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Ankara Üniversitesi
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# İÇİNDEKİLER - CONTENTS

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# Physio-Biochemical and Molecular Responses in Transgenic Cotton under Drought Stress

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**ABSTRACT**

Drought decreases the growth and productivity in cotton. Heat shock proteins accumulate in plants under water stress to protect the biochemical and physiological processes at the molecular level. In this study, plants of $T_2$ segregating generation of transgenic cotton, containing small heat shock protein gene (*GHSP26*) was compared with wild type plants for biochemical, physiological and molecular responses under different periods of drought stress. Transgenic plants accumulated 30% higher proline content than the wild type. Lipid peroxidation activity was reduced in transgenic plants which showed that the drought tolerance efficiency has been improved. Leaf relative water content was 69% and 45% in transgenic and wild-type plants, respectively at 10-day drought stress. Similarly, transgenic plants showed better performance for photosynthesis, stomatal conductance, transpiration and osmotic potential as compared to wild type. Real-time quantitative PCR of *GHSP26* and some other drought responsive genes such as *Gh-POD*, *Gh*-RuBisCO, *Gh-LHCP PSII*, *Gh-PIP*, *Gh-TPS* and *Gh-LEA* have supported the higher expression and proved drought tolerance in transgenic plants. The overexpression of *GHSP26* in transgenic plants improved the biochemical such as proline content and lipid peroxidation activity and physiological parameters like photosynthesis, osmotic potential and water related attributes. Hence, this study may be extended for selection of homozygous lines and breeding to improve the drought tolerance activity in plants.

Keywords: Gene expression; *Gossypium hirsutum*; Physiological analysis; Genetically modified cotton; Water stress; Biochemical analysis

# Transgenik Pamuk Bitkisinin Kuraklık Stresine Fizyo-Biyokimyasal ve Moleküler Tepkisi

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**ÖZET**

Kuraklık, pamuk bitkisinin gelişimini ve verimini azaltmaktadır. Su stresi koşullarında biyokimyasal ve fizyolojik prosesleri moleküler düzeyde korumak için bitkide ısı şok proteinleri birikmektedir. Bu çalışmada, küçük ısı şok proteinleri (*GHSP26*) içeren transgenik pamuk bitkisinin $T_2$ neslinin farklı kuraklık stresi altında biyokimyasal, fizyolojik ve moleküler düzeyde tepkileri yabani-tip bitki ile karşılaştırılmıştır. Transgenik bitkiler yabani-tip bitkilere gore % 30 daha fazla prolin biriktirmişlerdir. Kuraklık tolerasyon etkinliğinin arttığını gösteren lipid peroksidasyon aktivitesi transgenik bitkilerde azalmıştır. Kuraklığın onuncu gününde, transgenik ve yabani-tip bitkilerde oransal yaprak su içeriği sırasıyla % 69 ve % 45 olmuştur. Benzer şekilde yabani-tip bitkilerle karşılaştırıldığında, transgenik bitkiler fotosentez, stoma iletkenliği, transpirasyon ve ozmotik potansiyel açısından daha iyi performance göstermiştir. *GHSP26* ve *Gh-POD*, *Gh*-RuBisCO, *Gh-LHCP PSII*, *Gh-PIP*, *Gh-TPS* ve *Gh*-LEA gibi kimi kuraklığa tepki genlerinin gerçek zaman PCR sonuçları yüksek düzeyde gen ekspresyonu olduğunu ve transgenik bitkilerin kuraklık toleranslarının iyi olduğunu göstermiştir. Transgenik bitkilerde *GHSP26*'nın yüksek ekspresyonu prolin ve lipid peroksidasyonu gibi biyokimyasal, fotosentez, ozmotik potansiyel ve su durumuna bağlı fizyolojik özellikleri iyileştirmiştir. Bu yüzden, bu çalışma bitkilerde kuraklık toleransını artırmak üzere ıslah ve homozigot hatların seçiminde kullanılabilecektir.

Anahtar Kelimeler: Gen ekspresyonu; *Gossypium hirsutum*; Fizyolojik analiz; Genetik modifiye pamuk; Su stresi; Biyokimyasal analiz



## 1. Introduction

Drought stress is seen as loss of water from plants and altering its various structural, physiological, and biochemical processes. These losses would result as a reduction in leaf water content (Hadiarto & Tran 2011), interruption to enzymatic reactions (Mohamed et al 2015), leaf turgor loss (Yue et al 2012), water transpiration efficiency (Ashraf & Harris 2004), cessation of photosynthesis (Chaves et al 2009), nutrient imbalance and a reduction in plants' growth and yield. Plants adapt various ways to maintain cellular activities and integrity to survive under water scarcity (Mao et al 2010). Several genes including heat-shock proteins are involved in cellular protection by re-establishing normal protein conformation and hence normalize the cell homeostasis during stress (Al-Whaibi 2011).

Cotton is a major fiber crop, and *Gossypium hirsutum* is the most widely grown species around the world. *Gossypium arboreum* adjusts well to arid lands and needs low input for agricultural practices, therefore, it is considered as a pool of vital resistant genes that may lead to improving modern cotton cultivars (Liu et al 2006). Less availability of irrigation water is one of the major limiting factors for flower development, fiber production, and lint quality. Under drought stress, plants generally display many physiological and biochemical reactions which result in the observation of certain differentially expressed genes. Therefore, it is important to understand the genes, expressed during drought stress to develop the resistant varieties (Shamim et al 2013).

Conventional breeding has produced better cotton cultivars (Ashokkumar et al 2014), but the cotton genome research has made progress to develop genomic resources and tools for basic and applied genetics, genomics and breeding such as EST's data, DNA markers, QTL's and genes for special traits (Zhang et al 2008). Applications of the biotechnology and genomics approaches have led the studies related to the introduction of transgenic plants with the hope that the development of abiotic stress-tolerant cultivars would be appropriate and comparatively efficient (Rashid et al 2014; Ünlükara et al 2015). We have previously identified, isolated and characterized, small Heat Shock Protein gene (*GHSP26*) from a local variety of *G. arboreum* (Maqbool et al 2007), transformed to local variety of *G. hirsutum* (Maqbool et al 2010) and tested its potential role in segregating generations (Shamim et al 2013; Sarwar et al 2014). Thus, objective of the present research was to elucidate the prospective role of *GHSP26* in plants of $T_2$ segregating generation under 5 and 10 days drought (d) stress phase.

## 2. Material and Methods

### 2.1. Planting material, growth conditions and application of drought stress

Seeds of $T_2$ segregating population of *Gossypium hirsutum* previously transformed with *GHSP26* gene, which was isolated from the local variety of *G. arboreum* (Maqbool et al 2007; Maqbool et al 2010) and studied $T_1$ generation of the same (Shamim et al 2013) were used. Lint was removed with concentrated $H_2SO_4$ and washed with tap water. Sterilization was done with 0.5% $HgCl_2$ and 1% SDS for 10 min followed by washings with autoclaved water. Seeds were sown in pots (25x30 cm) containing soil, sand and peat moss (1:1:1) and kept in the greenhouse at 30±2 °C and 250-300 µmol $m^{-2}$ $s^{-1}$ light intensity. There were three replicates with five plants in each replicate. Forty-day-old plants were subjected to drought stress by stopping irrigation for 5 and 10 d (day stress), as described by (Yue et al 2012). Physiological, biochemical and molecular parameters of the transgenic and wild-type plants were observed under normal and drought stress condition. Transgenic and wild-type (WT) plants at 0 d were considered as control. So the treatments denoted as 0DS, 5DS and 10 DS.

### 2.2. Estimation of proline content and lipid peroxidation

The proline content in leaf was extracted as described by (Bates et al 1973). A standard curve with known concentration of proline was also obtained and proline content was calculated as µg $g^{-1}$ of fresh leaf tissue. Malondialdehyde (MDA) was analyzed as described by (Quan et al 2004). The absorbance of the supernatant was taken at 450, 532 and 600 nm with the spectrophotometer (spectra Max plus: molecular devices, USA). The MDA content was calculated using the Equation 1.

$$C\ (\mu mol\ g^{-1}) = 6.45x(OD_{532}-OD_{600})-0.56x(OD_{450}) \quad (1)$$

Where; *C*, MDA concentration; *OD*, optical density at given wavelength.

### 2.3. Leaf relative water content (LRWC)

Leaf relative water content (LRWC) was determined by using the (De Ronde et al 2004) protocol with little modification. About 1 g of leaf sample was cut into smaller pieces and determined the fresh weight (FW). Then samples were immersed in double distilled $H_2O$ for 24 h and turgor weight (TW) was determined. Samples were then oven dried at 80 ˚C for 24 h and the dry weight (DW) was obtained. The LRWC was calculated using the Equation 2.

$$\text{Leaf relative water content (LRWC)} = [(FW-DW)/(TW-DW)]x100 \quad (2)$$

Where; *FW*, fresh weight; *DW*, dry weight; *TW*, turgid weight.

### 2.4. Gas exchange parameters and osmotic potential (OP)

Gas exchange attributes, such as stomatal conductance (C), transpiration (E) and photosynthetic rate (PN) were calculated using an open system LCA-4 ADC portable infrared gas analyzer in the mid-day in sun shine (Analytical Development Company, United Kingdom) as described by Akram et al (2011). The Osmotic potential was measured with a Micro-Osmometer (Fiske Model 210, Fiske Associates) as mentioned by Mao et al (2010).

### 2.5. RNA extraction, cDNA synthesis and quantitative real time RT-PCR

Total RNA was extracted from leaves of transgenic and WT plants as described by Muoki et al (2012) with some modifications. Quantity and quality were analyzed with NanodropND-1000 spectrophotometer. RNA integrity was confirmed in 1.2% agarose gel and cDNA synthesis was done by using the kit (Fermentas cat# k1642). Gene-specific primers for *GHSP26* were designed as F-AGGCCTAAACGGTTGGCTAT, R-CCATCTTTGATGTCCCAAGG by using the primer-3 software. Expression of some drought linked genes (*Gh-POD*, *LHCP-PII*, *RuBisCO*, *Gh-TPS, LEA-5,* and *Gh-PIP*) were analyzed in transgenic and WT plants by quantitative real-time PCR. Data normalization was done by using

GAPDH as internal control. SYBER green PCR master mix (Fermentas: cat#k221) was used for reaction mix to run the cycle on Real-time PCR ABI 7500 device. The thermal profile was 3 min at 95 °C, followed by 35 cycles each at 95 °C for 30 sec, 60 °C for 40 sec and 72 °C for 30 sec. The Assay was performed in triplicate and relative gene expression analysis was done by REST 2009 V2.0.13 software provided by QIAGEN.

*2.6. Statistical analysis*

Experimental data are the means of at least three independent replicates, and results were determined using analysis of variance (ANOVA) Statistix software. Variation among treatment means were compared using least significant difference (LSD) ($P \leq 0.05$).

## 3. Results and Discussion

*3.1. Proline content and lipid peroxidation*

In this study, accumulation of proline was 30% higher in transgenic plants as compared to WT. So this indicates a positive correlation between the proline content and expression of the transgene against drought stress period (Figure 1A). Proline accumulation in plants in response to osmotic stress is vital for adaptation (Yue et al 2011). Proline accumulation helps the plants to minimize the dehydration damage to the cell membrane. It accumulates in a larger amount than any other amino acid in higher plants under drought and salt stress (Ashraf & Harris 2004). Statistical analysis showed that there is a significant difference for proline accumulation in transgenic and wild type cotton lines (F-test, $^{**}P<0.01$) (Table 1). Similarly (Liu et al 2009) reported higher proline content in transgenic rice plants than the wild types under drought and salt stress conditions. Therefore, these reports confirm the positive function of proline in plants under abiotic stresses.

Drought stress causes oxidative damage which results in cell membrane degradation which is a sign of membrane lipid peroxidation. The value of MDA production without drought stress was 2.0

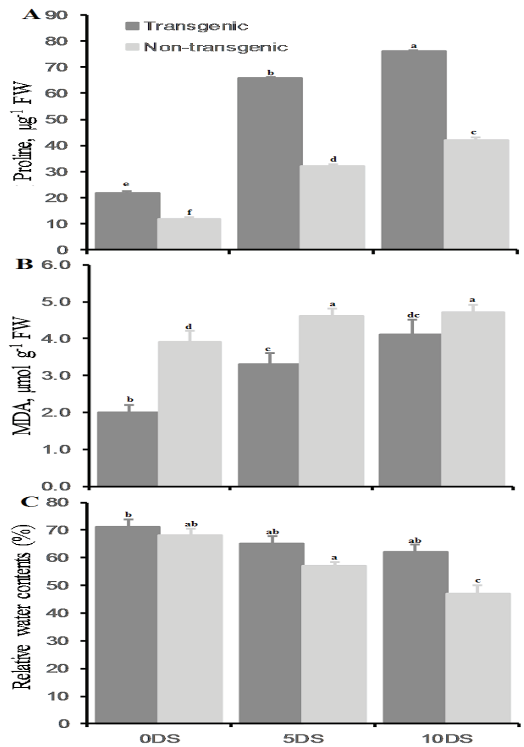


**Figure 1- Biochemical and physiological indicators of transgenic and WT plants under drought stress; A, proline; B, MDA; C, leaf relative water content; each value represents the mean±SD of three replicates; values with different letters are statistically different (LSD, P≤0.05)**

*Şekil 1- Transgenik ve yabani tip (WT) bitkilerin kuraklık stresi altında fizyolojik ve biyokimyasal özelliklerindeki değişimler; A, prolin; B, MDA; C, yaprak relative su içeriği; değerler 3 tekerrür ortalaması±SD; farklı harflerle gösterilen ortalamalar arası fark önemli (LSD, P≤0.05)*

and 4.0 µmol $g^1$ FW in transgenic and WT plants respectively. Its production was raised to 3.45, and 4.1 µmol $g^1$ FW in transgenic plants under 5 and 10 d respectively. However, MDA level was 4.6 and 4.9 µmol $g^1$ FW in WT plants under same period of drought (Figure 1B). It also indicates the generation of ROS, superoxide radicals and hydrogen peroxide (Ashraf & Harris 2004). It protects the membranes and macromolecules that result in lowering the ion leakage and transpiration losses and increasing water holding capacity. Statistical analysis showed that there is a significant difference for MDA accumulation F-test, **P<0.01 (Table 1). These results implied that the elevated level of small heat shock protein *in vivo* helps in efficient scavenging of ROS in transgenic plants which may be contributing to enhanceing the drought tolerance.

### *3.2. Over expression of GHSP26 improved the leaf relative water content (LRWC)*

Leaf relative water content is directly linked to total cell size and balance between water availability to leaves and transpiration rate (Mao et al 2010). The Value of LRWC without drought stress was 72.9% and 69.7% for transgenic and WT plants respectively. Transgenic plants held 69% LRWC while WT held only 45% at 10 d drought stress (Figure 1C). With the application of 5 d drought, LRWC decreased significantly in WT plants (F-test, **P<0.01). ANOVA and testing of means for significant differences indicates that the transgenic plants were less damaged as compared to WT under drought stress (F-test, *P<0.05) (Table 1). Variation in LRWC directly influences the cell turgidity, opening, and closing of stomata and photosynthetic rate. Hadiarto & Tran (2011) suggested that drought responsive genes have a positive role to maintain the leaf relative water content in the rice plants. Verslues & Bray (2006) discussed the correlation between hormonal level and the accumulation of osmolytes which in turn affects the water potential and relative water content within plants under dehydration stress.

### *3.3. Photosynthesis, stomatal conductance and transpiration rate in transgenic plants*

Drought stress leads to a substantial reduction in net photosynthesis, due to stomatal closure, which restricts the diffusion of $CO_2$ into the leaf or non-stomatal factors, such as inhibition of *RuBisCO* or ATP synthesis (Stepien & Johnson 2009). In our study, photosynthesis rate under irrigated phase was 9.04 µmol $m^{-2}$ $s^{-1}$ in transgenic and 5.32 µmol $m^{-2}$ $s^{-1}$ in WT plants. This was reduced to 5.82 and 3.08 µmol $m^{-2}$ $s^{-1}$ in transgenic plants and was 4.03 and 2.96 µmol $m^{-2}$ $s^{-1}$ in WT at 5 and 10 d drought stress, respectively (Figure 2A). This indicates that overexpressing *GHSP26* is maintaining the photosynthesis activity efficiently in transgenic plants under drought stress. ANOVA of the drought and the genotype variables and their interactions showed significant values F-test, **P<0.01 (Table 1).

**Table 1- Analysis of variance (ANOVA) for physiological and biochemical parameters of transgenic and wild type plants under drought stress**

*Çizelge 1- Transgenik ve yabani tip (WT) bitkilerin kuraklık stresi altında fizyolojik ve biyokimyasal özelliklerindeki değişimlere ait varyans analizi sonuçları*

| *Dependent variable* | *Independent variable* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | *Drought stress* | | | *Genotype* | | | *G×D* | | |
| | *SS* | *MS* | *F* | *SS* | *MS* | *F* | *SS* | *MS* | *F* |
| Proline | 5862 | 2931 | 2218** | 2451 | 2451 | 1855** | 541.95 | 270.98 | 205.0** |
| MDA | 7.18 | 3.59 | 47.8** | 7.70 | 7.70 | 102.4** | 1.06 | 0.53 | 7.10** |
| LRWC | 1488.7 | 744.33 | 10.3** | 1093.1 | 1093.1 | 15.12** | 1002.8 | 501.42 | 6.94* |
| PN | 51.57 | 25.78 | 45.8** | 15.99 | 15.99 | 28.40** | 9.75 | 4.87 | 8.65** |
| g | 10.64 | 5.32 | 79.9** | 6.61 | 6.61 | 99.36** | 2.52 | 1.26 | 19** |
| E | 11.53 | 5.76 | 70.2** | 3.87 | 3.87 | 47.22** | 3.99 | 1.99 | 24.3** |
| OP | 10.35 | 5.17 | 51** | 0.05 | 0.05 | 0.53 ns | 0.31 | 0.15 | 1.6ns |
| WP | 0.47 | 0.23 | 23.2** | 0.44 | 0.44 | 43.92** | 0.02 | 0.01 | 1.3ns |
| $F_V/F_M$ | 55975 | 27987 | 40.2** | 16272 | 16272 | 23.4** | 17286 | 8643 | 12.4** |

*, significant at P≤0.05; **, significant at P≤0.05; ns, non-significant; D, drought stress; G, genotype; G×D, interaction; MDA, malondialdehyde; LRWC, leaf relative water content; E, transpiration; OP, osmotic potential; WP, water potential

Small heat shock proteins play a critical role in cellular protection under drought stress and maintain water use efficiency (Gallé et al 2007). This may be a result of stomatal closure or degradation of the photosynthetic apparatus under stress. This study reports the positive response of the transgene for stomatal conductance which is enhanced under drought stress (Figure 2B). Different variables and their interaction showed significance for stomatal conductance (Table 1). Transpiration rate was 3.74 mmol $m^{-2}$ $s^{-1}$ in transgenic plants without drought stress and decreased to 2.0 and 1.0 mmol $m^{-2}$ $s^{-1}$ as the plants were subjected to 5 and 10 d of drought, respectively. Likewise in WT plants, the transpiration rate was 2.5 mmol $m^{-2}$ $s^{-1}$ at 0 d and decreased to 0.8 and 0.93 mmol $m^{-2}$ $s^{-1}$ at 5 d and 10 d of stress, respectively (Figure 2C). A significant difference in the transpiration rate was not observed under 10 d drought stresses. This may be due to the fact that negative water potential in the root generates a signal to shoot e.g. abscisic acid which has been suggested to be the operating mechanism for transpiration activity (Ashraf & Harris 2004). ANOVA determined a highly significant difference among the variables and their interactions F-test, **P<0.01 (Table 1). Transpiration activity may also be regulated by the waxy layer on the leaf surface which ultimately helps to monitor the stomatal aperture for opening and closing under environmental stresses.

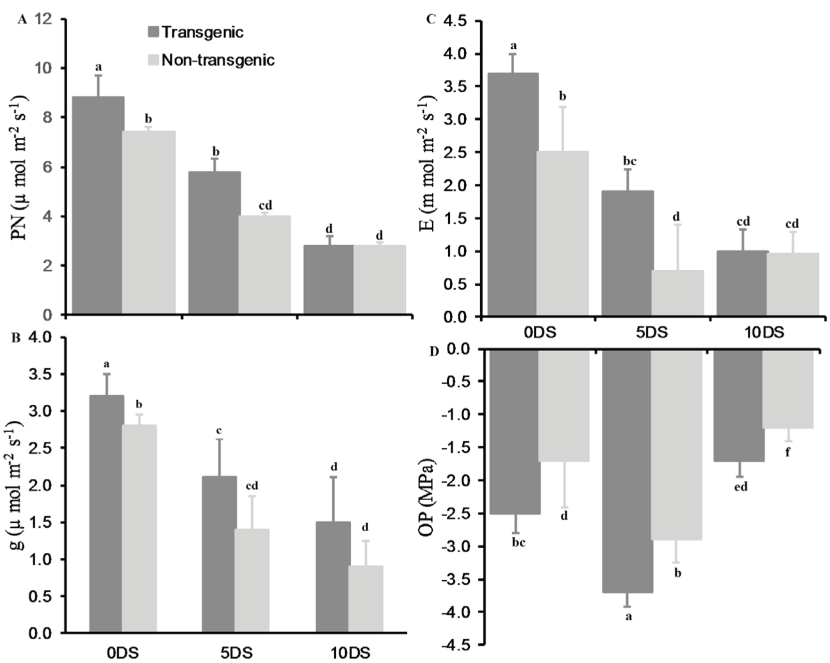


**Figure 2- Physiological measurements of transgenic and WT plants under control and drought stress; A, photosynthetic rate; B, stomatal conductance; C, transpiration rate; D, osmotic potential; each value represents the mean±SD of three replicates; values with the different letter are significantly different according to LSD tests (P<0.05)**

*Şekil 2- Transgenik ve yabani tip (WT) bitkilerin kuraklık stresi altında fizyolojik özelliklerindeki değişimler; A, fotosentez oranı; B, stoma iletkenliği; C, terleme oranı; D, ozmotik potansiyel; değerler 3 tekerrür ortalaması±SD; farklı harflerle gösterilen ortalamalar arası fark önemli (LSD, P≤0.05)*

The consequence of water stress on the stability of photosynthetic apparatus determines the chlorophyll fluorescence ratio ($F_v/F_m$) which is an indicator of the photochemical efficiency of Photosystem II (Efeoglu & Terzioglu 2009; Stepien & Johnson 2009). Photochemical efficiency ($F_v/F_m$ ratio) of transgenic and WT plants differ significantly (F-test, *P<0.05) (Table 1). These results, in correlation with previous reports, confirmed that the drought stress induces the reduction in LRWC, photosynthesis, stomatal conductance and transpiration rate, but in the present study, these parameters were not reduced due to the fact that the transgene has positive impact. Reduction in water flow due to drought may cause the decline of LRWC that would result in stomatal closure to maintain water status which regulates the physiological parameters (Chaves et al 2009).

