy set theory. Quantitative variables are made more meaningful by giving membership degrees with the help of membership functions. Membership function $\mu_{\tilde{B}}(x_i)$, is the degree of belonging of the cluster belonging to any fuzzy set. $\mu_{\tilde{B}}(x_i): E \to [0.0,1.0]$ the mathematical function that corresponds to a number with various degrees of membership is called "*membership function*" (Zimmermann 1996; Tanaka 1997; Nguyen & Wakler 2000; Bede 2013). Values calculated with the help of membership functions are also called membership degrees (Zadeh 1978). The degree of membership refers to the degree to which any object is a member of the universal cluster.

For example, let $E = \{x_i | i = 1,2,.,n\}$ a fuzzy universal cluster. In this universal cluster, fuzzy $\tilde{B}$ subset is defined as:

$$\tilde{B} = \{(x_1, \mu_{\tilde{B}}(x_1)), (x_2, \mu_{\tilde{B}}(x_2)), \ldots, (x_n, \mu_{\tilde{B}}(x_n)) | x_n, \mu_{\tilde{B}}(x_n) \ x \in E\} \quad (2)$$

Here $\mu_{\tilde{B}}(x_i)$: blurred clusters are members. $\tilde{B}$ is the value that indicates how much each x_i element belongs to the $\tilde{B}$ fuzzy set (Chiang & Lin 2000). It is identified as in Equality at 3 (Zadeh 1965; Abdalla 2012; Atanassov 2012) ;

$$\mu_{\tilde{B}}(x_i) = \begin{Bmatrix} \mu_{\tilde{B}}(x_i) = 1 \text{ if,} & x_i \text{ completely } \tilde{B} \text{ is a member of the cluster } x_i \in \tilde{B} \\ 0 < \mu_{\tilde{B}}(x_i) < 1 \text{ if,} & x_i \text{ partially } \tilde{B} \text{ is a member of} \\ \mu_{\tilde{B}}(x_i) = 0 \text{ if,} & x_i \ \tilde{B} \text{ is not a member of } x_i \notin \tilde{B} \end{Bmatrix} \quad (3)$$

Membership degree $\mu_{\tilde{B}}(x_i)$ with a value close to 1 is a high order element of the cluster and a membership degree close to 0 is the lower element of this cluster (Sakawa 1993).

In order to solve the many uncertainties encountered in determining the degree of relations between the clusters, it is tried to show that more reliable and consistent results can be obtained by using the alternative fuzzy Pearson correlation coefficient calculation method.

Fuzzy Pearson Correlation Coefficient

It is very important to determine the relationship direction and the degree and the statistical significance of this relationship in the interaction of two variables. Classical statistical methods are widely used to calculate the relationship between two or more variables, such as x and y, and to define conventional data sets. However, classical statistical methods cannot manage uncertainties in the natural structure of data very well. Because the source of uncertainties in the natural structure of the data affects many factors. We can define the uncertainties in the natural structure of the data with fuzzy measurements and mathematically express the measurements in each step. For example, if the correlation coefficient is calculated for a fuzzy data set, then the assumption that the independent variable (X) is the same for all values in defining the inherent ambiguities between the two variables can be assumed.

The fuzzy logic theory calculates the degree of linear relationship between fuzzy sets with a certain degree of membership, resulting in more reliable and consistent results (Xie & Wu 2012; Yang 2016). Ding-An Chiang and Nancy P. Lin (1999) developed a crisp correlation coefficient between two fuzzy sets. The crisp correlation coefficient lies in the interval [-1, 1]. Their method takes a random sample from a crisp set, with corresponding pairs of membership functions of the two fuzzy sets to compute the correlation between those two fuzzy sets. This method developed demonstrates not only the strength of the relationship between fuzzy sets, but also whether the relationship between fuzzy sets are positive (increasing) or negative (decreasing) (Lin et al 2007). A graphical representation of a fuzzy triangle number type data set is as shown in Figure 1 (Yongshen 2005).

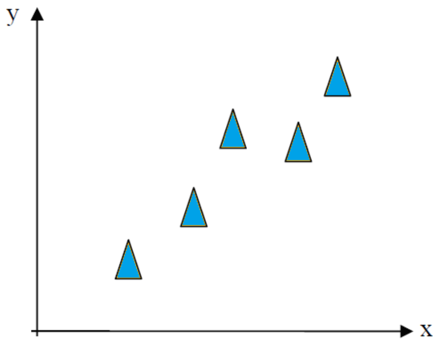

Figure 1
A blurred data set with a triangle membership function

The relationship between two fuzzy clusters such as $\widetilde{A}$ and $\widetilde{B}$ is linear as in classical clusters. The value that determines the degree of this linear relationship is also called the fuzzy correlation coefficient and can be shown in the form of $\widetilde{A} = \{x_i,\ \mu_{\widetilde{A}}(x_i) | x \in X\}$ and $\widetilde{B} = \widetilde{A} = \{x_i,\ \mu_{\widetilde{B}}(x_i) | x \in X\}$. Fuzzy correlation coefficient $\tilde{r}_{A,B}$ is calculated with the help of Equation (7) (Arnold 1990; Chiang & Lin 2000). There must be at least two different fuzzy sets for the implementation of Equation 7. If fuzzy correlation coefficient $\tilde{r}_{A,B} > 0$; $\widetilde{A}$ and $\widetilde{B}$ fuzzy sets are positively related, and the fuzzy correlation coefficient value for membership values is $\tilde{r}_{A,B} = 1$ (Yu 1993; Chiang & Lin 2000).

If the value of the fuzzy correlation coefficient $\tilde{r}_{A,B} < 0$, $\widetilde{A}$ and $\widetilde{B}$ The relationship between fuzzy sets is negative. If value of fuzzy correlation coefficient $\tilde{r}_{A,B} = 0$, there is no correlation between $\widetilde{A}$ and $\widetilde{B}$ fuzzy sets and the value of the fuzzy correlation coefficient for the membership values of the non-cluster members is $\tilde{r}_{A,B} = 0$. Intermediate values that are not included in the set are the values of the fuzzy correlation coefficient, which is calculated by using the equation of uncertainty (5) and the equation (8) $0 \leq \mu_{\widetilde{A},\widetilde{B}}(x_i) \leq 1$ receives very different membership levels (Yu 1993; Chiang & Lin 1999; Lin et al 2007).

The formula used in this study is Pearson's product sum correlation coefficient; a pair of membership function values replaces the original data values as follows.

$$\bar{\mu}_A = \frac{\sum_{i=1}^{n}(\mu_A(x_i)}{n} \quad \text{and} \quad \bar{\mu}_B = \frac{\sum_{i=1}^{n}(\mu_B(y_i)}{n} \tag{4}$$

$$\tilde{S}_A^2 = \frac{\sum_{i=1}^{n}\left((\mu_A(x_i)-\bar{\mu}_A\right)^2}{n-1} \quad \text{and} \quad \tilde{S}_B^2 = \frac{\sum_{i=1}^{n}\left((\mu_B(x_i)-\bar{\mu}_B\right)^2}{n-1} \tag{5}$$

$$\tilde{S}_A = \sqrt{\tilde{S}_A^2} \Rightarrow \tilde{S}_A = \sqrt{\frac{\sum_{i=1}^{n}\left((\mu_A(x_i)-\bar{\mu}_A\right)^2}{n-1}} \quad \text{and}$$

$$\tilde{S}_B = \sqrt{\tilde{S}_B^2} \Rightarrow \tilde{S}_B = \sqrt{\frac{\sum_{i=1}^{n}\left((\mu_B(x_i)-\bar{\mu}_B\right)^2}{n-1}} \tag{6}$$

$$\tilde{r}_{A,B} = \frac{\frac{\sum_{i=1}^{n}((\mu_A(x_i)-\bar{\mu}_A) x \sum_{i=1}^{n}((\mu_B(x_i)-\bar{\mu}_B)}{n-1}}{\sqrt{\frac{\sum_{i=1}^{n}((\mu_A(x_i)-\bar{\mu}_A)^2 x \sum_{i=1}^{n}((\mu_B(x_i)-\bar{\mu}_B)^2}{n-1}}} \tag{7}$$

$$\tilde{r}_{A,B} = \frac{\frac{\sum_{i=1}^{n}((\mu_A(x_i)-\bar{\mu}_A) x (\mu_B(x_i)-\bar{\mu}_B)}{n-1}}{\tilde{S}_A * \tilde{S}_B} \tag{8}$$

(Chiang & Lin 1999; Chiang & Lin 2000; Lin et al 2007; Yongshen & Cheung 2003). Here,

$\mu_{\widetilde{A}}(x_i)$: the membership function, which expresses the equivalent of x exact numbers in a fuzzy set such as $\widetilde{A}$,

$\mu_{\widetilde{B}}(x_i)$: the membership function,which expresses the equivalent of x exact numbers in a fuzzy set such as $\widetilde{B}$

~ : represents values for fuzzy sets.

$\bar{\mu}_{\widetilde{A}}$ and $\bar{\mu}_{\widetilde{B}}$: $\widetilde{A}$ and $\widetilde{B}$ mean values of membership functions of fuzzy sets,

$\tilde{S}_A$ and $\tilde{S}_B$: $\widetilde{A}$ and $\widetilde{B}$ shows the standard deviation values of the averages of membership functions of fuzzy sets (Chiang & Lin 1999).

Graphical fuzzy Perason correlation coefficient values are as in Figure 2 (Yongshen 2005).

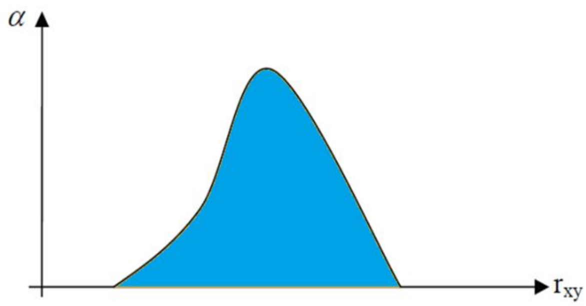

Figure 2
The fuzzy Pearson correlation coefficient values with the membership degrees

Fuzzy hypothesis testing for significance testing of fuzzy Pearson correlation coefficients can be established as follows (Buckley 2006).

$H_0: \bar{\tilde{\mu}} = 0$ and $H_1: \bar{\tilde{\mu}} \neq 0$

Here; $\bar{\tilde{\mu}}$ is the average of fuzzy Pearson correlation coefficients.

The hypothesis control of fuzzy Pearson correlation coefficients and the test statistic to be used for estimation of confidence limits are $\tilde{t}$ test (Buckley 2006). Test statistics for hypothesis testing are obtained in Equation (9) (Arnold 1990; Chiang & Lin 2000; Yongshen 2005).

$$\tilde{t} = \frac{\tilde{r}_{A,B} - \bar{\tilde{\mu}}}{\tilde{S}_r} \quad t_{n-2,\frac{\alpha}{2}} \qquad (9)$$

Here; $\tilde{S}_r$: is the fuzzy standard error value, supplied with:

$$\tilde{S}_r = \sqrt{\frac{1-\tilde{r}^2_{A,B}}{n-2}} \qquad (10)$$

For estimation of confidence limits;

$$\bar{\tilde{\mu}} = \tilde{r}_{A,B} \pm \tilde{t}_{\frac{\alpha}{2}}; \tilde{S}_r$$

equality is used. Fuzzy Pearson correlation coefficient $\tilde{r}_{A,B}$ of %95 confidence interval is estimated as in Equality (11) (Arnold 1990; Chiang & Lin 2000; Buckley 2006).,

$$\tilde{r}_{A,B} - \tilde{t}\frac{\alpha}{2}; \tilde{S}_r < \bar{\tilde{\mu}} < \tilde{r}_{A,B} + \tilde{t}\frac{\alpha}{2}; \tilde{S}_r = 1 - \alpha \qquad (11)$$

The fuzzy Pearson correlation coefficient calculated with Equation 8 shows the power and the distribution of the relationship between random variables (Ni & Cheung 2003; Lin et al 2007). For this correlation method, the values of the correlation coefficient will be in the interval [-1, 1] (Chiang & Lin 1999). As we have just described, the resultant correlation is a crisp value. A major contribution of this model is the development of partial correlation of fuzzy sets. If a random sample with multiple fuzzy attributes, Chiang and Lin's method can compute the correlation coefficient between the two fuzzy attributes.