### *3.4. Transgenic plants over expressing GHSP26 improved the osmotic and water potential*

Osmotic stress generates adverse modifications in cellular apparatus (Bartels & Sunkar 2005). The addition of an osmoprotectant to the cellular machinery is a helpful approach to improving the plants tolerance to osmotic stress (Yue et al 2012). The OP was reported as 2.5 and 1.9 (-MPa) in transgenic and WT plants under 0 d stress. But as the plants were subjected to 5 and 10 d stress, the OP was 3.75 and 1.75 (-MPa) in transgenic and 2.9 and 1.1 (-MPa) in WT plants respectively (Figure 2D). Our results strongly indicate that the improved OP and WP in transgenic plants may be due to over-expression of the transgene. This improvement usually indicates higher water retention capacity and a lower rate of water loss with higher water use efficiency (Mao et al 2010). This is in correlation to the report supported by Flexas & Medrano (2002) that leaf turgor maintains the osmotic and water potential under salt and dehydration stress, which will regulate the carbon dioxide within the cellular aperture. The photosynthetic activity is then regulated by the turgor effects, which are correlated with plant species, an age of plants and duration or nature of stress.

### *3.5. Over expression of GHSP26 and drought stress linked genes in transgenic cotton*

The drought-related genes *LHCP-PSII, Gh-POD, Gh-PIP and Gh-RuBisCO* showed similar expression under 0 d in transgenic and WT plants, but their relative fold expressions were significantly higher under water deficiency in transgenic as compared to WT plants (Figure 3A-C and F). The light-harvesting chlorophyll a/b-binding (*LHCB*) and *Gh*-RuBisCO proteins are solely positioned in the light harvesting pigmented protein complexes of PSI and PSII and are involved in the first major step of carbon fixation of Calvin cycle (de Montaigu et al 2010; Pruneda-Paz & Kay 2010). Existing studies indicate that the down-regulation of these genes reduced the effectiveness of plant tolerance to environmental stresses resulting in inferior productivity (Xu et al 2012). Hence, elevated expression shows the comparative stability and proper regulation of the chloroplast and other membrane-bound organelles which directly play vital roles in photosynthesis. Plants use the antioxidant mechanism as a protective strategy to overcome the oxidative stress damage by up-regulation of downstream antioxidant enzymes.

The present study indicates a significant increase in POD activity in transgenic plants under drought stress. Some of the previous studies have also reported similar results in other drought tolerant crops, like *Helianthus annuus* L. (Gunes et al 2008) and Brassica *campestris* L. (Jahangir et al 2009). Expression of *LEA5 and Gh-TPS,* showed interesting results as the expression of these genes increased during stress, which is an indication of osmotic tension (Kosmas et al 2006). However, the expression level of these genes decreased in transgenic plants under drought stress (Figure 3D-E), which may show that they are sensitive to water deficient conditions and relatively lower expression under increasing drought shows reduction in tolerance against stress. Relative fold expression of transgene *GHSP26* was increased under drought stress and maximum expression was observed at 10 d (33 fold expression) (Figure 3G). Elevated gene expression is a characteristic feature of small heat shock protein due to its chaperone activity under abiotic stress. The relative fold expression of *GHSP26* was increased in transgenic plants in under different developmental stages in $T_1$ generation under drought stress conditions (Shamim et al 2013). Waters et al (2008) reported the high level (100-400 fold) of small heat shock protein expression under abiotic stress which was very mild in the unstressed plants in *Arabidopsis thaliana.* Under stress conditions, the chaperone function of small heat shock protein increased to prevent irreversible aggregation and to re-solubilize proteins that have already aggregated. Our previous report also confirmed the integration and expression of the transgene in transgenic plants (Sarwar et al 2014). Analysis or the parameters presented in this study proved that the over expression of *GHSP26* improved the drought tolerance efficiency of transgenic plants.

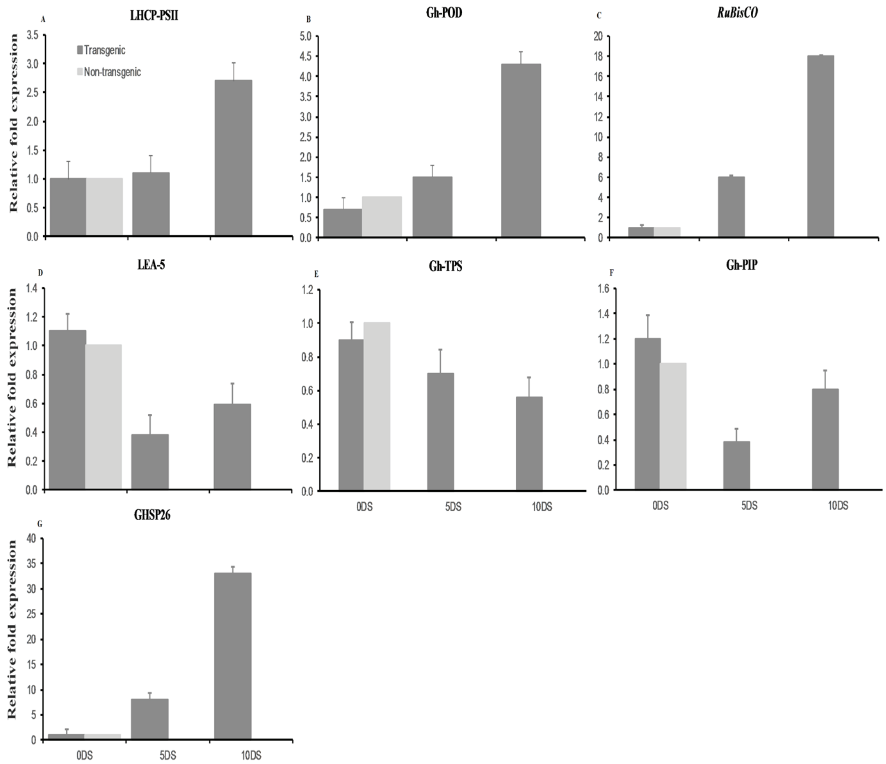


**Figure 3- Quantitative real time RT-PCR expression analyses of transgene and drought linked genes; A, photosynthesis-II chlorophyll A/B-binding protein (*LHCP PS-ll*); B, peroxidase (*Gh-POD*); C, ribulose-1,5-bisphosphate carboxylase/oxygenase small subunit gene (rubisco); D, late embryogenesis-abundant protein (*Gh-Lea5 D*); E, trehalose-6 phosphate (*Gh-TPS*); F, plasma intrinsic protein (Gh-PIP2); G, heat shock protein gene *GHSP26*; means were generated from three independent measurements; line on the bars indicate standard errors**

*Şekil 3- Transgen ve kuraklık bağlantılı genlerin kantitatif RT-PCR ekspresyon analizleri; A, fotosentez-II klorofil A/B-bağlı protein (LHCP PS-ll); B, peroksidaz (Gh-POD); C, ribuloz-1,5-bisfosfat karboksilaz/oksijenaz küçük altünite geni (rubisco); D, geç embiryogenesis-yoğun protein (Gh-Lea5 D); E, trehaloz-6 fosfat (Gh-TPS); F, plazma içi protein (Gh-PIP2); G, ısı şoku protein geni GHSP26; değerler üç tekerrür ortalaması olup çubuklar üzerindeki çizgiler standart hatadır*

## 4. Conclusions

The results of this study support the higher expression of the heat shock protein gene in transgenic cotton plants under drought stress. The transgenic plants maintained an efficient photosynthesis rate, higher osmotic and water potential, lower ion leakage and malondialdehyde activity and increased accumulation of proline content. In this way, the transgenic plants had the better performance at the physiological, biochemical and molecular levels.

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# The Effects of Seed Treatment with Melatonin on Germination and Emergence Performance of Pepper Seeds under Chilling Stress

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**ABSTRACT**

Melatonin was first isolated from bovine pineal gland more than half a century ago as an important animal hormone and since then it was proved to be present in almost all forms of life including eukaryotic unicells, prokaryotes, fungi, algae, animals and plants. In this study, the effects of pre-sowing seed treatment with melatonin on germination and emergence performance of pepper seeds under chilling conditions were investigated. Seeds were immersed in 0 (distilled water), 1, 5, 10 or 25 µM melatonin solutions for 24 hours after which they were dried for one day and subjected to germination and emergence tests at optimum (25 °C) and chilling stress (15 °C) conditions. Untreated (dry) seeds were used as a control. Exogenous melatonin treatment promoted pepper seed germination and emergence under chilling conditions. Treatment of seeds with melatonin especially in 1 or 5 µM concentrations significantly improved germination and emergence percentage whereas control seeds and seeds treated with water exhibited the lowest germination and emergence performance. Melatonin application also reduced the MDA and $H_2O_2$ contents and elevated SOD and CAT enzyme activities. The improvement in germination and emergence performance of pepper under chilling stress conditions following melatonin treatment may therefore be due to reduced lipid peroxidation and elevated activities of antioxidant enzymes.

Keywords: Antioxidant enzymes; *Capsicum annuum*; Chilling stress; Melatonin; Seed treatment

# Melatonin Uygulamalarının Üşüme Stresi Altındaki Biber Tohumlarının Çimlenme ve Çıkış Performansı Üzerine Etkisi

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**ÖZET**

Melatonin bir hayvansal hormon olarak ilk olarak sığır beyin üstü bezinden yarım yüzyılı aşkın bir süre önce izole edilmiş ve daha sonra tek hücreliler, mantarlar, algler, hayvanlar ve bitkiler gibi evrimsel olarak birbirlerinden çok farklı organizmalarda varlığı kanıtlanmıştır. Bu çalışmada dışarıdan yapılan melatonin uygulamaları ile biberde (*Capsicum annuum* L.) çimlenme sırasında üşüme stresine karşı toleransın arttırılması hedeflenmiştir. Biber tohumları 24 saat süreyle farklı konsantrasyonlarda (0, 1, 5, 10 ve 25 µM) melatonin ile muamele edilmişler ve daha sonra bir gün kurutularak optimum (25 °C) ve üşüme stresi (15 °C) koşullarında çimlenme ve çıkış testlerine tabi tutulmuşlardır. Ekim öncesi tohum muamelesi şeklinde yapılan melatonin uygulamaları ile üşüme stresi koşulları altında biberin tohum çimlenmesi ve fide çıkış performansının olumlu yönde etkilenebileceği görülmüştür. En etkili melatonin konsantrasyonu olarak belirlenen 1 ve 5 µM melatonin uygulamaları sonucunda kontrol uygulamalarına kıyasla çimlenme ve çıkış yüzdeleri ile hızlarının arttığı saptanmıştır. Melatonin uygulamaları fidelerde $H_2O_2$ ve MDA içeriğini düşürmüş, buna karşılık SOD ve CAT enzim aktivitelerini arttırmıştır. Bu araştırma sonuçlarına dayanarak, biber tohumlarının çimlenme ve fide çıkış performanslarının arttırılmasında antioksidan enzim aktivitelerinin seviyelerindeki artışın neden olduğu dokulardaki lipitlerin peroksidayonunda gerçekleşen bozulmanın azalması olduğu söylenebilir.

Anahtar Kelimeler: Antioksidan enzimler; *Capsicum annuum;* Melatonin; Tohum uygulaması; Üşüme stresi



## 1. Introduction

Pepper is a warm season vegetable that requires relatively higher soil temperatures for rapid seed germination and seedling emergence and the optimum temperature for germination and emergence is between 25 and 30 °C (Lorenz & Maynard 1988). Even though pepper is a vegetable that's been cultivated via transplants, direct seeding is still used in some parts of pepper growing areas such as Kahramanmaraş province of Turkey. When direct seeded in cool soils in the early spring, pepper seed germination could be very erratic and non-uniform and seedling emergence may prolong for several weeks. This erratic and non-uniform seed germination and seedling emergence often results in non-uniform seedlings, poor crop stands, and may require crop replanting. Often, slow stand establishment leads to reduced yields and delayed harvest (losing early high market prices) (Watkins & Cantliffe 1983). Thus, achieving ideal plant stands necessitates rapid and uniform seedling emergence to evade these problems.

Since the isolation from bovine pineal gland for the first time in the late 1950s (Lerner et al 1958), melatonin (N-acetyl-5-methoxytryptamine) was identified in evolutionary distant life forms including bacteria, animals and higher plants (Posmyk & Janas 2009; Tan et al 2012). Although some preliminary findings had been reported (Van Tassel et al 1993; Kolár & Machácková 1994), the first evidence that melatonin was indeed present in plants independently came from two different group of researchers (Dubbels et al 1995; Hattori et al 1995). In the following years, melatonin in varying quantities has also been detected in different organs of a variety of fruits, cereals, vegetables, and in medicinal herbs (Chen et al 2003; Reiter et al 2007a; Paredes et al 2009; Posmyk & Janas 2009; Korkmaz et al 2014).

Even though the physiological functions of melatonin in plants are still to be definitively established, some functional roles have already been proposed (Tan et al 2012). Recent studies have documented that melatonin is a proven powerful free radical scavenger and a broad spectrum antioxidant in plants (Paredes et al 2009; Tan et al 2012), and provides significant protection against such environmental stresses as cold (Posmyk et al 2009), salinity (Li et al 2012), water (Zhang et al 2013) and excess UV light (Afreen et al 2006). Additionally, melatonin is known to promote growth of roots (Arnao & Hernández-Ruiz 2007) and leaves (Okazaki et al 2010; Wang et al 2013), and it may also serve as the regulator of circadian rhythm and photoperiodic reactions (Kolár et al 1999; Kolár & Machácková 2005) in plants. In our ongoing research, we previously established the presence of melatonin in different organs of two pepper cultivars and its variation during various growth stages (Korkmaz et al 2014). In this research, our objective was to investigate whether pre-sowing treatment with melatonin would enhance pepper seed germination and subsequent seedling emergence at chilling temperatures.

## 2. Material and Methods

### *2.1. Plant material and treatments*

Seeds of 'Sena' red pepper (*Capsicum annuum* L.), all from the same seed lot, were obtained from Agricultural Research Institute, Kahramanmaras, Turkey. Seeds were disinfested in 1% (active ingredient) sodium hypochlorite for 15 minutes to eliminate seed-borne microorganisms. Following disinfestation, they were rinsed under running tap water for one minute and surface dried by placing them between paper towels for 30 minutes at room temperature.

Single layer of pepper seeds (5 g), placed in covered transparent polystyrene boxes (10x10x4 cm) on double layers of filter paper and wetted with 20 mL of 0 (distilled water), 1, 5, 10, and 25 µM melatonin (Sigma-Aldrich, MO, USA) solutions, were kept at 20 ˚C in darkness for 24 hours (Karaca 2013). The seeds then were rinsed for 1 minute under running water and left to dry on paper towels for 24 hours under room conditions (20-22 ˚C and 50-60% relative humidity). Due to light sensitive nature of melatonin, all experiments were always carried out under dim light.

### *2.2. Germination test*

Germination test was carried out in darkness in temperature-controlled incubators held at 15±1 ˚C (chilling stress) or 25±1 ˚C (optimum conditions, ISTA 2007). Fifty seeds were placed on two layers of filter paper moistened with 5 mL of distilled water in covered 10 cm petri dishes. To prevent fungal contamination, 1 mL of 0.5% Captan (Koruma, Turkey) was added to the water. Treatments were arranged in completely randomized design with four replications. Untreated dry seeds were taken as dry control. Radicle protrusion to 2 mm was scored as germination. Germination was recorded daily until the numbers stabilized and germinated seeds were removed from the petri dishes. From the total number of seeds germinated, final germination percentage (FGP) and days to 50% of FGP ($G_{50}$) (Farooq et al 2005), which is an inverse measure of germination rate, were calculated.

### *2.3. Emergence test*

Pepper seeds were treated with melatonin as described above and 40 seeds from each treatment were planted into 1.0 cm depth in 18x9x4 cm (length x width x height) plastic cups filled with growth medium consisting of peat and perlite in the ratio of 4:1. After watering the cups, half of them were placed in a growth room at 15±1 ˚C (chilling stress) while the other half was placed at 25 ˚C (optimum conditions) under cool fluorescent lamps providing a photosynthetic photon flux density of 250 µmol $m^{-2}$ $s^{-1}$ for 16 h $day^{-1}$ at the seedling level. Relative humidity levels varied between 60% and 75% in the growth rooms. The treatments were replicated four times and all the cups were arranged in completely randomized design in the growth chamber. Emergence counts (hypocotyl arch visible) were made daily until the percentage of emerging seedlings had stabilized in all treatments and final emergence percentage (FEP) and days to 50% of FEP ($E_{50}$) were calculated. When the percentage of emergence had stabilized in all treatments, seedlings were sampled for $H_2O_2$, malondialdehyde (MDA) and antioxidant enzyme analysis. The seedlings were cut at the medium surface and their fresh weights were recorded.

$H_2O_2$ content was determined according to the method suggested by Özden et al (2009). Shoot (cotyledons and hypocotyls) samples of 0.25 g were homogenized in 3 mL of 1% (w $v^{-1}$) trichloroacetic acid (TCA). The homogenate was centrifuged at 10,000 *g* and 4 ˚C for 10 minute. Subsequently, 0.75 mL of the supernatant was mixed with 0.75 mL of 10 mM potassium phosphate buffer (pH 7.0) and 1.5 mL of 1 M KI. $H_2O_2$ content of the supernatant was determined by comparing its absorbance at 390 nm to a standard calibration curve. The content of $H_2O_2$ was calculated from a standard curve plotted in the range from 0.1 to 100 µmol $mL^{-1}$. $H_2O_2$ concentration was expressed as µmol $g^{-1}$ FW.

The MDA concentration was determined according to the method of Zhang et al (2005) with some modification. Fresh shoot samples (0.25 g) were homogenized in 3 mL of 10% TCA and centrifuged at 10,000 *g* for 15 minute. The supernatant was collected and 1 mL was mixed with 1 mL of 0.6% thiobarbituric acid. The mixture was boiled at 100 ˚C for 20 min, cooled quickly, and centrifuged at 10,000 *g* for 10 minute after which its absorbance was measured at 532, 600, and 450 nm. The MDA concentration was calculated by Equation 1.

$$MDA\,(\mu mol\ g^{-1}\ FW)=6.45\times(A_{532}-A_{600})-0.56\times A_{450} \quad (1)$$

Enzyme extractions were performed as described in Seckin et al (2010). Fresh leaf samples (0.5 g) were rapidly extracted in a pre-chilled mortar on an ice bath with 1.5 mL of ice cold 50 mM sodium phosphate buffer (pH 7.8) containing 1 mM EDTA-$Na_2$ and 2% (w $v^{-1}$) PVPP. Samples were centrifuged at 14,000 *g* for 20 min, and supernatants were used for the determination of protein content and enzyme activities. Total soluble protein contents of the enzyme extracts were calculated according to Bradford (1976) using bovine serum albumin (BSA) as a standard and the protein concentration was determined from a BSA standard curve. The specific enzyme activity for all enzymes was expressed as in unit $mg^{-1}$ protein.

The activity of superoxide dismutase (SOD, EC 1.15.1.1) was determined using the slightly modified method of Xu et al (2008). One hundred µL of the enzyme extract was added to 2.465 mL of 100 mM phosphate buffer (pH 7.8), 75 µL of 55 mM methionine, 300 µL of 0.75 mM nitroblue tetrazolium (NBT) and 60 µL of 0.1 mM riboflavin in a test tube. The test tubes containing the reaction solution were placed under 2 fluorescent light tubes (40 µmol $m^{-2}$ $s^{-1}$) for 10 min and their absorbance were measured at 560 nm with a UV/visible spectrophotometer. Blanks and controls were run in the same manner but without illumination and enzyme, respectively. One unit of SOD activity was defined as the amount of enzyme that would inhibit 50% of NBT photo reduction.

Catalase (CAT, EC 1.11.1.6) activity was determined by the method of Çakmak & Horst (1991), which measures the initial rate of disappearance of $H_2O_2$ at 240 nm. The reaction mixture contained 70 µL crude enzyme extract, 930 µL 50 mM Na-phosphate buffer (pH 7.0) with 0.1 mM EDTA and 3% $H_2O_2$. The decrease in the absorption was followed for 3 minute and 1 µmol $H_2O_2$ $mL^{-1}$ $min^{-1}$ was defined as 1 unit of CAT.

Peroxidase (POX, EC 1.11.1.7) activity was measured according to the method described by Herzog & Fahimi (1973). The reaction mixture contained 75 µL crude enzyme extract and 925 µL 3,3-diaminobenzidine-tetra hydrochloride dihydrate solution containing 0.1% (w $v^{-1}$) gelatine and 150 mM Na-phosphate-citrate buffer (pH 4.4) and 0.6% $H_2O_2$. The increase in the absorbance at 465 nm was followed for 3 min and one unit of POX activity was defined as µmol $H_2O_2$ decomposed $mL^{-1}$ $min^{-1}$.

### *2.4. Statistical analysis*

Data from all experiments were subjected to analysis of variance and mean separation was performed by Fisher's least significant difference (LSD) test if F test was significant at P= 0.05. Germination and emergence percentage data were arcsine transformed before statistical analysis. Experiments were repeated twice and since there was no significant difference between the results of two experiments, data from both experiments were pooled and the mean values are presented (n= 8).

## 3. Results

### *3.1. Seed germination*

Pre-sowing seed treatment with melatonin significantly improved pepper seed germination under chilling stress conditions compared to dry seeds and seeds treated with 0 µM melatonin which had FGP of 45% and 61%, respectively (Figure 1A).

Even though all melatonin treatments had similar effect on FGP of pepper seeds, 25 µM treatment resulted in the highest FGP (93%). Under optimum conditions, however, melatonin had little or no effect on germination percentage of pepper seeds. Additionally, application of melatonin improved the germination rate of pepper seeds under chilling stress compared to dry seeds ($G_{50}$= 20.3 days) and 0 µM melatonin treatment ($G_{50}$= 17.0 days); and the highest germination rate was obtained from seeds treated with 1 µM melatonin ($G_{50}$= 15.6 days) (Figure 1B). Moreover, application of 1 µM and 5 µM melatonin were also effective in improving germination rate compared to the both control treatments under optimum conditions.

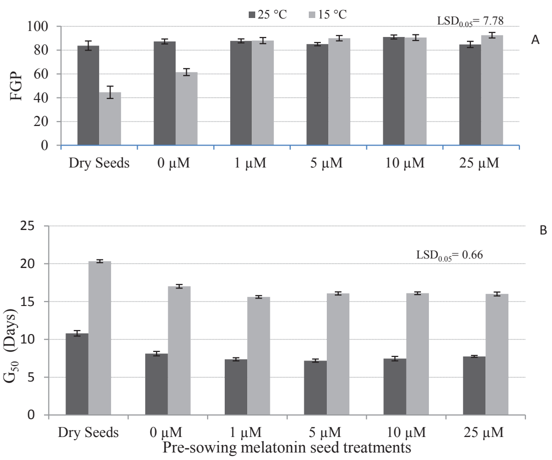


**Figure 1- Effect of pre-sowing seed treatment with melatonin on pepper seed final germination percentage (FGP, A) and germination rate ($G_{50}$, B), under optimum (25 ˚C) and chilling (15 ˚C) conditions. Vertical bars represent mean±SE (n= 8)**

*Şekil 1- Ekim öncesi tohuma yapılan melatonin uygulamalarının optimum (25 °C) ve üşüme stresi (15 °C) koşullarında biber tohumlarının çimlenme yüzdesi (FGP, A) ve çimlenme hızı ($G_{50}$, B) üzerine etkileri. Dikey barlar ortalama±standart hatayı temsil eder (n= 8)*

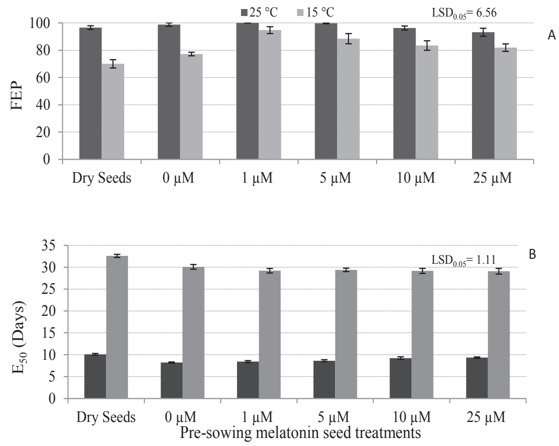


**Figure 2- Effect of pre-sowing seed treatment with melatonin on pepper seedling final emergence percentage (FEP, A) and emergence rate ($E_{50}$, B) under optimum (25 ˚C) and chilling (15 ˚C) conditions. Vertical bars represent mean±SE (n= 8)**

*Şekil 2- Ekim öncesi tohuma yapılan melatonin uygulamalarının optimum (25 °C) ve üşüme stresi (15 °C) koşullarında biber fidelerinin çıkış yüzdesi (FEP, A) ve çıkış hızı ($E_{50}$, B) üzerine etkileri. Dikey barlar ortalama±standart hatayı temsil eder (n= 8)*

### *3.2. Seedling emergence*

Seed application of melatonin in various concentrations enhanced the FEP of pepper seedlings under chilling conditions (Figure 2A). Treating the seeds with 1 µM (95%) and 5 µM (88%) melatonin increased the emergence percentage significantly under stress conditions compared to dry seeds (70%) and seeds treated with 0 µM (77%), while the FEP of 10 µM and 25 µM melatonin treatments were not statistically different than that of 0 µM melatonin treatment. Under optimum conditions, however, melatonin application prior to sowing did not have any major effect on seedling emergence performance and all treatments exhibited 93% or higher FEP. Moreover, all melatonin treatments enhanced the emergence rate of pepper seedlings compared to seedlings obtained from dry seeds under chilling conditions, while there was no difference in term of emergence rates of melatonin treatments in comparison with 0 µM treatment (Figure 2B). Additionally, no differences in emergence rates were observed between the melatonin treatments and control treatments under optimum conditions.

Imbibing of pepper seeds before sowing in 1 µM melatonin significantly affected seedling shoot fresh weight under optimum conditions while 5 µM melatonin treatment increased shoot fresh weight under chilling stress conditions compared to dry seeds (Figure 3). On the other hand, the fresh weight of seedlings obtained from 0 µM melatonin treatment was similar to those of the rest of melatonin treatments.

Even though all melatonin applications as pre-sowing seed treatment affected the $H_2O_2$ content of seedlings under chilling stress conditions, 1 µM melatonin application was the only treatment to significantly reduce $H_2O_2$ content under chilling stress conditions compared to both control

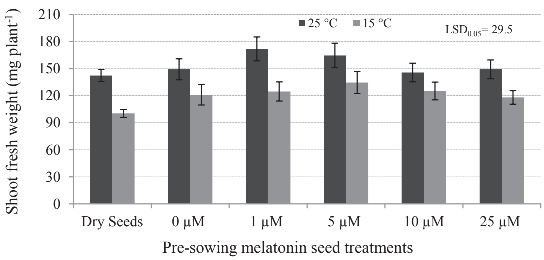


**Figure 3- Effect of pre-sowing seed treatment with melatonin on pepper seedling shoot fresh weight under optimum (25 °C) and chilling (15 °C) conditions. Vertical bars represent mean±SE (n= 8)**

*Şekil 3- Ekim öncesi tohuma yapılan melatonin uygulamalarının optimum (25 °C) ve üşüme stresi (15 °C) koşullarında biber fidelerinin taze ağırlığı üzerine etkileri. Dikey barlar ortalama±standart hatayı temsil eder (n= 8)*

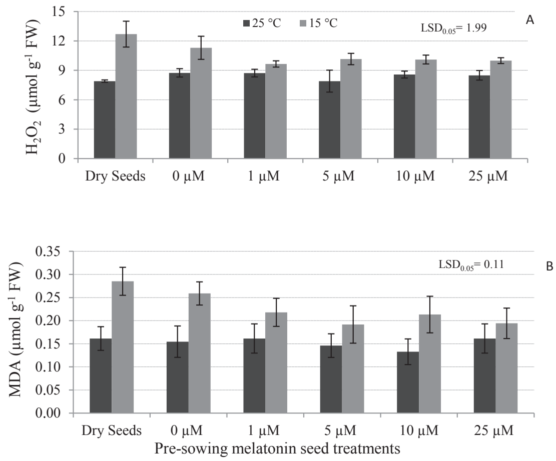


**Figure 4- Effect of pre-sowing seed treatment with melatonin on $H_2O_2$ content (A) and MDA concentration (B) of pepper seedlings under optimum (25 °C) and chilling (15 °C) conditions. Vertical bars represent mean±SE (n= 8)**

*Şekil 4- Ekim öncesi tohuma yapılan melatonin uygulamalarının optimum (25 °C) ve üşüme stresi (15 °C) koşullarında biber fidelerinin $H_2O_2$ (A) ve MDA (B) içerikleri üzerine etkileri. Dikey barlar ortalama±standart hatayı temsil eder (n= 8)*

treatments (Figure 4A). Moreover, though not statistically significant, melatonin pre-treatments also considerably lowered the MDA content of seedlings subjected to chilling stress, and of the melatonin concentrations tested, pre-treatment of the seeds with 5 µM reduced the MDA content of the seedlings the most (Figure 4B). Additionally, there were no significant differences among the treatments in terms of $H_2O_2$ and MDA contents under optimum conditions.

Moreover, pre-sowing seed treatment with increasing concentrations of melatonin significantly increased SOD enzyme activity under chilling stress conditions (Figure 5A). Seedlings obtained from 1 µM, 10 µM and 25 µM melatonin treatments exhibited higher SOD enzyme activity than the seedlings of 5 µM melatonin pre-treatment which had similar enzyme activity as those of dry seed and 0 µM melatonin treatments. Similarly, pre-treatment of seeds with 5 and 25 µM melatonin also significantly increased the CAT enzyme activity in seedlings compared to two control treatments under chilling stress conditions (Figure 5B). In the plants raised under optimum conditions, however, melatonin application as seed treatment did not alter the activities of SOD and CAT enzymes except that seedlings obtained from 1 µM melatonin treatment exhibited significantly higher SOD enzyme activity than both control treatments. Additionally, even though chilling stress enhanced the POX enzyme activity of pepper seedlings compared to optimum conditions, there were no significant differences among treatments in terms of POX enzyme activity of seedlings raised under both conditions (Figure 5C).

## 4. Discussion

Chilling stress is one of the most important abiotic stresses hindering seed germination and seedling emergence of crops that are native to tropics or subtropics. In this research, we found that germination performance of pepper seeds was found to be adversely affected by chilling stress and chilling-induced impairment of pepper seed germination has already been reported previously by a number of studies (Sachs et al 1980;

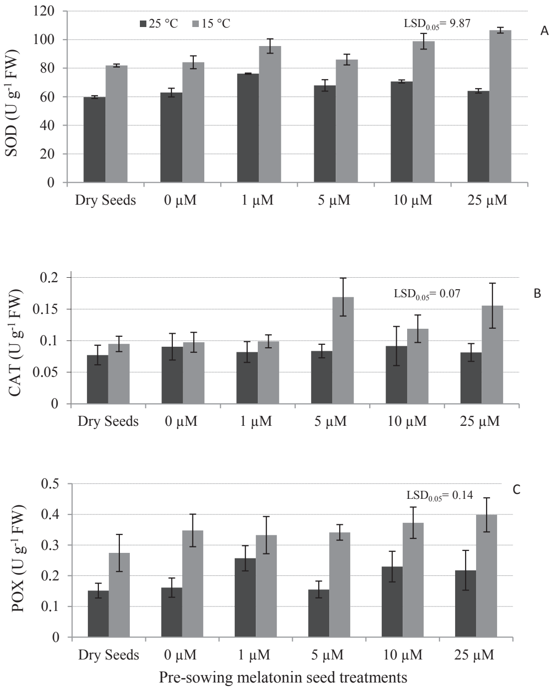


**Figure 5- Effect of pre-sowing seed treatment with melatonin on SOD (A), CAT (B), and POX (C) enzyme activity of pepper seedlings under optimum (25 ˚C) and chilling (15 ˚C) conditions. Vertical bars represent mean±SE (n= 8)**

*Şekil 5- Ekim öncesi tohuma yapılan melatonin uygulamalarının optimum (25 $^{o}$C) ve üşüme stresi (15 $^{o}$C) koşullarında biber fidelerinin SOD (A), CAT (B) ve POX (C) enzim aktiviteleri üzerine etkileri. Dikey barlar ortalama±standart hatayı temsil eder (n= 8)*

Korkmaz & Korkmaz 2009). Recently, Posmyk et al (2009) found that pre-treatment of seeds with melatonin during priming significantly enhanced the germination of cucumber seeds during chilling stress. Similarly, Tiryaki & Keles (2012) reported that melatonin application markedly reversed the inhibitory effects of light and high temperature in *Phacelia tanacetifolia* seed germination. Our results also showed strong evidence that melatonin has the ability to relieve the adverse effects of chilling stress on pepper seed germination. Pre-sowing seed treatment with melatonin improved significantly germination (Figure 1A and 1B) and emergence (Figure 2A and B) performance along with seedling growth (Figure 3) under chilling stress conditions.

Oxidative stress is considered as the main detrimental factor in seeds or plants subjected to a variety of abiotic stresses including chilling stress. Free radical accumulation and peroxidation of lipids in cellular membranes results in impaired membrane function, reduced fluidity, and inactivation of membrane-bound enzymes and receptors (Bewley et al 2013). Numerous studies have demonstrated that tolerance to chilling in various species results from an elevated antioxidant defense system (Hodges et al 1997; Kang & Saltveit 2002; Gill & Tuteja 2010). Damage caused by peroxidation of lipid portions of biological membranes might be decreased or avoided by protective mechanisms involving free radical and peroxide-scavenging enzymes such as SOD, CAT and POX. SOD is the enzyme that is involved in dismutation (or partitioning) of the superoxide ($O_2^{\cdot -}$) radical into either ordinary oxygen ($O_2$) molecule or hydrogen peroxide ($H_2O_2$) (Bowler et al 1992) whereas CAT along with POX catalyzes the decomposition of hydrogen peroxide to water and oxygen (Scandalios et al 1997; Dey et al 2007). Thus, the induction of a protective mechanism to reduce oxidative damage triggered by stress through boosting the activities of antioxidative enzymes could be characteristics of elevated levels of tolerance to abiotic stress conditions (Gill & Tuteja 2010).

Since the discovery of melatonin in plants, extensive research has been carried out to identify its physiological roles in plants. It has been postulated that melatonin may serve as a photoperiodic and circadian rhythm regulator as well as a universal antioxidant because of its wide distribution in fungi, algae, bacteria, animals and plants (Paredes et al 2009; Tan et al 2012). Melatonin and its wide variety of metabolites are known as endogenous free radical scavengers and potent broad-spectrum antioxidants, and may directly scavenge $H_2O_2$, maintaining intracellular $H_2O_2$ concentrations at constant levels (Tan et al 1993; Tan et al 2000; Reiter et al 2007b). We observed considerable reduction of $H_2O_2$ concentration (Figure 4A) and MDA accumulation (Figure 4B) by melatonin application, which may have resulted from direct free radical scavenging by melatonin and enhanced antioxidant enzyme activities. Similarly, Posmyk et al (2009) reported that seed application of melatonin in cucumber seeds germinated under chilling conditions provided significant protection of membrane structures against peroxidation and MDA accumulation. Our results also clearly indicate that melatonin is involved in boosting the activities of the antioxidant enzymes, signifying their essential role in providing antioxidative defense under chilling stress conditions. Melatonin was involved in free radical scavenging in chilling-stressed pepper seeds and seedlings since SOD, CAT and to some degree POX showed significant rises in activity with the melatonin treatment under chilling conditions (Figure 5A-C). Confirmatory findings have also been reported by Zhang et al (2013) who showed increased levels and activities of the antioxidant free radical scavenging enzymes, i.e., SOD, CAT, and POX by melatonin application in cucumber seeds germinated under drought stress conditions.

In summary, the result of the present study revealed that seed application of 1 µM or 5 µM melatonin significantly improved pepper seed germination and seedling emergence at chilling temperatures compared to seeds not treated with melatonin. Seed treatment with melatonin may be an effective way to shorten the time of emergence and improve the stand establishment in pepper during early spring sowings. The fact that melatonin, a broad spectrum antioxidant, could be used to prevent crop losses due to chilling temperatures may have a significant practical application. It is also possible to deduce from the results of current study that melatonin application enhanced the germination and emergence performance of pepper seeds by protecting the membranes against free radical destruction through enhancing antioxidant enzyme activities and by stabilizing the membranes during chilling stress.

## Acknowledgements

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# Evaluation of Fire Blight (*Erwinia amylovora*) Disease Reaction of Pear Hybrid Combinations

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**ABSTRACT**

Fire blight caused by pathogenic bacterium *Erwinia amylovora*, is the serious disease of pear. Since there is no effective chemical management to this disease except antibiotic-type compounds, it is very important to improve new fire blight resistant cultivars. In this research, it was aimed to select and develop fire blight resistant pear types and to determine fire blight susceptibility levels of pear hybrids, obtained from different projects. Hybrid plants were inoculated by shoot injections twice each year. Evaluations were made through necrotic shoot rate and susceptibility levels of hybrids were determined. During the experiments, 7036 hybrid pear seedlings inoculated, and 12.28% of them were found as "very low susceptibility" (A), 3.62% as "low susceptibility" (B) classes.

Keywords: Artificial inoculation; *Erwinia amylovora*; Hybrid; Pear

# Farklı Armut Melezleme Kombinasyonlarında Ateş Yanıklığı Hastalığı (*Erwinia amylovora*) Reaksiyonunun Değerlendirilmesi

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**ÖZET**

*Erwinia amylovora* bakterisinin neden olduğu ateş yanıklığı hastalığı, armudun önemli hastalıklarından biridir. Hastalığa karşı, antibiyotikler dışında etkili bir kimyasal mücadele bulunmaması nedeni ile ateş yanıklığına dayanıklı yeni

TARIM BİLİMLERİ DERGİSİ — JOURNAL OF AGRICULTURAL SCIENCES 23 (2017) 177-184

çeşitlerin geliştirilmesi çok önemlidir. Bu araştırmada, ateş yanıklığına dayanıklı armut tiplerinin seçilmesi ve geliştirilmesinin hedeflenmesinin yanısıra farklı projelerden farklı melezleme kombinasyonlarıyla elde edilen melezlerin ateş yanıklığına hassasiyet seviyelerinin belirlenmesi amaçlanmıştır. Melez bitkiler sürgün enjeksiyonu yoluyla her yıl iki kez inokule edilmişlerdir. Nekroz oluşturan sürgün oranına göre değerlendirmeler gerçekleştirilmiş ve hassasiyet sınıfları belirlenmiştir. Denemeler boyunca, inokule edilen toplam 7036 melez bitkiden, % 12.28'i "çok az duyarlı" (A), % 3.62'si ise "az duyarlı" (B) sınıfta yer almışlardır.

Anahtar Kelimeler: Suni inokulasyon; *Erwinia amylovora*; Melez; Armut



# 1. Introduction

Pear is one of the most important pome fruits in the World and included in family *Rosaceae*, and genus *Pyrus*. Most of the cultivated high quality varieties are belong to *Pyrus communis* species. Fire blight disease caused by *Erwinia amylovora* is the most destructive bacterial disease of pear (Van Der Zwet & Beer 1995). The disease occurs extensively in several regions of the World where pear and species belong to *Rosaceae* family is grown. Fire blight disease brings out significant damages at nurseries and affects trade seriously. *Pyrus communis* species namely European pear is highly susceptible to fire blight. On the other hand, other major species as *P. ussuriensis, P. pyrifolia,* and *P. serotina* are resistant to the disease (Shoemaker & Teskey 1959).

*E. amylovora* affects all upper organs as flowers, shoots, branches of host plants and kills whole plant. Disease development is connected to environment, host and pathogen interaction, and intensity and damage changes through year (Van Der Zwet & Beer 1995).

Cultural practices, different chemical and biological management methods can be used as integrated management against fire blight, though there is no certain management technique (Aysan et al 1999). Using resistant cultivars, rootstocks and interstocks can be thought as the best way of controlling fire blight disease (Layne & Quamme 1975; Bergamaschi et al 2006).

Related to resistance to fire blight of *E. amylovora*, disease reaction of pear cultivars and cultigens was investigated in different countries (Layne & Quamme 1975; Hasler & Kellerhals 1997; Saygılı et al 1999; Honty et al 2006; Sestras et al 2008; Ellis 2010; Yoder & Biggs 2010). To obtain resistant cultivars and rootstocks, hybridization breeding is widely used because of polygenic inheritance of fire blight disease (Bell et al 2005). Besides, new resistant varieties were improved by selection (Saygılı et al 1999), hybridization (Ryugo 1982; Durel et al 2004; Hevesi et al 2004; Hunter & Layne 2004; Bergamaschi et al 2006), and molecular level studies as gene transfers (Reynoird et al 1999 a, b; Chevreau et al 2000; Aldwinckle et al 2003; Brown 2003). Susceptibility of the hybrids, obtained from inter- and intra-specific crosses, to *E. amylovora* is determined by artificial inoculations (Layne & Quamme 1975).

Turkey is one of the origins of pear plant. Most of the superior quality pear cultivars grown in Turkey are known as susceptible to fire blight. In Turkey, hybridization projects have been performed to obtain fire blight resistant and high quality cultivars (Evrenosoğlu et al 2011; Öztürk et al 2011). In this study, different crosses [resistant x resistant; resistant x susceptible; susceptible x resistant; susceptible x susceptible (as the fire blight resistance character known as recessive and poligenic (Layne & Quamme 1975))] have been made between susceptible and resistant cultivars and cultigens to obtain fire blight resistant hybrids. The susceptibility levels of hybrids were determined by artificial inoculations and "very low susceptibility" (A) and "low susceptibility" (B) $F_1$ hybrids were planted in Eskişehir province of Turkey.

## 2. Material and Methods

*2.1. $F_1$ hybrid plants*

In this study, totally 10751 $F_1$ pear hybrids were used as material. For this purpose, different crosses (resistant x resistant; resistant x susceptible; susceptible x resistant; susceptible x susceptible) (Rosati et al 2002) have been made through research projects supported by TUBITAK (project numbers TOVAG 106O719 and 110O938). As maternal parents, susceptible 'Akça', 'Santa Maria' and 'Williams', moderate susceptible 'Mustafa Bey', and resistant 'Magness' and 'Kieffer' cultivars were used, and as pollinators, different resistant or susceptible cultivars and cultigens ('Akça', 'Ankara', 'Bursa', 'Conference', 'Güz', 'Kaiser Alexandre', 'Kieffer', 'Limon', 'Moonglow', 'Santa Maria', 'Taş', 'Williams') were used (Momol et al 1992; Van Der Zwet & Beer 1995; Ünal et al 1998; Aysan et al 1999; Çıtır & Mirik 1999; Öden 1999; Bell et al 2005; Honty et al 2006).