3. Results and Discussion

For the estimation of lactation milk yield for each animal, the age of the animal at lactation (days) (X_1), number of days milked (X_2), service period (days) (X_3), the first calving age (days) (X_4), to measure whether the assumption of normality is realized, Shapiro-Wilk test was applied. The level of relationships between variables, lactation milk yield (kg) (Y_i) with values (X_1), (X_2), (X_3), (X_4), confidence levels for relationship coefficients was calculated by fuzzy Pearson coefficient calculation methods. Relationship coefficients were compared by interpreting the confidence intervals.

In addition to the variables that are thought to affect lactation milk yields, it is tried to determine whether there are independent variables or not, and there are many related researches conducted and carried out. The results of these studies eliminate many uncertainties for producers. In order to solve many uncertainties related to lactation milk yields, the dependent and independent variables were defined and various equations were created.

Table 1
Descriptive statistics on lactation milk yield and reproductive characteristics(Topuz, 2018)

Variables	$\bar{X} \mp S_{\bar{X}}$
LMY (Y_i)	8078±107
Age (X_1)	1314 ± 32.1
DIM (X_2)	326.69 ± 1.19
SP(X_3)	173.77 ± 2.49
FCA(X_4)	745.25 ± 1.69

(LMY: lactation milk yield, Age: the age of the animal at lactation, DIM: days in milked, SP: service period (days), FCA: first calving age (days).

To determine whether the assumption has normality, Shapiro-Wilk test was applied. When performing normality tests, the control (H_0) and the opposite (H_1) hypotheses are established as follows:

H_0: The data shows normal distribution.

H_1: Data do not show normal distribution.

When the hypothesis control (H_0) was accepted as a result of the hypothesis control (p> 0.05), it was concluded that the data showed normal distribution. Shapiro-Wilk normality tests were performed for lactation milk yields, service period and first calving age, and it was determined that these characteristics did not show normal distribution (Figure 3, Figure 4, Figure 5, Figure 6, Figure 7).

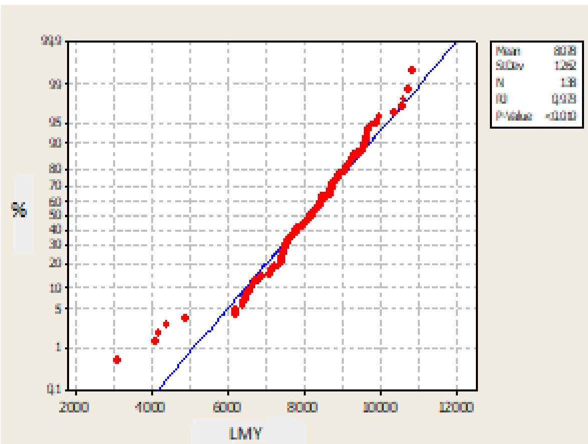

Figure 3
Lactation milk yield (LMY)

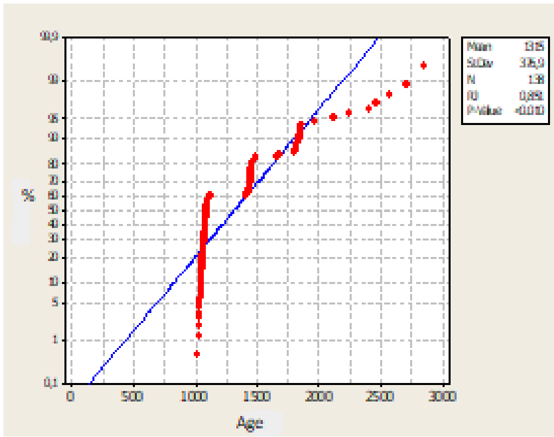

Figure 4
Normality tests for the age of the animal at lactation(Age)

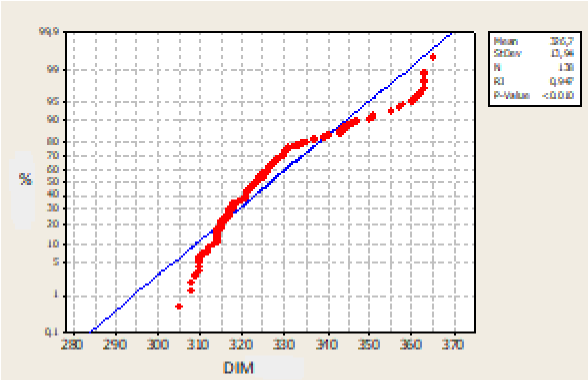

Figure 5
Normality tests days in milked (DIM)

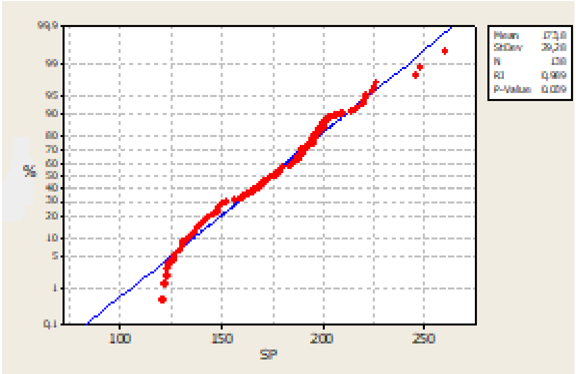

Figure 6
Normality tests for service period (SP)