*2.2. Pathogenic bacteria*

Highly virulent six *E. amylovora* strains, that were chosen according to their pathogenicity levels among 75 *E. amylovora* strains, isolated by Aysan et al (2004), Saygılı et al (2004), and Yılmaz & Aysan (2009) from different locations in Turkey (Adana, Amasya, Bursa, Eskisehir, Karaman and Konya), were used in the study.

*2.3. Artificial inoculation*

Inoculation of the pathogen was carried out twice each year, in May and August, between 2009 and 2011, on the same material. Equal amount of bacterial suspension was injected to the top of the shoots of each hybrid. As control, saplings of susceptible parents were inoculated by *E. amylovora* using the same procedure. After inoculation with pathogenic bacteria, plants were screened for eight weeks in greenhouse at 80-90% humidity and 27 ºC (Quamme et al 1976) and routinely fertilized and irrigated.

*2.4. Evaluation*

Disease development was examined through eight weeks and at the end of this period, necrotic parts of inoculated shoots were measured in proportion to the whole shoot length. Susceptibility level of the shoots was calculated as 'Variety Susceptibility Value' using the Equation 1 (Thompson et al 1962).

$$\text{Variety susceptibility value} = \frac{\text{Length of necrotic shoot (cm)}}{\text{Total shoot length (cm)}} \text{x}100 \quad (1)$$

Susceptibility values were calculated according to the table performed by Thibault et al (1987) and susceptibility characters and classes of hybrids were detected by scoring "A"-"E" susceptibility levels (Table 1).

## 3. Results and Discussion

Distribution of hybrids to susceptibility classes in general evaluation of all combinations at the end of two different inoculation periods each year is as follows; 12.28% of inoculated hydrids were found as "very low susceptibility" (class "A"), 3.62% were "low susceptibility" (class "B"), 5.56% were "moderate susceptibility" (class "C"), 11.34% were

**Table 1- Evaluation of susceptibility of pear tree against *E. amylovora* through artificial inoculation (Thibault et al 1987)**

*Çizelge 1- Suni inokulasyon sonucu armut ağacının E. amylovora'ya karşı hassasiyetinin değerlendirilmesi (Thibault et al 1987)*

| *Variety susceptibility value* | *0-10%* | *11-20%* | *21-40%* | *41-60%* | *61-100%* |
|---|---|---|---|---|---|
| Susceptibility class | A | B | C | D | E |
| Susceptibility character | Very low susceptibility | Low susceptibility | Moderate susceptibility | High susceptibility | Very high susceptibility |

"high susceptibility" (class "D"), and 67.20% were "very high susceptibility" (class "E"). 32.65% of totaly inoculated 10751 hybrids were died after inoculations (Table 2 and 3).

Totaly 304 inoculated hybrids of susceptible 'Akça' combinations were distributed to susceptibility classes (14.47% were in class "A", 2.96% were in class "B", 2.30% were in class "C", 4.93% were in class "D", 75.33% were in class "E"). 15.79% of hybrids were killed by *Erwinia amylovora*. 'Akça' x 'Kieffer' (18.75%) and 'Akça' open pollination (21.39%) had the highest amount of class "A" hybrids among all 'Akça' combinations. On the other hand, in proportion of 62.50-94.12% class "E" hybrids were obtained from all 'Akça' combinations. The highest died hybrid rate was found in the combination of 'Akça' x 'Conference' (40.38%) and 'Akça' x 'Taş' (41.67%) (Table 2).

As for evaluation of all combinations of resistant 'Kieffer' parent, 5.30% of totally inoculated 604 hybrid plants were "very low susceptibility" character, 2.15% were "low susceptibility" character, 5.63% were "moderate susceptibility" character, 13.25% were "high susceptibility" and 73.68% were "very high susceptibility" character. Only 3.81% of hybrids were died after inoculations. Although maternal parent is resistant to *Erwinia amylovora*, hybrid number belong to class "A" (very low susceptibility) was quite low (4.01-7.39%) (Table 2).

On the combinations of the resistant parent 'Magness', there were much more hybrids on "very low susceptibility" character (Class "A"), when compared to susceptible parents. 'Magness' x 'Kieffer' (48.62%) combination was remarkable in terms of high rates of class "A" hybrids, compared to other combinations. It is stated that, 'Magness' x 'Kaiser Alexandre' combination had the same remarkable conclusion on high rates of class "A" hybrids (54.10%), same as this combination (Evrenosoğlu et al 2014). The reason of this high resistance rates can be explained as high fire blight resistance of 'Magness' maternal parent (Spotts & Mielke 1999; McGraw 2006), besides, high fire blight resistance of pollinator varieties (Momol et al 1992; Honty et al 2006). Magness cultivar is thought to be used as pollinator for several combinations, but as this cultivar is pollen sterile, it could not be used as pollinator for any combination. The lowest hybrid rates on class "A" were determined on 'Magness' x 'Santa Maria' and 'Magness' x 'Akça' combinations with rates of 13.33% and 17.86%, respectively. Distribution of the hybrids to classes for Magness combinations as follows; 29.22% of inoculated 1509 'Magness' hybrids were placed in class "A", 7.95% were in class "B", 14.45% were in class "C", 21.87% were in class "D" and only 26.51% were in class "E" (Table 2).

When it comes to the distribution of 73 hybrid plants of moderate susceptible 'Mustafa Bey' combinations, 39.73% of them were took place in class "A", on the other hand, 41.10% of them were in class "E". Class "A" hybrid rate of 'Mustafa Bey' x 'Moonglow' combination (56.10%) was higher than other combinations. No hybrid loss has been detected in all 'Mustafa Bey' combinations (Table 2).

As it was seen in Table 3, totally 1113 hybrid plants of 'Santa Maria' combinations were distributed to susceptibility classes as, 3.59% of hybrids were belong to "very low susceptibility" character (A), 1.35% were belong to "low susceptibility" character (B), 2.34% were belong to "moderate susceptibility" character (C), 7.46% were belong to "high susceptibility" character (D), and 85.27% were belong to "very high susceptibility" character (E). 'Santa Maria' open pollination (7.36%) and 'Santa Maria' x 'Kieffer' combination (6.83%) had the highest class "A" hybrids in 'Santa Maria' combinations. On the other hand, any class "A" hybrids have not obtained from 'Santa Maria' x 'Güz' combination (Table 3). It was found that, 'Santa Maria' x 'Moonglow' combination had the highest class "A" hybrids (14.85%), compared to other 'Santa Maria' combinations (Evrenosoğlu et al 2014).

**Table 2- Distribution of hybrid plants to susceptibility classes**

*Çizelge 2- Melez bitkilerin hassasiyet sınıflarına dağılımı*

| *Combinations* | *Total hybrid number* | *Distribution of hybrid plants to susceptibility classes* | | | | | | | | | | *Died hybrids* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *A* | | *B* | | *C* | | *D* | | *E* | | | |
| | | *No* | *%* | *No* | *%* | *No* | *%* | *No* | *%* | *No* | *%* | *No* | *%* |
| 'Akça' | | | | | | | | | | | | | |
| x 'Conference' | 52 | 3 | 5.77 | - | 0.00 | 3 | 5.77 | - | 0.00 | 46 | 88.46 | 21 | 40.38 |
| x 'Kaiser Alexandre' | 20 | 1 | 5.00 | 2 | 10.00 | - | 0.00 | 1 | 5.00 | 16 | 80.00 | 5 | 25.00 |
| x 'Kieffer' | 16 | 3 | 18.75 | 2 | 12.50 | - | 0.00 | 1 | 6.25 | 10 | 62.50 | 1 | 6.25 |
| x 'Santa Maria' | 14 | - | 0.00 | - | 0.00 | - | 0.00 | 1 | 7.14 | 13 | 92.86 | - | 0.00 |
| x 'Taş' | 12 | - | 0.00 | - | 0.00 | - | 0.00 | 3 | 25.00 | 9 | 75.00 | 5 | 41.67 |
| x 'Williams' | 17 | - | 0.00 | 1 | 5.88 | - | 0.00 | - | 0.00 | 16 | 94.12 | 3 | 17.65 |
| Open Pollination | 173 | 37 | 21.39 | 4 | 2.31 | 4 | 2.31 | 9 | 5.20 | 119 | 68.79 | 13 | 7.51 |
| 'Akça' TOTAL | 304 | 44 | 14.47 | 9 | 2.96 | 7 | 2.30 | 15 | 4.93 | 229 | 75.33 | 48 | 15.79 |
| 'Kieffer' | | | | | | | | | | | | | |
| x 'Santa Maria' | 374 | 15 | 4.01 | 5 | 1.34 | 11 | 2.94 | 54 | 14.44 | 289 | 77.27 | 14 | 3.74 |
| Open Pollination | 230 | 17 | 7.39 | 8 | 3.48 | 23 | 10.00 | 26 | 11.30 | 156 | 67.83 | 9 | 3.91 |
| 'Kieffer' TOTAL | 604 | 32 | 5.30 | 13 | 2.15 | 34 | 5.63 | 80 | 13.25 | 445 | 73.68 | 23 | 3.81 |
| 'Magness' | | | | | | | | | | | | | |
| x 'Akça' | 280 | 50 | 17.86 | 13 | 4.64 | 30 | 10.71 | 75 | 26.79 | 112 | 40.00 | 39 | 13.93 |
| x 'Ankara' | 407 | 125 | 30.71 | 23 | 5.65 | 55 | 13.51 | 131 | 32.19 | 73 | 17.94 | 12 | 2.95 |
| x 'Güz' | 27 | 9 | 33.00 | 1 | 3.70 | 3 | 11.11 | 4 | 14.81 | 10 | 37.03 | - | 0.00 |
| x 'Kieffer' | 327 | 159 | 48.62 | 44 | 13.46 | 48 | 14.68 | 37 | 11.31 | 39 | 11.93 | 7 | 2.14 |
| x 'Limon' | 27 | 10 | 37.04 | - | 0.00 | - | 0.00 | 2 | 7.41 | 15 | 55.56 | 1 | 3.70 |
| x 'Santa Maria' | 105 | 14 | 13.33 | 8 | 7.62 | 12 | 11.43 | 6 | 5.71 | 65 | 61.90 | 2 | 1.90 |
| x 'Taş' | 265 | 55 | 20.75 | 29 | 10.94 | 59 | 22.26 | 64 | 24.15 | 58 | 21.89 | 23 | 8.68 |
| Open Pollination | 71 | 19 | 26.76 | 2 | 2.82 | 11 | 15.49 | 11 | 15.49 | 28 | 39.44 | 4 | 5.63 |
| 'Magness' TOTAL | 1509 | 441 | 29.22 | 120 | 7.95 | 218 | 14.45 | 330 | 21.87 | 400 | 26.51 | 88 | 5.83 |
| 'Mustafa Bey' | | | | | | | | | | | | | |
| x 'Güz' | 8 | 2 | 25.00 | - | 0.00 | - | 0.00 | - | 0.00 | 6 | 75.00 | - | 0.00 |
| x 'Moonglow' | 41 | 23 | 56.10 | 2 | 4.88 | 2 | 4.88 | 3 | 7.32 | 11 | 26.83 | - | 0.00 |
| x 'Williams' | 24 | 4 | 16.67 | - | 0.00 | 3 | 12.50 | 4 | 16.67 | 13 | 54.17 | - | 0.00 |
| 'Mustafa Bey' TOTAL | 73 | 29 | 39.73 | 2 | 2.74 | 5 | 6.85 | 7 | 9.59 | 30 | 41.10 | - | 0.00 |

No, hybrid number; %, rate of hybrids to total hybrid number

Distribution rates of "A", "B", "C", "D", and "E" classes of 3433 hybrid plants in 'Williams' combinations were 8.09%, 2.80%, 2.94%, 8.24%, and 77.92%, respectively. 'Williams' x 'Moonglow' combination (22.57%) had the highest rate of "very low susceptibility" class "A" hybrids among all 'Williams' combinations. But, only 0.88% of hybrids of 'Williams' x 'Taş' combination was included in class "A" (Table 3).

## 4. Conclusions

In the current study, totaly 4739 hybrids of inoculated 7036 hybrids survived and distributed to different susceptibility classes. Totally, 32.65% of all inoculated hybrids were killed by fire blight disease (Table 3). Distribution of hybrid plants, obtained from 'Magness' parent, to susceptibility classes was quite different than the other parents

**Table 3- Distribution of hybrid plants to susceptibility classes**

*Çizelge 3- Melez bitkilerin hassasiyet sınıflarına dağılımı*

| *Combinations* | *Total hybrid number* | *Distribution of hybrid plants to susceptibility classes* | | | | | | | | | | *Died hybrids* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *A* | | *B* | | *C* | | *D* | | *E* | | | |
| | | *No* | *%* | *No* | *%* | *No* | *%* | *No* | *%* | *No* | *%* | *No* | *%* |
| 'Santa Maria' | | | | | | | | | | | | | |
| x 'Bursa' | 70 | 4 | 5.71 | 4 | 5.71 | - | 0.00 | 11 | 15.71 | 51 | 72.86 | 36 | 51.43 |
| x 'Güz' | 64 | - | 0.00 | 2 | 3.13 | 1 | 1.56 | 3 | 4.69 | 58 | 90.63 | 27 | 42.19 |
| x 'Kieffer' | 161 | 11 | 6.83 | 3 | 1.86 | 9 | 5.59 | 15 | 9.31 | 123 | 76.40 | 97 | 60.25 |
| x 'Taş' | 453 | 6 | 1.32 | 2 | 0.44 | 11 | 2.43 | 44 | 9.71 | 390 | 86.09 | 360 | 79.47 |
| x 'Williams' | 134 | 2 | 1.49 | - | 0.00 | 1 | 0.75 | 3 | 2.24 | 128 | 95.52 | 14 | 10.45 |
| Open Pollination | 231 | 17 | 7.36 | 4 | 1.73 | 4 | 1.73 | 7 | 3.03 | 199 | 86.15 | 56 | 24.24 |
| 'Santa Maria' TOTAL | 1113 | 40 | 3.59 | 15 | 1.35 | 26 | 2.34 | 83 | 7.46 | 949 | 85.27 | 590 | 53.01 |
| 'Williams' | | | | | | | | | | | | | |
| x 'Akça' | 176 | 9 | 5.11 | 4 | 2.27 | 1 | 0.57 | 7 | 3.98 | 155 | 88.07 | 4 | 2.27 |
| x 'Ankara' | 1127 | 61 | 5.41 | 16 | 1.42 | 19 | 1.69 | 47 | 4.17 | 984 | 87.31 | 577 | 51.20 |
| x 'Bursa' | 44 | 1 | 2.27 | 1 | 2.27 | - | 0.00 | 2 | 4.55 | 40 | 90.91 | 18 | 40.91 |
| x 'Güz' | 42 | 1 | 2.38 | 1 | 2.38 | 1 | 2.38 | 3 | 7.14 | 36 | 85.71 | 3 | 7.14 |
| x 'Kaiser Alexandre' | 417 | 35 | 8.39 | 31 | 7.43 | 33 | 7.91 | 65 | 15.59 | 253 | 60.67 | 174 | 41.73 |
| x 'Kieffer' | 242 | 21 | 8.68 | 3 | 1.24 | 5 | 2.07 | 29 | 11.98 | 184 | 76.03 | 70 | 28.93 |
| x 'Moonglow' | 514 | 116 | 22.57 | 28 | 5.45 | 24 | 4.67 | 64 | 12.45 | 282 | 54.86 | 260 | 50.58 |
| x 'Santa Maria' | 184 | 19 | 10.33 | 4 | 2.17 | 7 | 3.80 | 21 | 11.41 | 133 | 72.28 | 110 | 59.78 |
| x 'Taş' | 454 | 4 | 0.88 | 3 | 0.66 | 3 | 0.66 | 31 | 6.83 | 413 | 90.97 | 279 | 61.45 |
| Open Pollination | 233 | 11 | 4.72 | 5 | 2.15 | 8 | 3.43 | 14 | 6.01 | 195 | 83.69 | 53 | 22.75 |
| 'Williams' TOTAL | 3433 | 278 | 8.09 | 96 | 2.80 | 101 | 2.94 | 283 | 8.24 | 2675 | 77.92 | 1548 | 45.09 |
| GENERAL TOTAL | 7036 | 864 | 12.28 | 255 | 3.62 | 391 | 5.56 | 798 | 11.34 | 4728 | 67.20 | 2297 | 32.65 |

No, hybrid number; %, rate of hybrids to total hybrid number

such as 'Santa Maria', 'Williams' and 'Akça'. Hybrid rates in "A", "B", "C", and "D" classes were much higher, but hybrid rate in class "E" was lower in 'Magness' combinations, when compared to other parents. Another parent that had significantly high rate of class "A" hybrids was 'Mustafa Bey' (39.73%) (Table 2). Furthermore, died hybrid rate after inoculations was 53.01% and 45.09% in 'Santa Maria' and 'Williams' parents respectively, and this rate was only 5.83% for 'Magness' combinations (Table 2 and 3). Other parents that had low rates of died hybrids were 'Mustafa Bey' (0.00%) and 'Kieffer' (3.81%) (Table 2). On the combinations of the resistant parent 'Magness', much more hybrids on "very low susceptibility" character were detected (Class "A"). Additionally, high rates of class "A" hybrids were obtained from 'Magness' x 'Kieffer' combinations (approximately 50%) (Table 2).

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TARIM BİLİMLERİ DERGİSİ — JOURNAL OF AGRICULTURAL SCIENCES 23 (2017) 185-194

# Fatigue Life Enhancement of Three Point Hitch System Brackets in the Garden Series Tractors

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**ABSTRACT**

The main objective of this research was to enhance the fatigue performance of the brackets found in the three point hitch system used in garden series tractors. This was achieved by using experimental tests and finite element analysis. The manufactured brackets were validated with fatigue rig tests, namely a lifting capacity test, a push-pull test and a lifting-lowering test. The lifting capacity test of three point hitch mechanism was established according to ISO 730-1 standards. In addition to the lift capacity test, problems were also experienced with the cylinder clamping brackets during the push-pull tests. The bracket brakeage occurred during the 11,218$^{th}$ test cycle. According to the test results and finite element analysis, the brackets were strengthened at critical damage points. The thickness of the bracket connection surface was increased from 12 mm to 19 mm and the bracket material was changed from GG25 to GG35. The enhanced brackets passed the tests without any breakage.

Keywords: Hydraulic lift; Three point hitch mechanism; Push-pull tests; Lifting-lowering tests; Fatigue analysis; Stress analysis

# Bahçe Tipi Traktörlerin Üç Nokta Askı Sistemi Braketlerinin Yorulma Ömürlerinin İyileştirilmesi

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**ÖZET**

Bu araştırmanın temel amacı bahçe tipi traktörlerde kullanılan hidrolik kaldırıcılı üç nokta askı sistemi bağlantı braketlerinin yorulma performanslarını iyileştirmektir. Bu amaca deneysel ve sonlu elemanlar analizi yardımıyla ulaşılmıştır. Üretilmiş olan braketlere kaldırma kapasitesi testi, çek bırak testi ve indir kaldır yorulma testleri uygulanmıştır. Kaldırma kapasitesi testleri ISO 730-1 standartlarına göre gerçekleştirilmiştir. Kaldırma kapasitesi testlerine ek olarak uygulanan çek bırak testlerinde silindir bağlantı braketlerinde problemler gözlenmiştir. Denemelerin

11218. çevriminde braketlerde kırılmalar görülmüştür. Test sonuçları ve sonlu elemanlar analizlerine göre braketlerin kritik hasar bölgeleri güçlendirilmiştir. Braket bağlantı yüzeyinin kalınlığı 12 mm'den 19 mm'ye çıkartılmıştır ve GG25 olan braket malzemesi GG35 olarak değiştirilmiştir. İyileştirilen braketler, deneysel testleri kırılma olmadan tamamlamıştır.

Anahtar Kelimeler: Hidrolik kaldırıcı; Üç nokta askı sistemi; Çek bırak testi; İndir kaldır testi; Yorulma analizi; Gerilme analizi



# 1. Introduction

The attachments of three point hitch (TPH) systems are mainly implemented in hydraulic lift design (Keçecioğlu & Gülsoylu 2005). The design of an adjustable three point hitch system (TPH) affects the force imposed on lift and tractor equipment (Al-Jalil et al 2001). Previous studies on TPH mechanisms were mainly focused on the transition of tillage forces between tillage implements and tractors, a factor which is extremely important for both operational efficiency and energy management (Alimardani et al 2008; Askari et al 2011).

Otmianowski (1983) expressed that all agricultural machines working on farms are exposed to dynamic loads during tillage especially at bed-like farmlands. Sule et al (2007) studied three-point lift system oscillations during the drafting and implementation of transport, resulting in partial parts failure of the lift system such as the stabilizer bracket. The dynamic behavior of a tractor lift system was modelled by many researchers (Laceklis-Bertmanis & Kronbergs 2010; Laceklis-Bertmanis et al 2013). In these works, the Working Model software for a tractor three point hitch-system with small amplitude oscillation simulations was used. Kolator & Białobrzewski (2011) developed a 2D model for working tractors which was implemented on various types of soil. Portes et al (2013) developed a model which transformed the load on the three-point linkage to the tractor driving wheels. Computer aided engineering analysis led to significant cooperation between design and testing departments. Agricultural machines are subjected to various loads according to different parameters, such as soil conditions and operation types throughout their working life. In order to asses fatigue life, strain data from maximum stressed locations must be obtained or estimated (Chisholm & Harral 1989). Koike & Tanaka (1976) measured the strains at tractor's rear axle housing, to calculate fatigue strength under random load conditions. Mattetti et al (2012) collected strain data from an 80 kW tractor and used field data for accelerated life tests. Paraforos et al (2013) investigated the fatigue properties of tractor chassis and axle housing under random vibration conditions based on dynamic road loads.

Khan et al (2007) expressed that measurement studies increased as different types of transducers were developed and implemented on test samples. Goodwin et al (1993) developed a tri-axial dynamometer for measuring the forces and moments along orthogonal axis. Data acquisition and varying strain-gauge systems were also used by many researchers to evaluate the effects of on the three-point hitch mechanism (Al-Janobi 2000).

A prediction of fatigue failure is important for determining effective design parameters for final production. The best-known fatigue analysis procedures are stress-life, strain-life and crack propagation methods (Socie & Marquis 2000). The stress-life method is generally accepted in the case of high-cycle fatigue problems. Using this method, the stress amplitude can be evaluated with an S-N or Wöhler curve (Radaj 1995). The stress life approach assumes all stresses occur below the elastic limit at all times. Strain life approach is applicable to low cycle fatigue problems.

In this study, the fatigue life of the tractor lift bracket was studied using experimental tests. The push-pull and lifting-lowering tests were additional tests to the standard lifting capacity test. The lifting capacity test results were compared with theoretical calculations based on ISO-

730-1 standards (ISO 1994). The parameters of push-pull and lifting-lowering tests, the leading sources of stress on the brackets, were calculated from the static equilibrium of mechanism. Then, strain life-based fatigue life predictions (Coffin-Manson approach) were calculated using finite element analysis. In experimental studies, broken brackets in the critical equipment were observed using push-pull tests and lifting-lowering tests. Critical damage points of the brackets were determined by cyclic loading. The brackets were then redesigned, dependent on the results.

## 2. Material and Methods

*2.1. Design criteria of hydraulic lift*

For this research, the brackets of the hydraulic lift cylinder in garden series tractors were investigated. Pistons were attached directly to the external lifting arms, as can be seen in Figure 1. Hydraulic lifts with external cylinders were preferred for high lifting capacity, easy assembly and servicing capabilities. The hydraulic lifts for the three point hitch mechanisms were designed according to ISO 730-1 standards. The technical properties of the hydraulic lift are given in Table 1. The three point hitch system and hydraulic lift mechanism can be seen in Figure 2.

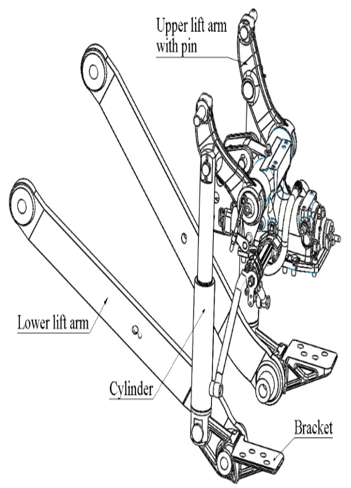



**Figure 1- Externally cylindered hydraulic lifts**

*Şekil 1- Dıştan silindirli hidrolik kaldırıcı*

**Table 1- Three point hitch system and hydraulic lift properties**

*Çizelge 1- Üç nokta askı sistemi ve hidrolik kaldırıcı özellikleri*

| *Property* | *Value* |
|---|---|
| TPH category | 2 |
| Lifting capacity (kg) | 3200 |
| System safety pressure (bar) | 195 |
| Flow rate (L min$^{-1}$) | 30 |
| Cylinder diameter (mm) | 60 |
| Upper lift arm (A) | 280 |
| Side suspension arm length (B) | 650 |
| Lower lift arm seam (C) | 405 |
| Lower lift arm length (D) | 900 |
| Top link (E) | 750 |
| Equipment height (F) | 610 |
| Equipment from the center of gravity (G) | 610 |

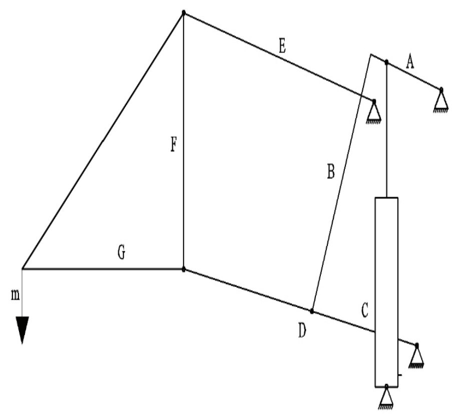



**Figure 2- Three point hitch system and hydraulic lift mechanism**

*Şekil 2- Üç nokta askı sistemi ve hidrolik kaldırıcı mekanizması*

*2.2. Lifting capacity test*

The theoretical lifting capacity was calculated after the first design sketches. Lifting capacity for the final design was tested in line with ISO 730 static capacity test procedure. Lifting capacity was tested with a hydraulic lift test setup that can be seen in Figure 3.

The hydraulic lift cylinders were pressurized with an externally integrated pump and the rods were raised. The pressure was controlled by a manometer installed between the hydraulic lift and pump. The lifting rods were connected via suitable apparatus to the load cell. Lifting capacity was measured with an Esit TB S-Type 5000 kg capacity load cell with an accuracy class of C3, in accordance with OIML R60. Hydraulic pressure of 190 Bar was applied to the cylinders. Per-second data from the load cell and sensors was collected during the experiments by a National Instruments PCIe-6363 data acquisition system and a LabVIEW-based data logger program. The results were compared with theoretical lifting capacity calculations.

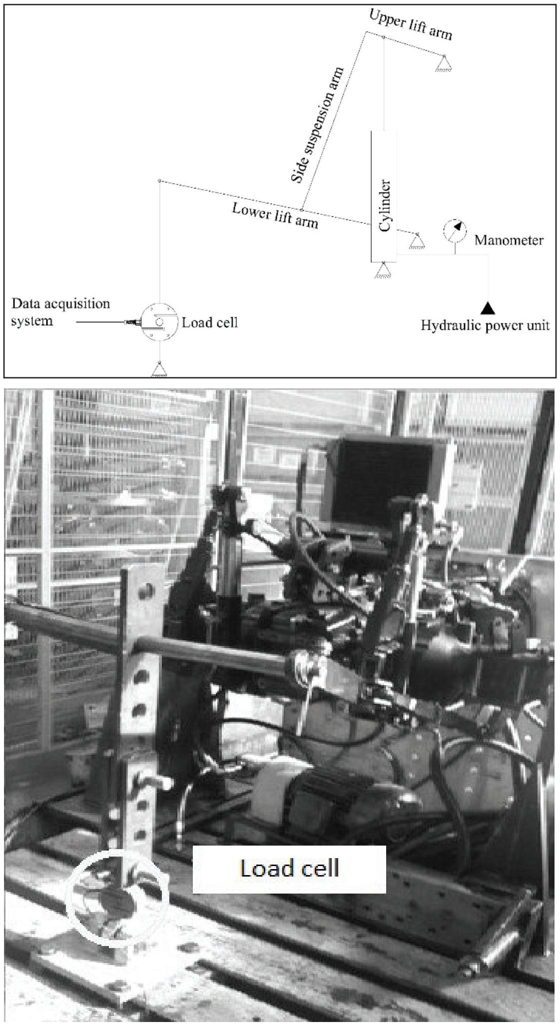



**Figure 3- Lifting capacity test setup**

*Şekil 3- Kaldırma kapasitesi test düzeneği*

During the cycle, effective loads for the TPH system were also established using static equilibrium calculations of the mechanism, which can be seen below. Loads placed on the TPH mechanism were calculated using the Equation 1-3, with the angles given in Figure 4.

$$F_s = P_{hyd.p.}.A \quad (1)$$

The equilibrium of AB rod and ED rod are expressed as follows.

$$\Sigma M_A = 0, \quad F_s \, Cos(\theta_p) \, l_{AP} - F_{bc} \, Cos\,(\theta_2) \, l_{AB} = 0 \quad (2)$$

$$\Sigma M_D = 0, \quad F_k \, Cos\,(\theta_4) \, l_{ED} - F_{bc} \, Cos(\theta_3) \, l_{CD} = 0 \quad (3)$$

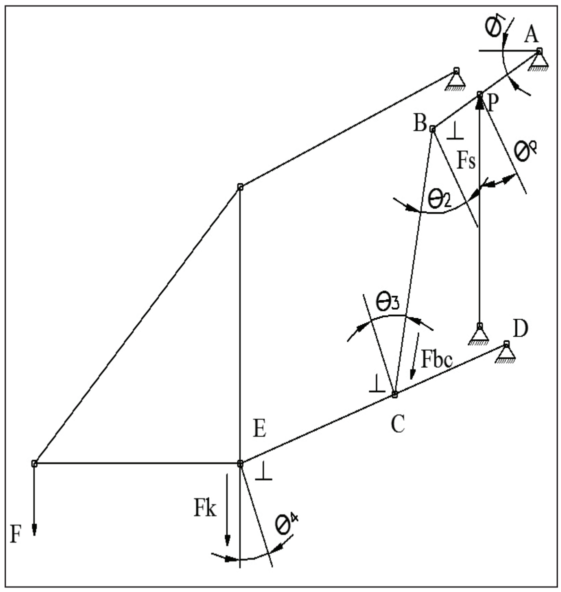



**Figure 4- Three point hitch mechanism**

*Şekil 4- Üç nokta askı sistemi mekanizması*

The parameters used in the calculations are given at Table 2. These parameters were determined from the experiments. The angles of the TPH rods were varied according to external rod angle ($\theta_1$).

The lengths used in calculations are taken as $l_{AP} = 157.88$ mm, $l_{AB} = 275$ mm, $l_{CD} = 405$ mm, $l_{DE} = 900$ mm.

**Table 2- Variables of TPH mechanism used in equilibrium calculations**

*Çizelge 2- Hesaplamalarında kullanılan TPH mekanizması değişkenleri*

| *Hydraulic cylinder data* | $\theta_1$ | $\theta_p$ | $\theta_2$ | $\theta_3$ | $\theta_4$ |
|---|---|---|---|---|---|
| 160 mm diameter 150 bar pressure | -30 | 33.09 | 45.9 | 36.34 | 20.44 |
| | -20 | 20.10 | 35.19 | 29.59 | 14.40 |
| | -10 | 9.04 | 24.85 | 22.82 | 7.97 |
| | 0 | 1.23 | 14.82 | 16.14 | 1.33 |
| | 10 | 10.84 | 5.06 | 9.55 | 5.41 |
| | 20 | 19.93 | 4.44 | 3.45 | 12.11 |
| | 30 | 28.58 | 13.68 | 2.37 | 18.69 |
| | 40 | 35.89 | 22.64 | 7.68 | 25.04 |
| | 50 | 44.94 | 31.28 | 12.38 | 31.07 |

*2.3. Push-pull test*

Hydraulic lift test apparatus was used for the push-pull test. The external bars of a hydraulic lift TPH mechanism were lifted up to maximum angle of 47° and fixed at that position. Pressure transducers were placed between the hydraulic pipe and the hydraulic lift for measuring pressure variations. The lower lifting arms of the TPH system were equipped with hydraulic lift apparatus at a 610 mm distance. A 1000 kg impulsive load was applied at the tip of TPH mechanism. The load was calculated using load cells at the tip of the piston, as seen in Figure 5. In these experiments, 40,000 cycles were found to be the optimum cycle count-where a bracket completed 40,000 cycles without any breakage, and passed load capacity tests and lifting-lowering tests. The push-pull test periods of 40,000 cycles were completed in approximately 55 hours (one cycle takes 5 seconds).

*2.4. Lifting-lowering test*

This was carried out in order to study the hydraulic lift system functions and to test the strength of the equipment, as seen in Figure 6. The test was also used for validation of the push-pull test at the final design stage of the brackets.

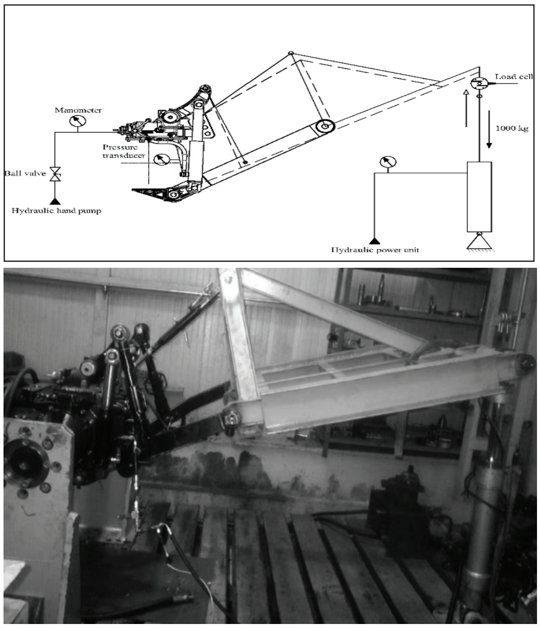



**Figure 5- Push-pull test setup**

*Şekil 5- Çek bırak test düzeneği*

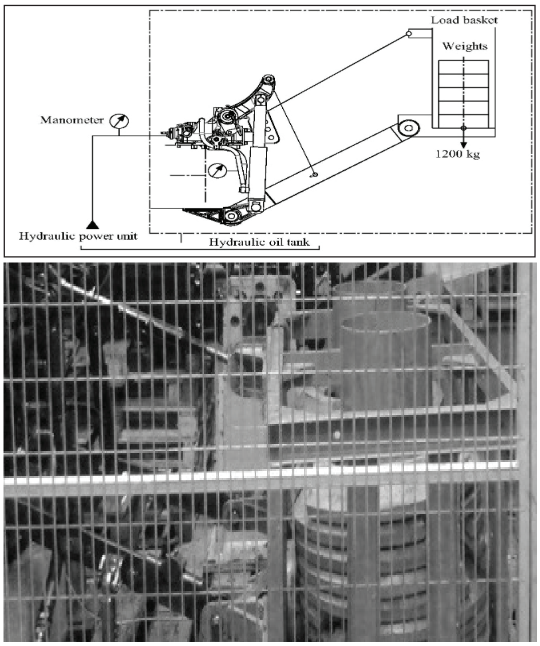



**Figure 6- Lifting-lowering test setup**

*Şekil 6- İndir kaldır test düzeneği*

A steel load basket connected to the three-point hitch system was used for the lifting-lowering tests. The load basket at the tip of TPH system was raised and lowered to the highest and lowest lifting points respectively. The gravity center of the basket was positioned 610 mm in height from lower arms. The basket was filled with 1200 kg of cast iron weights. One cycle was completed, with the lifting and lowering of the load basket taking 4 seconds. The position of the lower arms was determined by digital output proxy sensors. This process was repeated until a cycle count of 40,000 was achieved.

*2.5. Finite element analysis of bracket*

Finite element analysis was performed using ANSYS general finite element modeling software for study the stress and fatigue performance of brackets. The final design was achieved according to this analysis. The critical damage points of the brackets were determined under cyclic loading. Model mesh density was determined by convergence study of the bracket, as seen in Figure 7. The lifting-lowering test load procedure was used to convergence study. The finite element approximation of stress analysis was obtained for a number of 50,000 elements. The boundary conditions and applied mesh at the finite element model are given in Figure 8. Calculated loads at Equation 1-3 were applied to lower rod joints and cylinder rod joints, respectively and then the connections of the brackets were fixed.

At first, stage stress analyses of the brackets were performed. Nonlinear analysis with a multi-linear isotropic hardening material model was applied to the static stress analyses. Then strain life, based on the Coffin-Manson approach, was used to predict the fatigue life of the brackets. The stress of the critical breakage planes was evaluated according to the maximum principle stresses of the finite element analysis. The maximum principle stress results were used for the calculation of fatigue life because of the unyielding nature of GG materials.

Strain life-based, fatigue life-approximation was preferred because of the low cycle fatigue damages found in the experiments. In Table 3, the strain life parameters of the bracket materials GG25 and GG35 are given (ASM 1996).

The strain life was calculated using the Equation 4.

$$\frac{\Delta\varepsilon}{2} = \acute{\varepsilon}_f (2N_f)^c + \frac{\acute{\sigma}_f}{E}\ (2N_f)^{\mathrm{b}} \qquad (4)$$

The results of the finite element analysis are given in the related test sections.

**Table 3- Strain life parameters of bracket materials**

*Çizelge 3- Braket malzemelerinin gerilme ömür parametreleri*

| *Material* | $\sigma_y - \sigma_U$ *(MPa)* | *E (GPa)* | $\acute{\sigma}_f$*(MPa)* | *b* | $\acute{\varepsilon}_f$ | *c* |
|---|---|---|---|---|---|---|
| GG25 | 215-260 | 90 | 353 | -0.115 | 0.037 | -0.582 |
| GG35 | 345-438 | 134 | 696 | -0.114 | 0.016 | -0.383 |

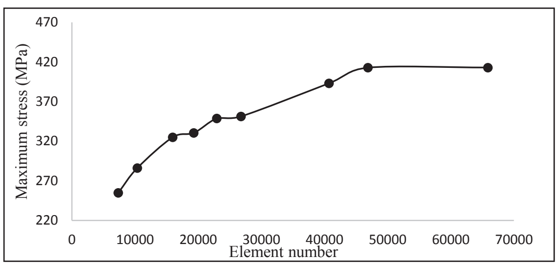



**Figure 7- Convergence study of bracket finite element model**

*Şekil 7- Braket sonlu elemanlar modelinin yakınsama çalışması*

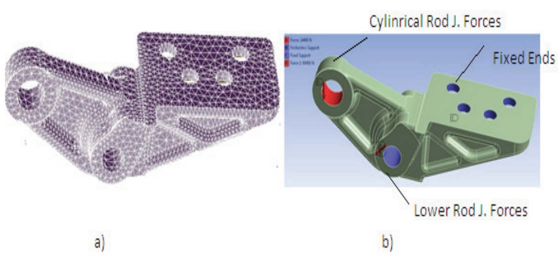



**Figure 8- a, mesh detail at finite element model; b, boundary conditions**

*Şekil 8- a, sonlu elemanlar modeli mesh detayı; b, sınır koşulları*

## 3. Results and Discussion

### *3.1. Lifting capacity test Results and bracket reaction forces for additional tests*

The experimental results of the lifting capacity were compared with the static equilibrium calculations (Figure 9). According to the results of the Chi-Square test, there is no significant difference between the theoretical calculations and experimental test results (P= 0.056>0.05).

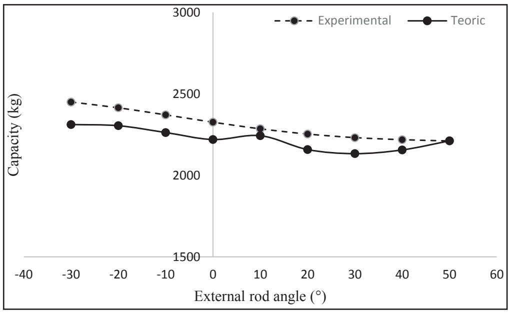



**Figure 9- Comparison of experimental and theoretical calculation result of the lifting capacity**

*Şekil 9- Kaldırma kapasitesinin deneysel ve teorik hesaplama sonuçlarının karşılaştırılması*

The TPH system cycle time was obtained from experimental tests. Cyclic loads applied to the TPH mechanism brackets, relative to the test loads, were calculated from equilibrium equations at Equation 1-3 as seen in Figure 10-12. It can be seen here that the theoretical maximum reaction force results of the lifting-lowering tests, obtained for the $0^0$ external rod angle, were applicable at lower rod and cylinder rod joints. Reaction forces of the bracket joints on the push-pull test varied, according to the load placed at the tip of the TPH mechanism. Reaction forces acting on cylinder rod joints were found to be higher than on lower rod joints because of hydraulic cylinder reactions. In push-pull tests, an impulsive load factor of 1.3 was determined from test data and fatigue life calculations.

### *3.2. Additional test results*

During the experimental push-pull tests, the breakage points of the brackets designed are shown in Figure 13. Breakage occurred after 11,218 cycles.

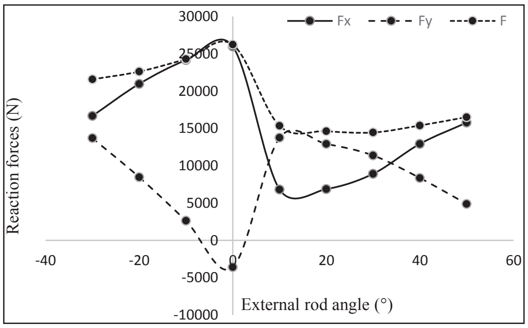



**Figure 10- Reaction forces acting on brackets lower rod joint (LRJ) at the lifting-lowering test**

*Şekil 10- İndir kaldır testinde, braket alt rod bağlantılarında oluşan reaksiyon kuvvetleri*

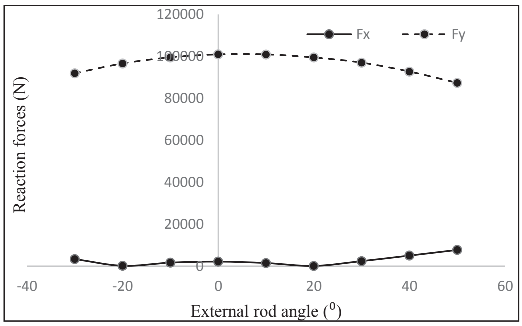



**Figure 11- Reaction forces acting on brackets cylinder rod joint (CRJ) at the lifting-lowering tests**

*Şekil 11- İndir kaldır testlerindeki braket silindir rod bağlantılarında oluşan reaksiyon kuvvetleri*

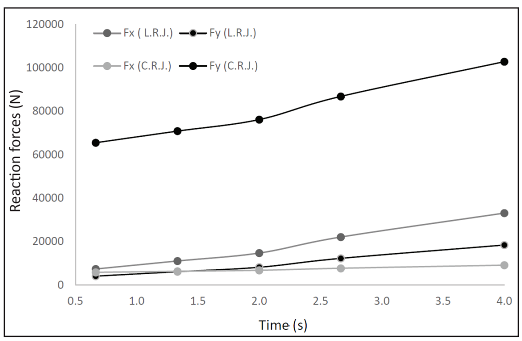



**Figure 12- Reaction forces acting on brackets joints at the push-pull test**

*Şekil 12- Çek bırak testindeki braket bağlantılarında oluşan reaksiyon kuvvetleri*

When the final design of the brackets was tested, it completed a full 40,000 cycles test period. During the lifting-lowering tests of the original bracket design, breakage occurred after 12,500 cycles. In comparison, the final bracket design completed a full 50,000 cycles test period without breakage. The difference between the two tests was the effect of impulsive load at the tip of the TPH mechanism. It was therefore assessed that push-pull tests give additional information about TPH mechanisms under impulsive load conditions.