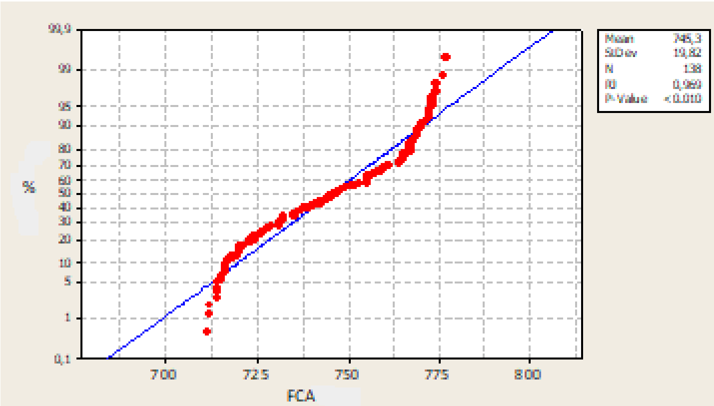

Figure 7
Normality tests for the first calving age (FCA)

In order to calculate the fuzzy Pearson correlation coefficient values and related statistics, Equation (8), Equation (9), Equality (10) and Equation (11) were applied and the values in Table 2 were obtained.

Table 2
Statistics on the classical Pearson and fuzzy Pearson correlation coefficient values between lactation milk yield and reproductive characteristics

Methods	Variables	r	μ(x)	SE	t	CI
Fuzzy Pearson Correla-tion	Age(X_1)	-0.0056	0.95	0.144	0.027	(-0.006) - (0.017)
	DIM(X_2)	0.1419	0.98	0.206	0.688	(-0.155) - (0.438)
	SP (X_3)	-0.272	1.0	-1.36	0.200	(-0.296) - (0.840)
	FCA(X_4)	-0.2543	0.90	0.200	-0.270	(-0.277) - (0.785)

**:P<0.01 (r: correlation coefficient, μ(x): degree of membership, SE: standard error, t: test value, CI: confidence interval)

As can be seen from Table 2, the fuzzy correlation coefficient value between lactation milk yield and the age of the animal at lactation was calculated as -0.0056, and the data of the calculated coefficient value was found to be represented by a membership degree close to one as high as 0.95 (95%) ($p < 0.01$) (Table 2 and Figure 8). The fuzzy correlation coefficient value between lactation milk yield and the number of days milked was calculated as 0.1419, and the data of the calculated coefficient value was found to be represented by a membership degree close to one as high as 0.98 (98%) ($p < 0.01$) (Table 2 and Figure 9). The fuzzy correlation coefficient value between lactation milk yield and service period was calculated as -0.272, and the data of the calculated coefficient value was found to be represented by a membership degree close to one as high as 1.0 (100%) ($p < 0.01$) (Table 2 and Figure 10). The fuzzy Pearson correlation coefficient value between lactation milk yield and the first calving age was calculated as -0.2543 and the calculated coefficient value was represented with a membership degree of 0.9 (90%) (Table 2 and Figure 11) (Topuz, 2018).

The distributions of the calculated fuzzy Pearson correlation coefficients with their membership degrees are similar to the graphs obtained from the study of Yongshen (2005). In the graphs, the vertical axis shows $\mu_{\tilde{A},\tilde{B}}(x_I)$ degrees, and the horizontal axis shows the calculated Pearson correlation coefficients $\tilde{r}_{A,B}$.

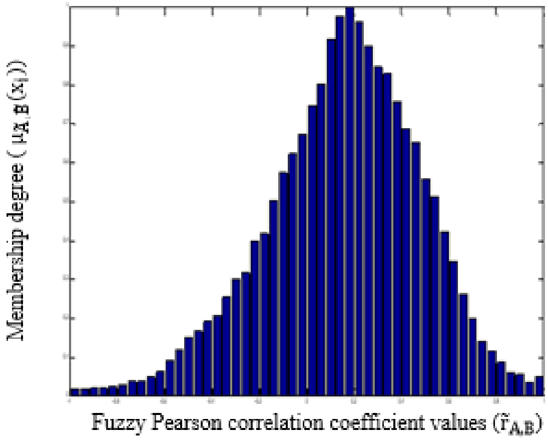

Figure 8
Distribution of fuzzy Pearson correlation coefficients between lactation milk yield and the age of the animal at lactation and membership degrees

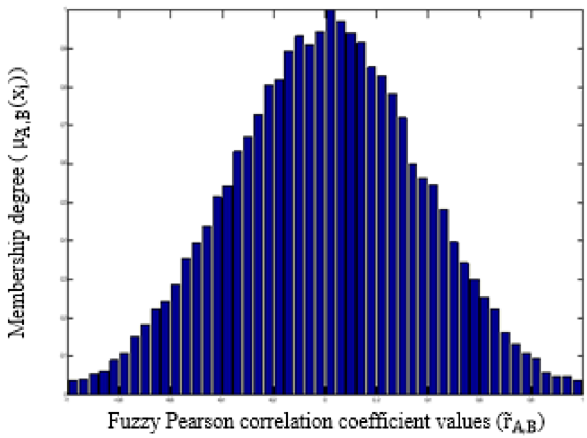

Figure 9
Distribution of fuzzy pearson correlation coefficients between lactation milk yield and number of days milked

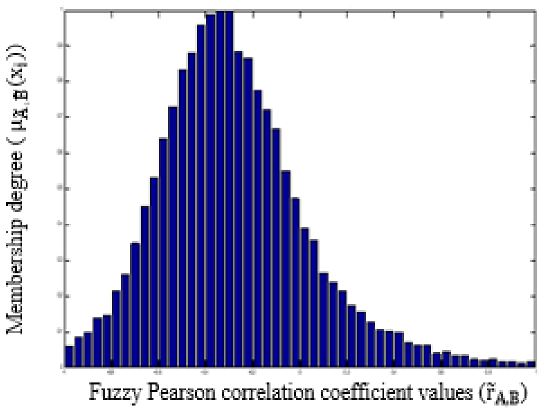

Figure 10
Distribution of fuzzy Pearson correlation coefficients between lactation milk yield and service period and membership degrees