**Figure 13- Brackets breakage points at the push-pull tests**

*Şekil 13- Çek bırak testinde braketlerde oluşan kırılma noktaları*

*3.3. Finite element results*

The analysis results of the failure zone, estimated by the finite element analysis, was compatible with the experimental results seen in fatigue life results, as seen in Figure 14-15. According to the test and analysis results, the breakage planes and maximum stress regions were determined, and the thickness of the connection surface of the brackets was increased from 12 mm to 19 mm. This modification increased the weight of the bracket from 4,540 to 4,800 g. The breakage section of the bracket was redesigned, as seen in Figure 16, and the material of the brackets was changed from GG25 to GG35. As a result of the new design, the stress placed on the fracture plane was reduced from 503 MPa to 371 MPa for the push-pull tests, as seen in Figure 17. It can be seen that the maximum stress variation across the thickness was reduced by the new design of the brackets.

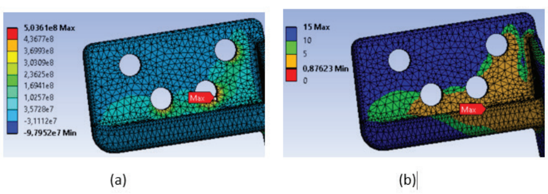



**Figure 14- Finite element analysis results of first design brackets at push-pull tests; a, the maximum stresses at the bracket; b, the results of the safety factor**

*Şekil 14- İlk tasarım braketlerin çek-bırak testi için sonlu elemanlar analizi sonuçları; a, braketlerdeki maksimum gerilmeler; b, emniyet faktörü sonuçları*

The analysis results of redesigned brackets at the lifting-lowering test are given in Figure 18. It can be seen here that maximum stresses were only 274 MPa and were reduced along the cross section at brackets. These results correlated with the push-pull tests. Similar maximum stress regions were found

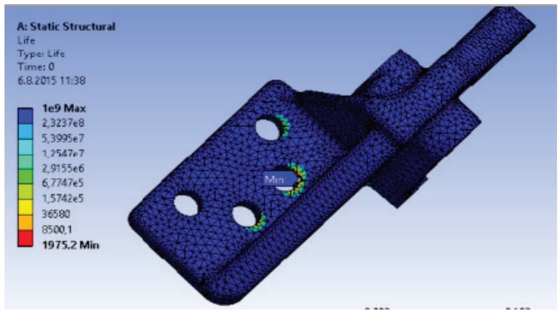



**Figure 15- Brackets fatigue life results at finite element analysis**

*Şekil 15- Sonlu elemanlar analizindeki braket yorulma ömrü sonuçları*

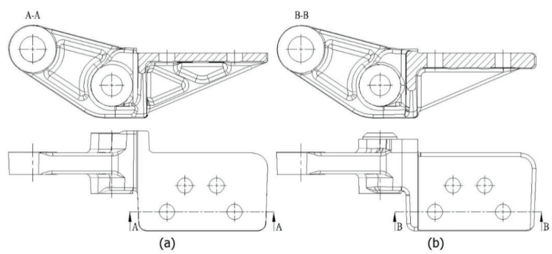
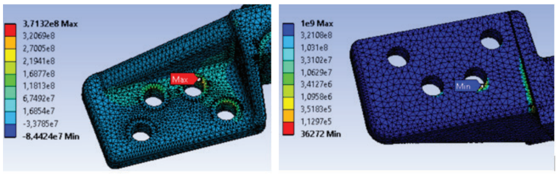



**Figure 16- Bracket enhancements according to push-pull test results; a, first designed bracket; b, final design enhanced bracket**

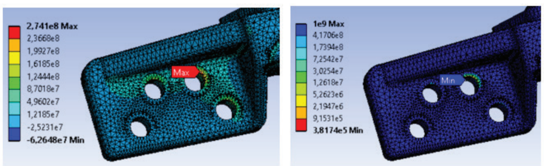
*Şekil 16- Çek-bırak test sonuçlarına göre braket iyileştirmeleri; a, ilk tasarlanan braket; b, iyileştirilmiş son tasarlanan braket*



(a) (b)

**Figure 17- Finite element analysis results of optimized brackets at push-pull tests; a, the maximum stresses at the bracket; b, the results of the fatigue life**

*Şekil 17- Optimize edilen braketlerin çek-bırak testi için sonlu elemanlar analizi sonuçları; a, braketlerdeki maksimum gerilmeler; b, yorulma ömür sonuçları*



(a) (b)

**Figure 18- Finite element analysis results of optimized brackets at lifting-lowering tests; a, the maximum stresses at the bracket; b, the results of the fatigue life**

*Şekil 18- Optimize edilen braketlerin indir-kaldır testi için sonlu elemanlar analizi sonuçları; a, braketlerdeki maksimum gerilmeler; b, yorulma ömür sonuçları*

for both tests. However, stress values obtained from the lifting-lowering tests were lower than those from the push-pull tests where the impulsive load effect on the TPH tip was a factor.

TPH mechanisms are generally tested according to Iso Standart Static Test methods. Some studies are focused on calculations and failure analysis of oscillations or dynamic loads acting on TPH mechanisms during drafting and implementations Otmianowski (1983), Sule et al (2007). There is not any test procedure is developed according to these dynamic loads. In our study newly developed tests on TPH mechanisms under impulsive dynamic loads are presented implemented to standard tests.

## 4. Conclusions

In the analysis, the boundary conditions were determined from system operating conditions. The maximum stress regions were examined comprehensively.

Improved safety factor results at the critical points were achieved by the material, shape and thickness modifications of the brackets. For this paper, three experimental test methods and finite element modeling were used in order to establish a methodology that could assess fatigue life in agricultural machine parts, namely the push-pull test, the lifting-lowering test and the lifting capacity test. In these experiments, it was seen that the push-pull test in particular was a very effective tool in determining the fatigue life of three point hitch system components. The results show that if any part of the TPH mechanism could complete 40,000 cycles of the push-pull test, it was also capable of passing the other tests. Therefore it was concluded that push-pull test data was implemented the standard tests for TPH mechanisms in order to assess impulsive loading.

## Acknowledgements

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**Abbreviations and Symbols**

| | |
|---|---|
| *TPH* | Three point hitch |
| *OIML R60* | International organization of legal metrology recommendations 60 |
| $F_s$ | Hydraulic force |
| $P_{hyd,p}$ | Hydraulic pressure |
| A | Piston cross section |
| $F_k$ | Lifting load |
| $l_{AP}, l_{AB}, l_{ED}, l_{CD}$ | Length of rod parts |
| $\theta_1, \theta_2, \theta_3, \theta_4, \theta_p,$ | TPH mechanism rod angles |
| $F_x, F_y, F$ | Reaction forces |
| $\acute{\varepsilon}_f$ | Fatigue ductility coefficient |
| $\sigma_y$ | Yield strength |
| $\sigma_u$ | Ultimate |
| $\sigma_f$ | Fatigue strength coefficient |
| $N_f$ | Cycles to failure |
| $b$ | Fatigue strength exponent |
| $c$ | Fatigue ductility exponent |

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# Baltalı ve Diskli Gömücü Ayağa Sahip Tek Dane Ekim Makinalarının Sırta Ekim Performanslarının Karşılaştırılması

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**ÖZET**

Bu çalışmada, baltalı ve diskli gömücü ayağa sahip tek dane ekim makinalarının, sırta mısır ekim performanslarının belirlenmesi ve aralarındaki farklılıkların ortaya konması amaçlanmıştır. Makina ekim performanslarının belirlenmesi amacıyla hem laboratuvar hem de tarla denemeleri gerçekleştirilmiştir. Laboratuvarda yapılan yapışkan bant denemeleriyle makinaların sıra üzeri tohum dağılım düzgünlükleri belirlenmiştir. Tarla denemelerinde ise makinaların sıra üzeri bitki dağılım düzgünlüğü, tarla çıkış derecesi, ekim derinliği düzgünlüğü, ekim makinası tarla (tahrik) tekerleği negatif patinaj oranı (kayma) ve traktör tahrik tekerleği patinaj oranı değerleri saptanmıştır. Denemeler sonucunda, sıra üzeri tohum dağılım düzgünlüğü açısından laboratuvar şartlarında tüm makinalar genellikle "iyi" kalitede ekim yaparken, tarla şartlarında sırta ekimde kalitenin bir miktar azaldığı, ancak diskli gömücü ayağa sahip ekim makinalarının balta tipi gömücü ayağa sahip ekim makinalarına göre mısır tohumlarını çok daha yüksek kalitede ekebildiği belirlenmiştir. Firma bazında diskli tip makinaların baltalı tip makinalara oranla hem daha yüksek tarla çıkışı hem de daha düzgün ekim derinliği sağladığı saptanmıştır. Ekim makinası tarla tekerleğinde meydana gelen negatif patinaj (kayma) değerleri baltalı tip makinalarda % 0.93-5.34, diskli makinalarda ise % 9.14-10.24 değerlerinde bulunmuştur. Traktör arka tekerleğinde meydana gelen patinaj değerleri ise baltalı ve diskli makinalarda sırasıyla % 1.38-3.83 ve % 5.39-9.50 olarak belirlenmiştir. Tüm bulgular doğrultusunda sırta ekimde diskli tip gömücü ayağa sahip ekim makinalarının kullanılmasının uygun olacağı saptanmıştır.

Anahtar Kelimeler: Mısır; Sırta ekim; Dağılım düzgünlüğü; Ekim kalitesi

# Comparing of Ridge Planting Performance of Precision Planters Equipped with Shoe and Disc Coulters

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**ABSTRACT**

The objective of this study was to determine ridge planting performance of the precision seeders equipped with shoe and disc type coulters and to reveal differences between seeders. To meet this target both laboratory and field experiments

TARIM BİLİMLERİ DERGİSİ — JOURNAL OF AGRICULTURAL SCIENCES 23 (2017) 195-207

were conducted. Seed spacing distribution uniformity of the machines were determined using sticky belt tests at the laboratory. The values of plant spacing distribution uniformity, ratio of plant emergence, seeding depth uniformity, negative driven wheel slips of the seeders and driven wheel slips of the tractors were determined by the tests carried out on field conditions. Based on the experimental results, it was determined that, all seeders performances in terms of seed spacing distribution uniformity were found in "good" quality under laboratory conditions, while seeding quality in ridge planting on the field was determined lower than laboratory conditions for all seeders. But seeders equipped with disc type coulters were determined more effective than seeders equipped with shoe type coulters in high quality corn seeding under field conditions. It was found that seeders equipped with disc type coulters provided both higher plant emergences and more uniform seed depths in firm terms. The values of negative driven wheel slips of the seeders were determined as 0.93-5.34% and 9.14-10.24% for shoe type and disc type seeders, respectively. The values of driven wheel slips of the tractors were ranged from 1.38% to 3.83% and from 5.39% to 9.50% for shoe type and disc type seeders, respectively. Based on the all findings it was determined that seeders equipped with disc type coulters should be used in ridge planting.

Keywords: Corn; Ridge planting; Seed distribution uniformity; Planting quality



## 1. Giriş

Toprak, su ve çevre korumanın yanında önemli bir girdi maliyeti tasarrufu sağlayan koruyucu toprak işleme, azaltılmış toprak işleme ve doğrudan ekime olan ilgi dünyada olduğu gibi ülkemizde de artış eğilimindedir. Koruyucu toprak işlemede ekim; doğrudan ekim, sırta ekim ve malçlı ekim olmak üzere üç farklı şekilde uygulanabilmekte olup, aşırı yağışlı alanlarda toprağın erozyonla kaybedilmesini önlemek amacıyla malçlı ekim, yağışın az olduğu alanlarda ise toprak neminin korunması amacıyla doğrudan ekim uygulamaları tercih edilmektedir.

Sırta ekim, sulama yapılan alanlarda mevcut suyun en etkili bir şekilde kullanılabilmesi için uygulandığı gibi düzensiz yağış alan alanlarda drenaj amaçlı da uygulanmaktadır. Sırta ekim sistemi birçok avantaj sağlamakta ve bu avantajlar nedeniyle de son yıllarda daha çok uygulamaktadır. Sulama suyu yönetiminde kolaylık ve tasarruf sağlaması, yağmur sonrası sırt üstünün daha hızlı kuruması ve bitki köklerinin daha sağlıklı gelişmesi nedeniyle bitki kök hastalıklarının kontrol altına alınabilmesi, süne ile mücadelede yer aletlerinin kullanımına olanak sağlaması, yağışın fazla ve düzensiz olduğu alanlarda su kesmesini engellenmesi, sırtlar arasındaki hava sirkülasyonu nedeniyle bitkilerin hava ve güneşten yararlanma derecesinin artması sonucunda güçlü bitki gövdesi oluşumu sağlaması, traktör tekerleğinin karıklardan geçmesi nedeniyle bitkilere zarar vermeden ilaçlama, gübreleme, çapalama gibi bakım işlemlerinin düze ekime göre daha rahat yapılabilmesi, toprak sıcaklığının korunması nedeniyle ekimde erkencilik sağlanması sırta ekim sisteminin avantajlarından bazılarıdır. Bu sistemin en fazla uygulandığı ürünlerin başında buğday gelmekle birlikte pamuk, mısır, soya ayçiçeği gibi çapa bitkilerinin yanında nohut, kolza gibi bitkilerin de ekiminde başarıyla uygulanabileceği tespit edilmiştir. Özellikle pamuk buğday ekim nöbetinde pamuk sonrası sırtlar bozulmadan daimi sırtlara zamanında yapılan ekim ile birlikte girdilerin azaltılmasının mümkün olduğu belirtilmektedir (Aykanat 2009).

Tarımsal üretimde üretimin artırılmasında ve rasyonelleştirilmesinde gerek tohum tüketimini azaltmanın, gerekse ideal agroteknik koşullar sağlamanın ilk adımı "Optimum Ekim İşlemi"dir. Teknolojinin ilerlemesiyle yeni nesil ekim makinaları tasarlanmakta, teleskobik olarak daralan veya katlanan üniteler kullanılmakta, çapa bitkileri için sıra arası 65-80 cm arasında ayarlanabilmekte, pnömatik tek dane ekici düzen ve farklı tohumlara uygun ekici plakalarla sıra üzeri tohum mesafesi seçilebilmekte, otomatik markörle çalışma rahatlamakta, gübre düzeneğinin eklenmesiyle ideal ekim ve ideal gübreleme tek geçişte gerçekleştirebilmektedir. Farklı tohumların ekiminde aynı makinanın kullanılması mekanizasyon planlaması ve maliyet bakımından çok önemli avantajlar sağlamaktadır (Ulusoy et al 2011). Ancak bu avantajların yanında makinalardan maksimum yararlanma ve uygun makina seçimi için, çeşitli şartlarda yürütülen denemelerle makina performans değerlerinin de saptanması gerekmektedir. Tek dane ekim makinalarının performans değerlendirmelerine ilişkin laboratuvar ve tarla şartlarında araştırmacılar tarafından yürütülen birçok çalışma bulunmasına karşılık, sırta ekimde makina performansına yönelik çalışmalar sınırlı sayıdadır. Sırta ekime ilişkin gerek dünyada gerekse ülkemizde yürütülen çalışmalarda, çoğunlukla bu sistemin diğer toprak işleme ve ekim sistemleriyle (düze ekim, normal sıraya ekim, malçlı ekim vb) karşılaştırılarak, ağırlıklı olarak ürün verimi, toprak yapısı ve su korunumu üzerine etkileri araştırılmıştır. Tisdall & Hodgson (1990) tarafından yürütülen çalışmada, ince tekstürlü topraklarda normal sıraya ekim ve sırta ekim yöntemlerinin sebze ve tarla bitkileri üzerine etkileri araştırılmış, araştırma sonucunda bitki köklerinin iyi havalanma nedeniyle sırta ekimde normal sıraya ekime göre bitki gelişiminin daha iyi olduğu ve verim artışının sağlandığı belirtilmiştir. Çekiç & Savaşlı (2003), buğdayda sırta ekim yönteminin İç Anadolu Bölgesi koşullarında uygulanabilirliğini saptamak amacıyla geleneksel ekim ile iki farklı sırta ekim yöntemini (sırta 2 sıralı ekim ve sırta 3 sıralı ekim) karşılaştırmış ve uygulanan yöntemler arasında verim bakımından istatistiki olarak önemli bir fark olmadığını saptamışlardır. Li et al (2007), Çin'de, ürün verimin düşük olduğu, kurak bir bölgede yürüttükleri çalışmalarında, sırta yonca (*Medicago sativa* L.) ekimi gerçekleştirerek sırta ekimin verim üzerine etkilerini araştırmışlardır. Farklı genişliklerdeki (30, 45 ve 60 cm) sırtları ayrıca plastik örtü ile kapatarak hem örtülü hem de örtüsüz olarak sırtlardaki nem düzeyini düze ekim ile karşılaştırmışlardır. Araştırma sonucunda sırt tipi ve genişliğinin ortalama yonca verimi üzerine önemli etkisi olduğu belirlenmiştir. Çalışmada örtüyle kaplı sırtların (5114 kg ha$^{-1}$) örtüsüz sırtlara (2534 kg ha$^{-1}$), örtüsüz sırtların ise düze ekime (1925 kg ha$^{-1}$) göre daha yüksek verim sağladığı saptanmıştır. Araştırmada ayrıca sırt genişliğinin artışıyla verimin azaldığı belirlenmiştir. Gürsoy et al (2012) üç farklı çeşit durum buğdayı kullanarak yürüttükleri çalışmalarında sırta ekim ile geleneksel ekim arasındaki farklılıkları, süne zararlısı ve ürün verimi açısından incelemişler, süne yoğunluğu ve verim üzerinde ekim yönteminin önemli etkisinin olmadığını, farklılığın buğday çeşidine bağlı olduğunu saptamışlardır. Zhang et al (2007) kışlık buğdayda sırta üç sıralı ekim, malçlı karığa üç sıralı ekim ve geleneksel düze ekim sistemlerini kullanarak su tüketimi ve ürün verimini araştırmışlardır. Çalışma sonucunda en yüksek su tüketiminin 404.4 mm ile düze ekimde gerçekleştiği, sırta ekimde tüketimin 354.5 mm, malçlı ekimde ise 323.6 mm olduğu saptanmıştır. Çalışmada en yüksek buğday verimi sırta ekimde (7995.32 kg ha$^{-1}$) elde edilirken, malçlı ekimde ve düze ekimde sırasıyla 7005.9 kg ha$^{-1}$ ve 7602.3 kg ha$^{-1}$ verim değerlerine ulaşılmıştır.

Bu çalışmaların dışında genellikle agronomistler tarafından yürütülen patates, mısır, pamuk, yulaf gibi bitkiler kullanılarak farklı toprak işleme ve ekim yöntemlerinin toprak nemi, ürün verimi, su kullanım etkinliği ve toprak partikül yapısının değişimine etkilerinin araştırıldığı pek çok tarla çalışmasına (Bakht et al 2006; Boulal et al 2012; Süzer & Demir 2012; Song et al 2013; Qin et al 2014) ulaşılabilirken, makinalı sırta ekime ilişkin tarla çalışmaları sınırlı sayıdadır. Altuntaş & Dede (2009), silajlık mısırda geleneksel, sırta ve doğrudan ekimin, toprak yapısı ve bitki çıkışına etkisini araştırmışlardır. Çalışmada her üç ekim yönteminde de vakumlu tip tek dane ekim makinasını kullanılmış, çalışma sonucunda toprak nem içeriği, hacim ağırlığı, penetrasyon direnci, bitki çıkış derecesi değerlerinin, sırta ekimde düze göre daha yüksek olduğu ve bitki çıkış süresinin azaldığı saptanmıştır. Pikul et al (2001)'ın mısır ve soya rotasyonunda uyguladıkları sırta ekim ve geleneksel ekim sistemlerini içeren çalışmalarında, üç farklı gübre değerinde ürün performansı ve toprak durumu incelenmiştir. Her iki sistemde de vakumlu tip tek dane ekim makinası kullanılmıştır. 11 yıllık araştırma sonucunda, mısırda ortalama ürün verimi geleneksel ekimde 6500 kg ha$^{-1}$, sırta ekimde 6267 kg ha$^{-1}$ olarak elde edilirken, soyada önemli bir farklılık saptanmamıştır. Çalışmada 15 cm'lik toprak katmanında pH değeri toprak işleme sistemi farklılığından etkilenmezken, toprak hacim ağırlığının sırtlarda düze göre daha yüksek olduğu belirlenmiştir.

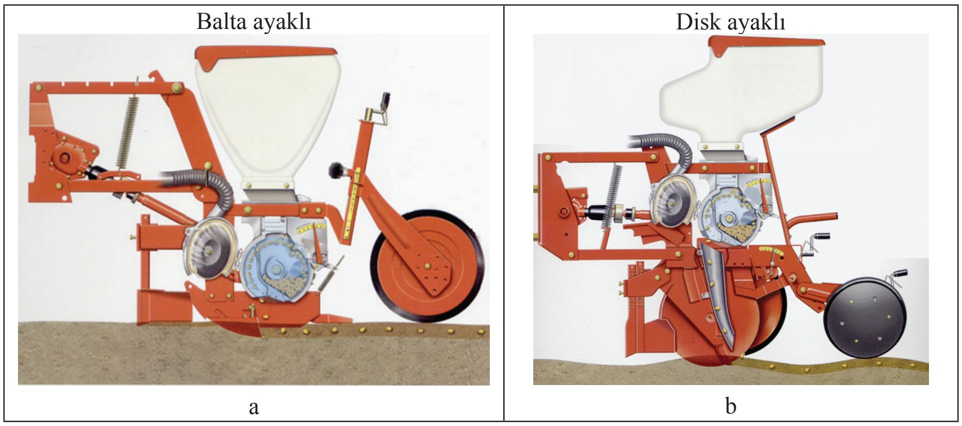
Tarla çalışmalarında denemelerin araştırmacılar tarafından küçük deneme parsellerinde yürütülmüş olması ya da ekimin aynı makinayla yapılmış olması diğer parametrelere bağlı olarak ürün verimi, toprak yapısı ve su tutma kapasitesi hakkında değerli bilgiler elde edilmesini sağlamıştır. Ancak geniş alanlarda yapılan bitkisel üretimde kilit işlem olan ekimin, bitki çıkışı ve hasadı da doğrudan etkileyeceği düşünüldüğünde, özellikle uygulanacak ekim yöntemine göre ekim makinası seçiminin önemi daha belirgin olarak ortaya çıkmaktadır.