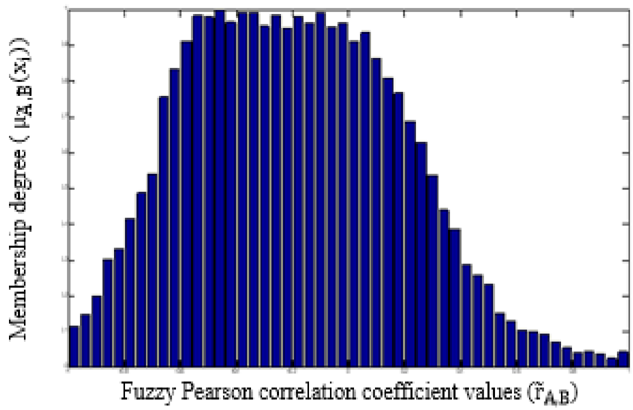

Figure 11
Distribution of fuzzy Pearson correlation coefficients between lactation milk yield and first calving age

In cases where the data do not show normal distribution, it is possible to obtain more reliable and consistent results by calculating the fuzzy Pearson correlation coefficient value which can be calculated instead of classical Pearson correlation coefficient value. Researchers misinterpret by thinking that there is a strong relationship between the variables considering the sizes of the relationship coefficients calculated in this kind and similar studies. In order to calculate real and reliable relationship coefficients Matlab codes are created in our study.

4. Conclusion and Suggestions

Pearson's product-sum formula has been widely accepted to compute the correlation coefficient between two crisp random variables. In recent years, changing problems in daily life according to the conditions and continuous development of the research have led to more complex structure. The developments that have taken place during this time have revealed the necessity to change the standart analysis methods and perspectives depending on the development of science and technique. Fuzzy set theory is widely used in applications in different fields recently (Chiang et al 2004). However, one of the fuzzy logic approaches in practice is the fuzzy Pearson correlation coefficient, which has been done to analyze the correlation of fuzzy data. For example, applications in many fields such as engineering, medicine, psychology, business, agriculture, pharmacy and veterinary medicine have been done. In this study, an easy method based on theoretical foundations of classical Pearson correlation coefficient was used. The range of the calculated fuzzy coefficient is a fuzzy number with interval $[-1, 1]$, which consists with the classic range of Pearson correlation. In addition, it was found that the coefficient value calculated by the classical Pearson correlation method was the same as the coefficient values calculated with the fuzzy Pearson correlation method.

The aim of this study is to calculate the Fuzzy Pearson correlation coefficient value and membership degrees on the exact dataset using the written MATLAB codes.

It is observed that if the original data set is in symmetric shape, then the fuzzy correlation takes on roughly symmetric distribution; otherwise, the membership function of the fuzzy correlation is a skew distributed.

In cases where the data used in the model contain uncertainty, the method works more efficiently. It is concluded that it is appropriate for researchers to use the fuzzy Pearson correlation coefficient method when they want to reach the approximate results with the information that does not make any certainty when deciding for any situation.

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Endocrine Disruptors in Baby Formulas: A Literature Review

Ozge YESILDEMIR[1,*], Yasemin AKDEVELIOGLU[1]
[1]Gazi University, Faculty of Health Sciences, Department of Nutrition and Dietetics, Ankara, Turkey

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ABSTRACT

Baby formulas are foods designed and marketed for feeding babies. The use of baby formulas is increasing worldwide due to various reasons. In parallel, there is increasing concern about endocrine disrupting compounds (EDCs) in baby formulas. EDCs cover a large class of compounds able to interact with the endocrine system. EDCs can disrupt many different hormones, so they are linked to numerous adverse outcomes in human health. Babies are more sensitive to environmental toxins than adults. In this review, the type and amount of some EDCs in the composition of baby formulas in addition to their effects on health are examined. The evaluation of EDCs in baby formulas, which are considered a source for EDCs, has become necessary. Soy-based baby formulas are seen as a source of phytoestrogens for newborns. Organohalogens are high in especially milk-based. Pesticides are generally below the maximum limits. Phthalate levels vary depending on the package content of baby formulas. The phthalate level is higher in formulas with metal packaging. Although bisphenol A (BPA) exposure decreases with the spread of BPA-free packaging, it should be kept in mind that even very low exposures can cause significant health problems. With strict legal regulations, melamine exposure has decreased considerably. Given the susceptibility of babies to EDCs, it is essential to closely monitor the EDCs content of baby formulas.

1. Introduction

The health authorities suggest exclusive breastfeeding for the first six months of life and breastfeeding until at least two years of age with appropriate complementary foods after the sixth month (Lopes et al., 2018). Despite the superior characteristics of breast milk, the production and usage of baby formulas has increased due to the development of technology, industrialization, rapid change in the social role of women, increased difficulty in breastfeeding with the active role of women (Hendaus et al., 2018; Masum et al., 2020).

Baby formula market has been expected to be the fastest growing packaged food industry in recent years (Baker et al., 2021). With the boom of the baby formula market, concerns related to the presence of endocrine disrupting compounds (EDCs) in baby formulas are increasing. Fetuses, babies, and children are more vulnerable to EDCs as these substances affect the vital organs of the body and the development of the hormonal system (Kiess et al., 2021). In addition, the nervous, respiratory, and reproductive systems of babies are not fully developed. This causes some toxins to be less excreted from the body (Carroquino et al., 2013). Babies may be exposed to food chemicals at a higher rate as they consume more nutrients per body weight (de Mendonça Pereira et al., 2020). In this review, the types and quantities of endocrine disruptors in the composition and packaging of baby formulas in addition to their effects on health are examined.

2. What are Baby Formulas?

Although it is not possible to produce a product identical to breast milk, efforts are made to ensure growth and development in babies (Martin et al., 2016). Therefore, baby formulas are designed as an effective alternative in baby nutrition (Harris and Pomeranz, 2020). According to Codex Alimentarius guidelines, baby formula is a breast milk substitute specially manufactured to satisfy, by itself, the nutritional requirements of the babies (World Health Organization, 1981).

Baby formulas are used in the absence and inadequacy of breast milk or presence of certain metabolic diseases. Baby formulas are classified as adapted, specialized, and ready-to-feed (Rossen et al., 2016).

3. What are Endocrine Disruptors?

The World Health Organization (WHO) defines EDCs as exogenous substances or mixtures that induce

* Corresponding author email: *ozgeyesildemir@gazi.edu.tr*

adverse health effects by affecting the functions of the endocrine system (World Health Organization, 2013). These substances can directly interfere with the production, release, binding, transport, destruction, and elimination of natural hormones in the body and can change their effects in the target cell. In addition, EDCs can indirectly affect the organs and systems for which they are not directly effective (Lauretta et al., 2019). Many of the EDCs are substances used to protect plants against pests. In addition, synthetic products used in the plastic industry, various building materials, and insulation materials contain EDCs (Barrios-Estrada et al., 2018). Some endocrine disruptors that can be found in baby formulas are shown in Figure 1.

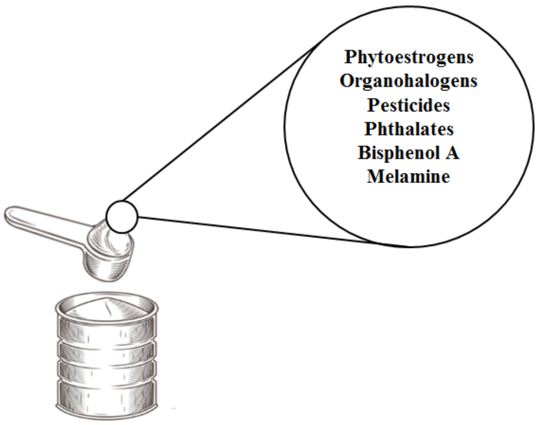

Figure 1
Some endocrine disruptors that can be found in baby formulas (Diamanti-Kandarakis et al., 2009)

4. Endocrine Disruptors in Baby Formulas

4.1. Phytoestrogens

Phytoestrogens are defined as polyphenolic compounds which are structurally or functionally similar to endogenous estrogens and synthesized by plants (Nikolić et al., 2017). Due to their structural similarity to estradiol through their phenol rings, these molecules may bind and activate the estrogen receptor promoting (anti) estrogenic effects (Gorzkiewicz et al., 2021). Phytoestrogens include classes of flavonoids, ligands, coumestan, stilbens, and zearalenone (Lecomte et al., 2017). Genistein, daidzein, and glycitein, which are among the subgroup of isoflavonoids, are the most researched phytochemicals in baby formulas, particularly soy-based formulas (Křížová et al., 2019).

There is huge interest in the effects of dietary phytoestrogens on human and animal reproductive health. It is known that very high phytoestrogen intake has negative effects on both adult female reproductive function and sexual development (Desmawati and Sulastri, 2019). Although the adverse effects of phytoestrogen on reproductive health have not been clearly demonstrated, many studies suggest that isoflavones in baby formulas have a negative effect on reproductive health in babies (Cederroth et al., 2012). The risk of congenital malformation, cancer, malabsorption, immunological dysfunction, endocrine diseases, and neurobehavioral insufficiency increases as a result of exposure to phytoestrogens early in life (Petrine et al., 2021).

One of the ways of exposure to phytoestrogens is through soy-based baby formulas. It is known that soy-based baby formulas contain poor genistein and daidzein along with their glycan forms, genistin as well as daidzin (Testa et al., 2018). Studies have shown that the concentration of isoflavones in soy-based baby formulas varies in a wide range. The total isoflavone concentration ranged from 16.2 to 85.4 μg/g (Fonseca et al., 2014). In the light of this information, it is known that the daily intake of the isoflavones of a baby fed soy-based formulas can rise up to 11 mg/kg, which is a much higher amount than that of adults (Setchell et al., 1997). In addition, differences in isoflavone content in soy-based formulas may be due to differences in the manufacturing process, analysis methods and biological properties of the product (Westmark, 2017). Moreover, isoflavones also may be found in breast milk and milk-based formulas, but the concentration is low (Bhatia and Greer, 2008; Johns et al., 2003).

While it is a fact that soy-based baby formulas are rich sources of isoflavones, it is known that babies may effectually digest, absorb, and excrete isoflavones (Westmark, 2017). On the other hand, there are a few studies showing that urinary daidzein and genistein concentrations in babies are lower than that of adults taking the same amount of isoflavones (Cao et al., 2009; Halm et al., 2007). This can be attributed to individual differences in the maturation of the digestive ability of babies (Nguyen et al., 2015). In addition, poor renal clearance in the first period of life may also be effective (Halm et al., 2007). Therefore, more studies are needed to confirm the safety of consumption of soy-based baby formulas known to contain isoflavones early in life. In this context, the European Society for Pediatric Gastroenterology, Hepatology and Nutrition (ESPGHAN) recommends that soy-based baby formulas not be used as the only source of nutrition for children under 6 months of age (ESPGHAN, 2006).

4.2. Organohalogen Compounds

There are 75 different dioxins in addition to 135 different furans and 209 different polychlorinated biphenyl (PCB) varieties, which are subgroups of organohalogens in nature, 29 of which are the most toxic (Jeanjean et al., 2021). Dioxins, furans, and PCBs can be found in water, air and soil ecosystems, and food chains. Dioxins and furans are not commercially produced compounds. They often appear as undesirable by-products in the production of chemical products (Zubair and Adrees, 2019).