Yukarıdaki bilgiler ışığında planlanan ve yürütülen bu çalışmada, geleneksel ekimde yaygın olarak kullanılan baltalı tip gömücü ayağa sahip tek dane ekim makinaları ve doğrudan ekimde yaygın olarak kullanılan diskli tip tek dane ekim makinalarının sırta mısır ekiminde kullanılabilirliğinin belirlenmesi ve makinalar arasındaki performans farklılıklarının ortaya konması amaçlanmıştır. Ayrıca çiftçiler tarafından denenen ve önerilen sırta ekimde diskli makina kullanımının uygunluğunun bilimsel nitelikte ortaya konması da amaçlanmıştır.

## 2. Materyal ve Yöntem

Ülkemizde ve dünyada ekim makinalarında meydana gelen teknolojik gelişmelerle mısır ekimi, tek dane ekim makinalarıyla geleneksel ya da doğrudan ekim sistemleri kullanılarak yapılabilmektedir. Geleneksel ekimde çoğunlukla balta tip gömücü ayağa sahip ekim makinaları kullanılırken, doğrudan ekimde ise diskli tip ekim makinaları tercih edilmektedir. Aynı imalatçı firma tarafından üretilen baltalı ve diskli gömücü ayağa sahip, vakumlu tip tek dane ekim makinalarında, çalışma prensibi açısından, düşey tohum diskli ekici düzen aynı özellikleri taşırken, toprakla temas eden, diğer bir ifadeyle tohumu toprağa yerleştiren tohum yönlendirme sistemi ve gömücü ayaklar birbirinden farklılık göstermektedir. Balta ayaklı ekim makinalarında tohum vakum etkisinden kurtulup doğrudan gömücü ayağın açtığı çiziye bırakılırken, diskli tip ekim makinalarında ekim plakasından bırakılan tohum, tohum borusundan geçtikten sonra çiziye bırakılmaktadır (Şekil 1). Denemelerde farklı firmalara ait iki adet yerli üretim, bir adet ithal olmak üzere üç adet balta tipi gömücü ayağa sahip ekim makinası ile yine bu firmalara ait diskli gömücü ayağa sahip üç farklı ekim makinası kullanılmıştır (Şekil 2). Makinalara ilişkin bazı teknik özellikler Çizelge 1'de verilmiştir. Tüm makinalarda ekici üniteler hareketini ekim makinası tahrik tekerleğinden almakta ve merkezi transmisyon sistemi yardımıyla farklı sıra üzeri aralık değerleri elde edilmektedir. Denemeler sırasında tüm makinalarda öngörülen dişli kademeleri seçilerek sıra üzeri anma ekim aralığı (Z) değeri 14 cm'ye ayarlanmıştır. Hem laboratuvar hem de tarla denemelerinde bin dane ağırlığı 275 g olan KWS-Kermess çeşidi hibrit mısır tohumu ve tohuma uygun 26 delikli, 4.5 mm delik çaplı ekici plakalar kullanılmıştır. Laboratuvarda yapışkan bant düzeneğinde üç tekerrürlü olarak yapılan denemelerde, 1.0, 1.5 ve 2.0 m $s^{-1}$ ilerleme hızlarında ve 70 mbar sabit vakum basıncı değerinde çalışılmış, makina performansları sıra üzeri tohum dağılım düzgünlüğü olarak belirlenmiştir. Tek dane ekim makinaları performans göstergeleri olan kabul edilebilir tohum aralığı (0.5 Z-1.5 Z), ikizlenme (<0.5 Z) ve boşluk (>1.5 Z) oranı değerleri, bilgisayar destekli lazerli otomatik mesafe ölçüm sistemi (Önal & Önal 2009) yardımıyla Çizelge 2'deki plana (Önal 2011) göre belirlenmiş ve Çizelge 3'e (Anonim 1999) göre yorumlanmıştır.

Tarla denemelerinde, ekim öncesi yöreye özgü geleneksel yöntemlerle toprak işlenmiş, sırt tapanı kullanılarak, taban genişliği 45±5 cm ve sırt yüksekliği 17±3 cm olan sırtlar oluşturularak tohum yatağı hazırlanmıştır (Şekil 3). Ekim denemeleri her makina ile; 14 cm sıra üzeri anma ekim aralığı, 70 cm sıra aralığı, 5 cm ekim derinliği, 70 mbar vakum basıncı ve 6 km $h^{-1}$ (1.67 m $s^{-1}$) ilerleme hızı değerlerinde gerçekleştirilmiştir. Denemelerde 6 sıralı makinalar TD 110 D, 4 sıralı makinalar ise TD 65-56 D traktörlerine bağlanmıştır. Adana-Karataş Mevkii'nde yürütülen denemelerde 6 sıralı makinalarla 4.2'şer da, 4 sıralı makinalarla ise 2.8'er da olmak üzere toplam 19.6 da alanda sırta mısır ekimi




**Şekil 1- a, balta tip ve b, diskli tip gömücü ayağa sahip tek dane ekim makinaları üniteleri ve çalışma prensibi (Gaspardo 2007a; Gaspardo 2007b)**

*Figure 1- Operational principle of planters equipped with a, shoe type and b, disc type coulters (Gaspardo 2007a; Gaspardo 2007b)*


**Şekil 2- Denemelerde kullanılan tek dane ekim makinaları**

*Figure 2- The precision seeders used in the experiments*

gerçekleştirilmiştir. Ekim denemeleri sonucunda makinaların tarla performansları, sıra üzeri bitki çıkışındaki dağılım düzgünlüğü olarak incelenmiş, tarla çıkış derecesi, ekim derinliği düzgünlüğü, ekim makinası tahrik tekerleği kayma oranı ve traktör arka tekerlek patinaj değerleri belirlenmiştir.

**Çizelge 1- Makinalara ilişkin bazı teknik özellikler**

*Table 1- Some technical properties of the machines*

| | *BA-1* | *BA-2* | *BA-3* | *DA-1* | *DA-2* | *DA-3* |
|---|---|---|---|---|---|---|
| Traktöre bağlama düzeni | Asma tip | Asma tip | Asma tip | Asma tip | Asma tip | Asma tip |
| Ünite sayısı | 4 | 4 | 4 | 6 | 6 | 4 |
| Gömücü ayak tipi | Balta | Balta | Balta | Çift diskli | Çift diskli | Çift diskli |
| Ağırlık | 880 kg | 1050 kg | 780 kg | 1400 kg | 1280 kg | 890 kg |
| Ekici düzen | Delikli plaka | Delikli plaka | Delikli plaka | Delikli plaka | Delikli plaka | Delikli plaka |
| Plaka delik sayısı | 26 adet | 26 adet | 26 adet | 26 adet | 26 adet | 26 adet |
| Delik çapı | 4.5 mm | 4.5 mm | 4.5 mm | 4.5 mm | 4.5 mm | 4.5 mm |
| Tohumun ekici plakadan bırakılma yüksekliği | 10 cm | 10 cm | 10 cm | 45 cm | 45 cm | 45 cm |
| Tohum deposu hacmi | 30 $dm^3$ | 50 $dm^3$ | 32 $dm^3$ | 35 $dm^3$ | 50 $dm^3$ | 32 $dm^3$ |
| Kullanılan traktör | TD 65-56 D | TD 65-56 D | TD 65-56 D | TD 110 D | TD 110 D | TD 65-56 D |

**Çizelge 2- Sıra üzeri tohum dağılım düzgünlüğü değerlendirme planı**

*Table 2- Evaluation table for the seed spacing distribution*

| *Sıra üzeri tohum aralığı* | *Tanım* |
|---|---|
| < 0.5 Z | İkizlenme |
| (0.5-1.5) Z | Kabul edilebilir tohum aralığı (KETA) |
| >1.5 Z | Boşluk |

**Şekil 3- Sırtların oluşturulması, mısır ekimi ve bitki çıkışı**

*Figure 3- Ridge formation, corn planting and plant emergence*

Tarla denemeleri tesadüf blokları deneme düzenine göre yürütülmüştür. Sıra üzeri bitki dağılım düzgünlüğü ve tarla çıkış derecesinin saptanması amacıyla araştırmanın yapıldığı deneme tarlasında 3 blok oluşturulmuş, ekilen tohumların filizlenmesinin ardından her bloktan rastgele seçilen alanlarda 3 tekerrürlü olarak 10 m uzunluğundaki çizilerde çimlenen bitkiler sayılmış ve bu çizilerdeki bitki aralıkları ölçülmüştür. Bitki ölçümleri ekim işleminden 14 gün sonra yapılmıştır.

Sıra üzeri bitki dağılım düzgünlüğünün değerlendirilmesi tek dane ekim kriterleri uyarınca Çizelge 4'deki plana (Önal 2011) göre belirlenmiş ve Çizelge 3'e (Anonim 1999) göre yorumlanmıştır. Tarla çıkış derecesinin (TÇD) saptanmasında ise Eşitlik 1 kullanılmıştır.

$$TÇD = [(N_x - N_0)/N_i] \text{x} 100 \quad (1)$$

Burada; $N_x$, belirli sıra uzunluğunda tüm bitki aralıklarının toplam sayısı; $N_0$, 0.5 Z'den küçük aralıkların toplam sayısı; $N_i$, teorik toplam bitki sayısıdır (Anonim 1999).

**Çizelge 3- Kabul edilebilir sıra üzeri tohum/bitki aralıkları, ikizlenme ve boşluk oranları değerlendirme planı**

*Table 3- Evaluation of the quality of feed index for seed/plant, multiple index and miss index*

| *Kabul edilebilir tohum/bitki aralıkları oranı (KETA/KEBA, %)* | *İkizlenme oranı (İO, %)* | *Toplam boşluk oranı (BO, %)* | *Değerlendirme* |
|---|---|---|---|
| >98.6 | <0.7 | <0.7 | Çok iyi |
| >90.4-≤98.6 | ≥0.7-<4.8 | ≥0.7-<4.8 | İyi |
| ≥82.3-90.4 | ≥4.8-≤7.7 | ≥4.8-≤10 | Orta |
| <82.3 | >7.7 | >10 | Yetersiz |

Laboratuvar denemelerinden elde edilen sıra üzeri tohum dağılım düzgünlüğü, tarla denemelerinden elde edilen tarla çıkış derecesi ve sıra üzeri bitki dağılım düzgünlüğü değerleri açısından makinalar arasındaki farklılıklar, varyans analizi yapılarak istatistiksel olarak değerlendirilmiştir.

**Çizelge 4- Sıra üzeri bitki dağılım düzgünlüğü değerlendirme planı**

*Table 4- Evaluation table for the plant spacing distribution*

| *Sıra üzeri bitki aralığı* | *Tanım* |
|---|---|
| < 0.5 Z / TÇD | İkizlenme |
| (0.5-1.5) Z / TÇD | Kabul edilebilir bitki aralığı (KEBA) |
| >1.5 Z / TÇD | Boşluk |

Ekim derinliğindeki düzgünlüğün belirlenmesinde, bitki çıkışından sonra parsellerin farklı yerlerinden sökülen 10'ar adet fidenin kök derinlikleri ölçülmüş ve ekim derinliğindeki değişim varyasyon katsayısı ile değerlendirilmiştir. Ekim derinliği dağılımında varyasyon katsayısının % 20 değerinden yüksek olmaması referans eşik olarak kabul edilmiştir (Önal 2011). Ekim sırasında ekim makinalarının tahrik (tarla) tekerleğindeki kayma oranını (negatif patinaj) saptamak amacıyla, ekim makinası tarla tekerleğinin 10 turunda gidilen mesafe ölçülmüş ve tarla tekerleğinin patinajsız durumda teorik olarak gitmesi gereken mesafeye oranlanarak kayma değeri belirlenmiştir. İyi bir ekim işleminde makina tahrik tekerleğinde meydana gelecek negatif patinaj/kayma miktarı en çok % 10 değerinde olmalıdır (Önal 2011). Denemelerde traktör arka tekerleğinde meydana gelen patinajı belirlemek amacıyla, 50 m mesafedeki tekerlek devri ölçülerek, tekerleğin bu mesafede atması gereken teorik devir sayısı ile oranlanmasıyla patinaj değeri hesaplanmıştır.

## 3. Bulgular ve Tartışma

### *3.1. Laboratuvar denemelerine ilişkin sonuçlar*

Yapışkan bant deneme düzeni kullanılarak 1.0, 1.5, 2.0 m $s^{-1}$ ilerleme hızlarında, 14 cm sıra üzeri tohum aralığında, 70 mbar vakum basıncında tüm makinalarla mısır ekim denemeleri gerçekleştirilmiş ve laboratuvar denemelerinden elde edilen, kabul edilebilir tohum aralığı (KETA), ikizlenme ve boşluk oranlarına ilişkin sonuçlar Çizelge 5'te üç tekerrürün ortalaması olarak verilmiştir. Denemelerde makina tekleme düzenleri, delikte sadece bir tohumun tutulmasını sağlayacak şekilde ayarlanarak, ikizleme ve/veya boşluğun tamamen deneysel olarak meydana gelmesi sağlanmıştır. Çizelge 5'ten görüldüğü gibi laboratuvar şartlarında tüm makinalarla genellikle "iyi" kalitede ekim yapmak mümkün olmaktadır. İlerleme hızının artışıyla KETA değerlerinde bir miktar azalma görülse de bu değerler yeterli kalitede ekim yapıldığının göstergesi olan sınır değerinin (% 82.3) bir hayli üzerinde kalmaktadır. Tüm makinalarda 1 m $s^{-1}$ ilerleme hızında KETA maksimum değerlerini alırken, ilerleme hızı 2 m $s^{-1}$'ye çıktığında özellikle boşluk oranında büyük artışlar meydana gelmektedir. Firma bazında, aynı ekici plaka ve transmisyon özelliklerine sahip, sadece gömücü ayak özellikleri farklı baltalı ve diskli makinalarda aynı ilerleme hızı değerlerinde elde edilen KETA değerleri incelendiğinde firmalar arası farklılıklar saptanmıştır. Örneğin, A firmasına ait BA-1 ve DA-1 makinalarına ilişkin sonuçlar incelendiğinde tüm hızlarda DA-1'in performansının BA-1'den daha yüksek olduğu ve 2.0 m $s^{-1}$ ilerleme hızında BA-1'in performansındaki azalmanın DA-1'e göre daha fazla olduğu saptanmıştır. Ayrıca DA-1'in, 1.0 ve 1.5 m $s^{-1}$ ilerleme hızlarında herhangi bir boşluk ya da ikizlenme yapmaksızın tüm tohumları 14 cm sıra üzeri aralıkta maksimum performansla (% 100) ekebilecek yetenekte olduğu belirlenmiştir (Çizelge 5). B firmasının baltalı (BA-2) ve diskli (DA-2) makinalarının 1.0 ve 1.5 m $s^{-1}$ ilerleme hızlarındaki performansları incelendiğinde, aynı hız değerinde, makinalar arasındaki farkın istatistiksel açıdan önemli olmadığı saptanmıştır. Ancak, hız 2.0 m $s^{-1}$ değerindeyken DA-2'nin performansının BA-2'ye oranla oldukça düşük olduğu belirlenmiştir (Çizelge 5). % 95 önem seviyesinde yapılan istatistik analiz sonuçları da 2.0 m $s^{-1}$ ilerleme hızında makinalar arasındaki farkın önemli olduğunu doğrulamaktadır (Çizelge 5). C firmasında ise, diğer makinaların aksine, aynı hız değerinde, baltalı ve diskli makinalar arasında makina performansı açısından istatistiksel olarak önemli herhangi bir farklılık görülmemiştir.

Yazgı (2013) tarafından pamuk ve mısır tohumları kullanılarak yapılan laboratuvar çalışmasında, yüksek ekim üniteli diskli gömücü ayağa sahip tek dane ekim makinası performansının, özellikle tohum yolu ve geometrisi nedeniyle, alçak ekim üniteli balta tip gömücü ayağa sahip makinalara göre daha düşük olduğu saptanmıştır. Sırta ekime yönelik laboratuvar sonuçlarını da

**Çizelge 5- Yapışkan bant denemelerinden elde edilen sıra üzeri tohum dağılım düzgünlüğü değerleri**

*Table 5- Seed distribution uniformity values obtained from sticky belt experiments*

| *Ekim makinası* | *İlerleme hızı* | *Kabul edilebilir tohum aralıkları oranı (KETA, %)** | *İkizlenme oranı (İO, %)* | *Toplam boşluk oranı (BO, %)* | *Değerlendirme* |
|---|---|---|---|---|---|
| | 1.0 | $98.27^{b}$ | 0.85 | 0.88 | İyi |
| BA-1 | 1.5 | $96.84^{AB}$ | 1.16 | 2.00 | İyi |
| | 2.0 | $88.88^{III}$ | 0.95 | 10.17 | Orta |
| | 1.0 | $98.29^{b}$ | 0.88 | 0.83 | İyi |
| BA-2 | 1.5 | $98.29^{AB}$ | 0.86 | 0.85 | İyi |
| | 2.0 | $97.41^{I}$ | 0 | 2.59 | İyi |
| | 1.0 | $98.20^{b}$ | 0 | 1.80 | İyi |
| BA-3 | 1.5 | $96.85^{B}$ | 0 | 3.15 | İyi |
| | 2.0 | $92.90^{II}$ | 0 | 7.10 | İyi |
| | 1.0 | $100^{a}$ | 0 | 0 | Çok iyi |
| DA-1 | 1.5 | $100^{A}$ | 0 | 0 | Çok iyi |
| | 2.0 | $96.36^{I}$ | 1.75 | 1.89 | İyi |
| | 1.0 | $97.81^{b}$ | 0.72 | 1.46 | İyi |
| DA-2 | 1.5 | $97.46^{AB}$ | 0.85 | 1.69 | İyi |
| | 2.0 | $88.21^{III}$ | 0 | 11.79 | Orta |
| | 1.0 | $98.32^{b}$ | 0 | 1.68 | İyi |
| DA-3 | 1.5 | $96.60^{B}$ | 0 | 3.40 | İyi |
| | 2.0 | $92.66^{II}$ | 0 | 7.34 | İyi |

*, KETA değerlerinin yanında aynı harf ya da rakamla gösterilen ortalamalar % 95 önem düzeyindeki LSD testine göre birbirinden faklı değildir; küçük harfler, 1.0 m $s^{-1}$ ilerleme hızı; büyük harfler, 1.5 m $s^{-1}$ ilerleme hızı; I, II, III, 2.0 m $s^{-1}$ ilerleme hızı için farklılıkları ifade etmektedir

içeren bu çalışmadan elde edilen bulgular ise, performansın firmaya göre farklılık gösterebildiğini ve makina konstrüksiyonunun iyileştirilmesiyle baltalı ve diskli makinalar arasındaki farklılığın azaltılabileceğini göstermektedir. Ancak gözden kaçırılmaması gereken önemli bir nokta da her iki çalışmada ele alınan tohum çeşidi, sıra üzeri aralık ve vakum basıncı gibi parametrelerin birbirinden farklı olmasıdır. Bu parametreler ekim kalitesi üzerinde önemli role sahiptir.

*3.2. Tarla denemelerine ilişkin sonuçlar*

Adana-Karataş Mevkii'nde, 14 cm sıra üzeri tohum aralığında, 6 km $h^{-1}$ (1.67 m $s^{-1}$) ilerleme hızında, 3 farklı firmaya ait 3 balta ayaklı, 3 disk ayaklı olmak üzere toplam 6 adet tek dane ekim makinası kullanılarak gerçekleştirilen tarla denemelerinde, tüm makinalar için tarla çıkış derecesi, sıra üzeri bitki dağılım düzgünlüğü, ekim derinliği düzgünlüğü, ekim makinası tarla tekerleği negatif patinaj (kayma) ve traktör arka tekerleği patinaj değerleri saptanmış, deneme sonuçları Çizelge 6-10'da verilmiştir.

*3.2.1. Tarla çıkış derecesine ilişkin sonuçlar*

Eşitlik 1 uyarınca tüm makinalar için hesaplanan tarla çıkış derecesine ilişkin sonuçlar Çizelge 6'da verilmiştir. Elde edilen sonuçlar doğrultusunda aynı firmaya ait diskli ekim makinalarının baltalı ekim makinalarına göre daha yüksek tarla çıkışına sahip olduğu, ancak aynı firmaya ait makinalar arasındaki bu farkın, % 95 önem düzeyinde istatistiksel olarak anlamlı olmadığı belirlenmiştir.