The adverse health effects which occur as a result of exposure to organohalogens include cancers, developmental disorders, wasting syndrome, hepatotoxicity, and renal dysplasia. They can also lead to immunotoxicity, neurotoxicity, cardiotoxicity, reproductive disorders, hypertension, and asthma (Xu et al., 2017). The main sources of exposure to organohalogen compounds during infancy are breast milk and baby formula (Pandelova et al., 2010).

It is set the exposure limits for dioxins and dioxin-like PCBs to 1-4 pg WHO-the equivalent toxic concentrations (TEQ)/kg (body weight)/day (EFSA et al., 2018a). However, the upper range should be considered as “temporary tolerable daily intake” and it should be aimed to reduce the daily intake to below 1 WHO-TEQ/kg (body weight)/day. It should be noted that the higher the dioxin intake above the specified levels, the greater the risk of cancer (World Health Organization, 1998). Studies on content of dioxins in baby formulas are very limited, and most of these studies compare breast milk and baby formulas (Hsu et al., 2007; Kerger et al., 2007; Pandelova et al., 2010). Although dioxin exposure is higher in breastfed babies compared to formula-fed babies, formula feeding should not be recommended instead of breastfeeding for low dioxin exposure, considering the benefits of breast milk (Pandelova et al., 2010).

Furan, a colorless, volatile, and lipophilic component, is classified as a carcinogen for humans by the International Agency for Research on Cancer (IARC). The primary source of furan in foods is considered to be the thermal degradation of carbohydrates such as glucose, lactose, and fructose (Javed et al., 2021). Furan, which is ingested and inhaleted, is rapidly absorbed and extensively metabolised. It is known to cause adverse health effects on the liver and kidneys (Javed et al., 2021; Li et al., 2020).

There are many studies to determine the furan levels in baby formulas. According to these studies, furan levels in baby formulas increased from undetectable levels to 28.7 ng/g (Lambert et al., 2018; Liu and Tsai, 2010; Nie et al., 2013). The European Food Safety Authority (EFSA) (2004) reported that furan levels ranged from undetectable levels to 112 ng/g in analyzes on 273 baby formulas. Baby formulas for milk protein allergy have relatively higher furan levels than other formulas. It is thought that furans may occur during spray drying or hydrolysis while the protein is hydrolyzed (Pandelova et al., 2010). Furan formation in baby formulas is a serious food safety problem. The new production techniques should be developed to prevent furan formation as a result of heat treatment in baby formulas (Javed et al., 2021).

PCBs are also one of the EDCs which can be found anywhere and classified as carcinogens. However, the number of studies examining PCB levels in baby formulas is very low (Agathokleous et al., 2018). In a study, 174 breast milk samples, 16 cow’s milk samples, and 6 baby formula samples were analyzed and the lowest concentration PCBs were found in baby formulas (Pietrzak-Fiećko et al., 2005). As the PCB levels in cow’s milk are generally higher than in baby formulas, most of the lipids of animal origin are deliberately removed from milk based formulas and are replaced with vegetable oil with relatively low PCBs content (Mahmoud et al., 2021). However, in all cases the exposure of PCBs appears to remain below the determined maximum levels. Baby formulas are not thought to be a risk factor for PCBs, but it should be taken into account that exposure of PCBs will increase with complementary feeding (Lorán et al., 2009).

4.3. Pesticides

Pesticides are synthetic chemical compounds used to eliminate pests such as unwanted plants, insects, rodents, and fungi (Malik and Kumar, 2021). Humans can exposure to pesticides through dermal, inhalation, or ingestion. Pesticides cause acute effects and many chronic effects such as poisoning, neurotoxicity, developmental disorders, as well as cancer in children (Kapsi et al., 2019).

Considering that baby formulas are produced from dried hydrolyzed cow’s milk or soybean, or that modifications are applied to make the protein more digestible, it is predicted that pesticides are transmitted by contamination (Westmark, 2017). The maximum residue limit (MRL) of pesticides in foods should be determined in legal regulations and kept under control. For this reason, the European Commission (2006) set MRL of 0.01 mg/kg for each pesticide in baby foods. In addition, the use of several highly toxic pesticides has been limited and some pesticides have been banned in agricultural products used in the production of baby formulas. More recently, EFSA (2018b) recommended that MRL for pesticide should be below 0.01 mg/kg for infants younger than 16 weeks.

In most studies to determine the pesticide residue in baby formulas, the pesticide levels remained below detectable limits (Dobrinas et al., 2016; Kilic et al., 2018). The absence of pesticides in milk-based baby formulas may be a result of the fact that the used milk was a mixture of milk varieties of different origins, causing a dilution of any pesticide contamination. In addition, pesticide concentrations may decrease as a result of heat treatment (Melgar et al., 2010).

4.4. Phthalates

Phthalates are one of the most widely produced organic chemical classes in the world as their annual production is reached approximately 8 million tons (Wang et al., 2019). Diesters of 1,2-benzenedicarboxylic acid, commonly known as phthalates, are a group of industrial chemicals used mostly in the production of polyvinyl chloride (PVC) and as a plasticizer in the synthesis of a small number of other polymers (Giuliani et al., 2020). Various types of plastic tubing are widely used to transport milk, and PVC is included in the packaging of foods as well as baby formulas in several countries (Mankidy et al., 2013).

When phthalates enter the organism, they are hydrolyzed to monoesters and later oxidized in complex ways. Although it is not clear which molecules are more toxic, many studies have shown that exposure to phthalates negatively affects sexual characteristics. Also, phthalates can alter the deoxyribonucleic acid (DNA) methylation and therefore transmit these effects to future generations (Dutta et al., 2020).

The maximum contaminant level (MCL) set by the Food and Drug Administration (FDA) (2012) for DEHP is 0.006 milligram per liter. Based on its adverse effects on animals, the oral reference dose (RfD) established by the Environmental Protection Agency (EPA) for DBP is 0.1 mg/kg/day. The recommended RfD for DEHP is 0.02 mg/kg/day. According to the European Scientific Committee on Toxicity, Ecotoxicity, and the Environment (EU-CSTEE), in addition to the Scientific Committee on Food (EU-SCF), the maximum acceptable daily intake is equal to 50 μg/kg (body weight), whereas a lower acceptable dose (22 μg/kg (body weight) was proposed by EPA (Del Bubba et al., 2018).

When the phthalate content of four ready-to-feed formulas commercially available in the Italian market was examined, it was found that the detectability of all phthalate types was 100%. Assuming an infant body weight of 5 kg and daily milk feeding of 800 mL, the equivalent DEHP intake for baby formulas was in the range of 21-45 μg/kg (body weight). The equivalent DEHP intake for all baby formulas remained above the EPA recommendation limits, while below EU-CSTEE and EU-SCF (Del Bubba et al., 2018). Apart from this study, there are a small number of studies detecting phthalate concentration in baby formulas (Cirillo et al., 2015; Ge et al., 2016). However, the phthalate levels in baby formulas vary widely in these studies. This difference may be caused by the content of the product, production processes, packaging materials, and storage conditions. Generally, phthalate levels in metal packaged products are much lower than in plastic packaged products (Ge et al., 2016).

4.5. Bisphenol A

Bisphenol A (BPA), 2,2-bis (27 4-hydroxyphenyl) propane, is an estrogenic compound and a synthetic substance used in polycarbonate in addition to epoxy resins (Iyigundogdu et al., 2020). The most important source of exposure to BPA is nutrition as a result of the migration of the BPA monomer from the packaging (Almeida et al., 2018). Baby formula packaging containing BPA has been banned in Europe since March 2011 (European Commission, 2011).

BPA is associated with reproductive system cancers, fertility problems, and other endocrine disorders. Most of the estrogenic effects caused by BPA have been reported to occur at concentrations below the recommended safe daily exposure (Ribeiro et al., 2017).

The total daily intake set by EFSA (2015) for BPA has been 4 μg/kg/day since January 2015. Also, the specific migration limit (SML) is determined 0.05 mg/kg (EFSA, 2015). BPA was detected in 4 of the 10 baby formulas taken from different supermarkets in Camerino (Italy) and Valencia (Spain). The mean of samples was determined in a range of 0.07-1.29 mg/kg (Ferrer et al., 2011). Shao et al. (2007) found a positive sample from 10 powdered baby formula samples and determined the amount as 0.49 mg/kg. The BPA content of baby formulas should be monitored regularly to ensure the safety of infants (Karsauliya et al., 2021).

4.6. Melamine

Melamine (2,4,6-triamino-1,3,5-triazine) is a nitrogen-rich industrial chemical produced in high volumes (Wu et al., 2016). Products made of melamine-formaldehyde plastic can also be found in food as a result of use in materials, including box coatings, paper, cardboard, and adhesives (Ebner et al., 2020). It is illegally used in food or feed products to increase the content of the false protein (Rajpoot et al., 2020).

Interest in melamine first began with the death of many pets due to kidney failure in 2007. Scientists observed melamine contamination in pet foods. Later, in 2008, thousands of Chinese babies and young children were hospitalized with urine problems due to the consumption of melamine-contaminated baby formulas and related dairy products (Gossner et al., 2009).

The current SML for plastics, as specified in the European Union legislation, is 2.5 mg/kg (European Commission, 2019). The MRLs are set for different products in many countries. Many countries state that baby formulas must not contain melamine (Wen et al., 2016). In addition, the tolerable daily intake set by WHO for melamine is 0.2 mg/kg (World Health Organization, 2015).

Deabes and El-Habib (2012) evaluated the melamine content in 22 samples, including baby formula, follow-on milk, and whole milk powder. Melamine was detected in all samples, and the highest melamine content (258 mg/kg) was in baby formulas. In a study conducted in Iran, melamine in baby formulas was found to be 1.38 mg/kg (Poorjafari et al., 2015). In another Canadian study, melamine was detected in 71 of 94 baby formulas in concentrations ranging from 4.31-346 μg/kg (Tittlemier et al., 2009). Recent studies have shown that infants' daily melamine intake is lower than the tolerable daily intake (Zheng et al., 2020; Zhu and Kannan, 2018). However, there is a risk of nephrolithiasis even in intakes below the tolerable daily intake. Therefore, the debate about the tolerable daily intake of melamine continues (Wu and Zhang, 2013).

5. Conclusions

Clinical studies on the effects of phytoestrogens on baby health are insufficient. There are no published opinions of international organizations regarding the maximum limits of phytoestrogens in baby formulas. Both the American Academy of Pediatrics and the ESPGHAN reported that there is little data for the safe use of soy-based formulas in baby nutrition. For this reason, it may be recommended to conduct clinical trials, especially regarding phytoestrogens in soy-based baby formulas. Since the MRL of pesticides in baby formulas has been determined, the probability of pesticides is very low, or the detected amounts are generally below the MRL. Powdered baby formulas packaged with containers including phthalates are considered risky for phthalates. For this reason, legal limits should be determined for the packaging materials used in baby formulas. In addition, after the baby formulas are produced, they should be evaluated in terms of maximum limits at the expiry date. In recent years, the presence of BPA in baby formulas has decreased due to the tendency to use BPA-free coatings. However, considering the long shelf life and high lipid content of baby formulas, it cannot eliminate the health risks of BPA. The amount of melamine in baby formulas that will be reliable is quite controversial. The safety of baby formulas should be handled internationally due to the death and health problems caused by melamine in various countries. It is inevitable that every event in this matter has an international dimension.

Consequently, given the importance of baby nutrition, it is necessary to set legal limits for EDCs in baby formulas and routine checks to detect them. In addition, consumers should not forget the importance of healthy and reliable infant formulas. Consumers should pay attention to the food label, ingredient list, shelf life, special storage and instructions of use when purchasing baby formula.

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