**Çizelge 6- Makinalara ilişkin TÇD ve CV değerleri**

*Table 6- Values of plant emergence and CV for the planters*

| *Ekim makinası* | *Tarla çıkış derecesi (TÇD, %)** | *Varyasyon katsayısı (CV, %)* |
|---|---|---|
| BA-1 | 85.7$^{a}$±5.68 | 6.62 |
| BA-2 | 72.2$^{c}$±21.4 | 29.62 |
| BA-3 | 79.3$^{b}$±8.10 | 10.21 |
| DA-1 | 86.1$^{a}$±5.72 | 6.54 |
| DA-2 | 73.8$^{c}$±2.54 | 3.44 |
| DA-3 | 80.6$^{b}$±3.37 | 4.18 |

*, TÇD değerlerinin yanında aynı harfle gösterilen ortalamalar % 95 önem düzeyindeki LSD testine göre birbirinden faklı değildir

En yüksek tarla çıkışı A firmasına ait makinalar (BA-1, DA-1) kullanılarak gerçekleşirken, C ve B firmalarına ait makinalar (BA-2, BA-3, DA-2 ve DA-3) A firmasının makinalarını takip etmektedir. Makinalar arasındaki fark istatistiksel olarak önemli olup, Çizelge 6'da belirtilmiştir.

Ayrıca diskli ekim makinalarında tarla çıkış derecesi değerleri arasındaki varyasyonun, baltalılara göre daha düşük olduğu saptanmıştır. TÇD'deki en yüksek varyasyon % 29.62 değeriyle BA-2 ile elde edilmiş olup bu makinayla gerçekleştirilecek ekimde bitki çıkışının ≈% 72 olacağı dikkate alınmalıdır.

Altuntaş & Dede (2009) tarafından da saptandığı gibi sırta ekimde düze ekime göre daha yüksek bitki çıkışı sağlanmaktadır. Yüksek bitki çıkışı sağlayan bir ekim makinası ile yapılacak sırta ekimde ise bitki çıkışı açısından daha büyük avantajlar sağlanması kaçınılmazdır.

*3.2.2. Sıra üzeri bitki dağılım düzgünlüğüne ilişkin sonuçlar*

İkisi yerli biri yabancı üç farklı firmaya ait baltalı ve diskli gömücü ayağa sahip 6 farklı pnömatik tek dane ekim makinasıyla gerçekleştirilen denemeler sonucunda elde edilen makinalara ilişkin sıra üzeri bitki dağılım düzgünlüğü değerlendirmesinde kabul edilebilir bitki aralığı (KEBA), ikizlenme ve boşluk oranı değerleri Çizelge 7'de verilmiştir. Kullanılan tüm ekim makinalarının laboratuvar denemelerinde sıra üzeri tohum dağılım düzgünlüğü değerleri birbirine yakın ve genellikle "iyi" kalitede saptanmıştır.

Ancak laboratuvarda elde edilen bu bulgulara rağmen, Adana-Karataş koşullarında mısır ekiminde, sıra üzeri bitki dağılım düzgünlüğü açısından sadece A firmasına ait BA-1 ve DA-1 makinaları ile "orta" kalitede sırta ekim yapılabileceği saptanmıştır. BA-1 ve DA-1'in "orta" kalitedeki performans değerlendirmesinde DA-1'in BA-1'e göre üstünlüğü (KEBA= % 88.5) Çizelge 7'den açıkça görülmektedir. Bu bulgunun istatistiksel olarak anlamlı olduğu yapılan varyans analiziyle de doğrulanmıştır.

**Çizelge 7- Makinalara ilişkin sıra üzeri bitki dağılım düzgünlüğü değerleri**

*Table 7- Values of seed distribution uniformity for the planters*

| *Ekim makinası* | *Kabul edilebilir bitki aralıkları oranı (KEBA, %)** | *İkizlenme oranı (İO, %)* | *Toplam boşluk oranı (BO, %)* | *Değerlendirme* |
|---|---|---|---|---|
| BA-1 | 82.9[b] | 9.5 | 7.6 | Orta |
| BA-2 | 66.8[d] | 25.9 | 7.3 | Yetersiz |
| BA-3 | 74.3[c] | 18.6 | 7.1 | Yetersiz |
| DA-1 | 88.5[a] | 3.6 | 7.9 | Orta |
| DA-2 | 80.2[b] | 11.6 | 8.2 | Yetersiz |
| DA-3 | 80.2[b] | 11.9 | 7.9 | Yetersiz |

*, KEBA değerlerinin yanında aynı harfle gösterilen ortalamalar % 95 önem düzeyindeki LSD testine göre birbirinden faklı değildir

BA-1 ile elde edilen % 82.9 değerindeki performans "orta" kalite değerlendirmesinin sınır değerine oldukça yakındır. Tüm makinalar firma bazında incelendiğinde, aynı firmanın diskli makinalarıyla yapılan sırta mısır ekiminde baltalı makinalara oranla daha yüksek performans elde edildiği ve aradaki farkın istatistiksel olarak anlamlı olduğu saptanmıştır (Çizelge 7). B ve C firmalarının baltalı tip makinalarıyla (BA-2, BA-3) sırta ekimdeki yetersizliği diskli tip makinalarında (DA-2, DA-3) daha az ortaya çıkmakta olup, DA-2 ve DA-3 makinalarıyla çalışmadan elde edilen % 80.2 değeri, kalite sınıflandırmasının minimum değerine yakın olarak bulunmuştur (Çizelge 7). B ve C firmalarına ait diskli gömücü ayağa sahip DA-2 ve DA-3 makinalarında yapılacak küçük konstrüksiyon değişiklikleri ile ekici düzenlerin bölge şartlarına adaptasyonunun mümkün olabileceği ve sırta ekimde bu makinaların da kullanılabileceği düşünülmektedir. Laboratuvar şartlarında tüm makinalarda ikizlenmeden çok boşluk değerleri elde edilmişken, tarla şartlarında DA-1 hariç diğer tüm makinalarda ikizlenmenin ortaya çıktığı saptanmıştır. Bu çalışmadan görüldüğü üzere, laboratuvar şartlarında yapılan makina denemeleri tarla koşulları için sadece bir referans niteliğinde olup, tarla şartlarında toprak özelliklerinin yanında, ekici ünite ve özellikle de toprakla temas eden işleyici organların konstrüksiyonunun ekim başarısına doğrudan etkili olduğu göz ardı edilmemelidir.

Aynı firmaya ait baltalı ve diskli makinalarda kullanılan ekici düzen, vakum sistemi, transmisyon sistemi vb. sistemleri aynı, sadece gömücü ayak konstrüksiyonu farklı olduğundan çalışmada makina performans farklılıklarının gömücü ayak farklılığından ileri geldiği saptanmıştır.

Ancak farklı firmalara ait makinalarda; vakum sağlama, transmisyon, ekici ünite, hareket iletim, tohum iletim düzenleri ve gömücü ayak konstrüksiyonları birbirinden farklıdır. Örneğin; çalışmada her makina 70 mbar vakum basıncına ayarlanmıştır. Ancak farklı firmalara ait makinalarda vakum sağlama düzenleri birbirinden farklı olduğundan vakum basıncı değeri farklı devirlerde elde edilmiştir.

Tüm makinalarla çalışmada 26 delikli ekim plakası kullanılmasına rağmen, makinaların transmisyon ve hareket iletim düzenindeki farklılıklar nedeniyle ekim plakaları farklı devirlerde dönmektedir. Vakum düzeni ve ekici ünitelerdeki bu gibi farklılıklar tohumun plakada tutulma kalitesine de etki etmektedir.

Diskli tip makinalarda özellikle farklı tohum iletim borusu dizaynı ile uzun tohum yolu ve dolayısıyla değişen tohum hareketi nedeniyle de farklılıklar ortaya çıkmaktadır. Tohuma iyi yönlendirme sağlayan tohum iletim borusuna sahip makinalarda performansın daha yüksek olduğu saptanmıştır. Ayrıca plaka yüzey pürüzlülüğü ve malzemesi de tohumun ekici plakadan bırakılma ve toprağa düzgün iletilmesinde etkin faktörler olarak ortaya çıkmaktadır.

"Optimum ekim işlemi" için toprak işlemeden ekime, tohum çeşidinden vakum basıncına kadar farklı çalışma şartlarına ilişkin tüm parametreler tarla öncesi gözden geçirilmeli ve doğru değerler seçilmelidir.

*3.2.3. Ekim derinliği düzgünlüğüne ilişkin sonuçlar*

Makinalara ilişkin ekim derinliği düzgünlüğü ve dağılımın varyasyon katsayısı değerleri Çizelge 8'de verildiği gibidir. Çizelgeden görüldüğü gibi ekim derinliği değerlerinin baltalı tip ekim makinalarında 5.1-5.6 cm, diskli makinalarda ise 5.8-6.7 cm değerleri arasında değiştiği saptanmıştır. Dağılım düzgünlüğünü ifade eden varyasyon katsayısı değerleri tüm makinalar için % 20 referans değerinin altında olup, baltalı tip ekim makinalarında elde edilen varyasyonun diskli makinalara oranla daha yüksek olduğu belirlenmiştir.

**Çizelge 8- Makinalara ilişkin ekim derinliği düzgünlüğü değerleri**

*Table 8- Values of planting depth for the planters*

| *Ekim makinası* | *Ortalama ekim derinliği (cm)* | *Varyasyon katsayısı (CV, %)* |
|---|---|---|
| BA-1 | 5.3±0.90 | 17.32 |
| BA-2 | 5.6±0.62 | 11.19 |
| BA-3 | 5.1±0.71 | 13.85 |
| DA-1 | 6.1±0.51 | 8.40 |
| DA-2 | 6.7±0.59 | 8.92 |
| DA-3 | 5.8±0.50 | 8.69 |

*3.2.4. Ekim makinalarının tahrik tekerleğindeki negatif patinaj (kayma) değerlerine ilişkin sonuçlar*

Ekim makinalarında transmisyon sistemi, miller ve ekici düzenlerin tahrik edilmesinde makinaların tarla tekerleğinden yararlanıldığından tekerlekte bir miktar zorlanma olmakta ve negatif patinaj (kayma) meydana gelmektedir. Denemeler sırasında ekim makinası tarla tekelerleğinde meydana gelen patinaj değerleri Çizelge 9'da verilmiştir. Çizelgeden görüldüğü gibi sırta mısır ekiminde kullanılan tüm makinalar için sırta ekimde tarla tekerleğindeki kayma oranı % 10 referans değerinin altındadır.

**Çizelge 9- Makinaların tarla tekerleğindeki negatif patinaj (kayma) oranları**

*Table 9- Negative wheel slipping of the planters*

| *Ekim makinası* | *Patinaj (%)* |
|---|---|
| BA-1 | -4.72 |
| BA-2 | -5.34 |
| BA-3 | -0.93 |
| DA-1 | -9.14 |
| DA-2 | -9.65 |
| DA-3 | -10.24 |

Diskli tip ekim makinalarında meydana gelen negatif patinaj (kayma) değerleri, baltalı tip ekim makinalarına oranla daha yüksek olmasına karşılık, ekim performansı diskli tip makinalarda baltalı tip makinalara göre daha yüksek değerlerde elde edilmiştir. Bu sonuç negatif patinajın (kayma) ekim performansı üzerinde önemli bir etkisinin olmadığının göstergesidir.

Diskli ekim makinalarında tohumu toprağa yönlendirmede kullanılan tohum iletim boruları sahip oldukları kavisli geometri nedeniyle birbiri ardına gelen tohumların belli bir yörünge (kızak etkisi) izlemesine yardımcı olmakta ve düzensizlikler giderilmektedir. Ayrıca borunun çıkış ağzına gelen tohum disklerin arasından hemen toprağa bırakılmaktadır. Bu nedenle kayma ve tohum düşme yüksekliği daha fazla olmasına rağmen, diskli ekim makinalarında sıra üzeri bitki dağılım düzgünlüğü baltalı ekim makinalarına göre daha iyidir.

*3.2.5. Traktör arka tekerleğindeki patinaj değerlerine ilişkin sonuçlar*

Tüm tek dane ekim makinaları traktöre üç nokta askı düzeni yardımıyla bağlandığından traktör arka tekerleğinde zorlanma nedeniyle patinaj meydana gelebilmektedir. Denemeler sırasında traktör arka tekelerleğinde meydana gelen patinaj değerleri Çizelge 10'da verilmiştir. Çizelgeden görüldüğü gibi tüm makinalar için traktör arka tekerleğindeki patinaj oranı % 10 referans değerinin altında olup, baltalı tip ekim makinaları diskli tip ekim makinalarına oranla daha düşük patinaja neden olmaktadır. Baltalı tip ekim makinalarının 4 sıralı, DA-3 hariç diskli tip diğer tüm ekim makinalarının 6 sıralı olması da elde edilen patinaj değerlerini farklı kılmaktadır. Ancak 4 sıralı ve diskli DA-3 ile 4 sıralı ve baltalı BA-3 makinaları karşılaştırıldığında yine diskli ekim makinalarının daha yüksek patinaja neden olduğu saptanmıştır. Diskli tip ekim makinalarıyla çalışmada traktör tekerleği daha çok patinaj yapma eğiliminde olmasına rağmen, baltalı tip ekim makinalarıyla çalışmada daha düşük ekim performansı değerleri elde edildiğinden patinajın ekim performansı üzerindeki etkisinin önemsiz olduğu belirlenmiştir.

**Çizelge 10- Traktör arka tekerleğindeki patinaj oranları**

*Table 10- Slipping of rear wheel of the tractors*

| *Ekim makinası* | *Traktör* | *Patinaj (%)* |
|---|---|---|
| BA-1 | TD 65-56 D | 3.83 |
| BA-2 | TD 65-56 D | 1.80 |
| BA-3 | TD 65-56 D | 1.38 |
| DA-1 | TD 110 D | 9.50 |
| DA-2 | TD 110 D | 7.49 |
| DA-3 | TD 65-56 D | 5.39 |

## 4. Sonuçlar

Farklı hızlardaki laboratuvar denemelerinde tüm makinalar ile "çok iyi", "iyi" ya da "orta" kalitede ekim yapılabilmesine karşılık tarla denemelerinde bazı makinalar ekim kalitesi açısından "yetersiz" kalmıştır. Aynı firmaya ait baltalı ve diskli makinalarda kullanılan ekici düzen, vakum sistemi, transmisyon sistemi vb. sistemler aynı olup, sadece gömücü ayak konstrüksiyonu farklı olduğundan makina performans farklılıklarının özellikle gömücü ayaktan ileri geldiği saptanmıştır.

Ayrıca sırta ekimde baltalı tip gömücü ayaklar toprağa yeteri kadar tutunamamakta ve sırt yapısının bozulmasına neden olmaktadır. Bu da hem sıra üzeri tohum dağılım düzgünlüğünü bozmakta, hem de sırta ekimin avantajlarından yararlanılabilmesini olumsuz yönde etkilemektedir.

Çalışma sonunda elde edilen tüm bulgular doğrultusunda sırta mısır ekiminde balta tip gömücü ayağa sahip ekim makinaları yerine, diskli tip ekim makinalarının kullanılmasının uygun olacağı saptanmıştır.

| **Kısaltmalar ve Semboller** | |
|---|---|
| BA | Balta ayaklı |
| CV | Varyasyon katsayısı, % |
| DA | Disk ayaklı |
| KEBA | Kabul edilebilir bitki aralığı, % |
| KETA | Kabul edilebilir tohum aralığı, % |
| $N_0$ | 0.5 Z'den küçük aralıkların toplam sayısı |
| $N_i$ | Teorik toplam bitki sayısı |
| $N_x$ | Belirli sıra uzunluğunda tüm bitki aralıklarının toplam sayısı |
| TÇD | Tarla çıkış derecesi, % |
| Z | Anma ekim aralığı, cm |

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# Inheritance of Rose-Flowered Mutation in Chickpea (*Cicer arietinum* L.)

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**ABSTRACT**

Mutations are the most important phenomenon in the living organisms including plant species due to creating variation. Variation in crop plants can be increased by induced mutations. The present study deals with inheritance of an induced mutation with rose-flowered in the cultivated chickpea (*Cicer arietinum* L.). A mutant having rose-shaped flowers without male and female organs in the cultivated chickpea was isolated in $M_2$ and harvested as a single plant with its sisters (sibs). In $M_3$, inheritance of the rose-flowered mutant was studied in the segregated rows because hybridization between the mutant and parent or the other genotype of the cultivated chickpea was not possible. Results indicated that the rose-flowered mutation was controlled by a single recessive gene (*rs*). This study is an alternative approach on inheritance studies if hybridization is impossible due to sterility.

Keywords: *Cicer arietinum;* Mutagenesis; Rose-flowered mutant

# Nohutta (*Cicer arietinum* L.) Gül-Çiçekli Mutasyonun Kalıtımı

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**ÖZET**

Mutasyonlar, bitki türlerini de içeren canlı organizmalarda varyasyon yaratmak için en önemli varyasyon kaynağıdırlar. Bitkilerde varyasyon yapay mutasyonlarla artırılabilmektedir. Bu çalışma kültürü yapılan nohutta (*Cicer arietinum* L.) gül-çiçekli yapay mutasyonun kalıtımıyla ilgilidir. Erkek ve dişi organları olmayan gül-çiçekli nohut mutantı $M_2$ generasyonunda belirlenmiş ve kardeşleriyle birlikte tek bitki hasadı yapılmıştır. Gül-çiçekli mutantın kalıtımı, mutant ve ebeveyn ya da diğer genotiplerle döllenmenin olanaksız olduğu $M_3$ generasyonunda açılan sıralarda çalışılmıştır. Sonuçlar gül-çiçeklilik özelliğinin resesif bir genle (*rs*) idare edildiğini göstermektedir. Bu çalışma kısırlıktan dolayı döllenmenin mümkün olmadığı durumlar için alternatif bir yaklaşımdır.

Anahtar Kelimeler: *Cicer arietinum*; Mutagenesis; Gül-çiçekli mutant

## 1. Introduction

*Cicer* L. consists of 49 taxa including 9 annuals with the cultivated chickpea (*Cicer arietinum* L.) and 40 perennials (van der Maesen et al 2007; Donmez 2011; Ozturk et al 2011; 2013; Smykal et al 2015). Among the 49 taxa, *Cicer arietinum* L. is solely species under cultivation. It is diploid with 2n= 2x= 16 chromosomes (van der Maesen 1972) and its genome size ~738-Mb with 28,269 genes (Varshney et al 2013). Its solitary flowers are borne in an axillary raceme (Cubero 1987) despite being from 2 to 9 flowers on the same node (Gaur & Gour 2002; Yasar et al 2014). Flowers in the cultivated chickpea are completely bisexual and self-pollinated owing to its cleistogamic (closed) flowers shape (Cubero 1987), while there was low level of outcrossing (Toker et al 2006).

Flowers of the cultivated chickpea are different colors viz., white, pink or purple and blue in color (Kumar et al 2000; Yasar et al 2014). Flowers have papilionaceous corolla and five petals, which are generally polypetalous i.e., occurring of standard (vexillium), wings, and keel. The vexillum is obovate shaped, 8-11 mm long, and 7-10 mm wide. The wings are obovate with short pedicels, 6-9 mm long and about 4 mm wide with an auriculate base. The keel is rhomboid, 6-8 mm long, with a pedicel 2-3 mm long. Androecium forms from 10 stamens in diadelphous (9+1) condition. The anthers burst longitudinally, and the adult pollens are orange colored. Gynoecium consists of the stigma, style and ovary. The ovary is ovate with a pubescent surface, 2-3 mm long and 1-15 mm wide. It contains 1-4 ovules. The style is linear shaped, upturned, and glabrous except at the bottom with 3-4 mm long. The stigma is globose and capitate (van der Maesen 1972; Cubero 1987; Singh & Diwakar 1995). Despite of being cleistogamous flowers, some different induced mutants with open flowers were reported (Pundir & Reddy 1998; Srinivasan & Gaur 2012; Yildirim et al 2013). There are two different flower shapes as (i) cleistogamous flowers and (ii) open flowers in the cultivated chickpea when the available literature has been searched (ISI 2015). This type of flowers was created by spontaneous (Pundir & Reddy 1998; Srinivasan & Gaur 2012) or induced (Yildirim et al 2013) mutations. Mutations are referred to as the most important phenomenon in the living organisms including plant species due to creating variation (van Harten 1998). Mutation breeding is considered as the most efficient powerful method to create variation compared to those hybridizations, and also it takes shorter time to the release of the mutant cultivars than those of hybridizations (Salimath et al 2007). Both of qualitative and quantitative traits, previously the known alleles or unknown alleles and linkage among genes can be altered by mutation breeding (van Harten 1998; Tomlekova 2010). Genetic variability in the cultivated chickpeas has been narrowed by using pure line selection or hybridization followed by the pedigree method, the bulk method, the single seed descent, or modification of these methods for a longer period (Salimath et al 2007). To create genetic variability in chickpea, the most efficient way is mutagenesis (Salimath et al 2007; Toker & Uzun 2010; Wani et al 2014). Considerable traits in chickpeas have been induced by Toker (2014) by mutagenesis. One of them was rose-flowered mutant chickpea (Toker 2014). Therefore, the present study deals with inheritance of the rose-flowered mutation in the cultivated chickpea.

## 2. Material and Methods

### *2.1. Selection of rose-flowered mutant*

The rose-flowered mutant in the present study was identified in $M_2$ generation of irradiated seeds of the cultivated chickpea (*Cicer arietinum* L.) cv. Sierra (Toker et al 2010; Toker 2014). Irradiation was applied on seeds with 12% moisture as 200, 300 and 400 Gy of gamma rays with rate was 1.66 $kGy^{-1}$ from a $^{60}Co$ source in Turkish Atomic Energy Agency (TAEK), Ankara, Turkey (Toker et al 2005). Approximately 500 seeds each treatment level were used and irradiated seeds were stored at 4 $^{o}C$ up to sowing date. $M_1$ plants were harvested as a single plant and then each $M_1$ plant was grown as single plant progeny in $M_2$. $M_2$ plants were screened for all kind of morphological mutations and morphologically different plants from Sierra were isolated as putative mutants. The putative mutants and their sister plants (sibs) were grown as single plant progeny in $M_3$. In $M_3$, the mutants were confirmed for whether they were true mutant or not. Number of mutants in the segregating rows was recorded for chi-square test.

*2.2. Growing of rose-flowered mutant*

The row-to-row and plant-to-plant spacing was 50 cm and 10 cm, respectively. The fertilizers with N, P and K were applied at a rate of 20 kg per ha prior to sowing. The all generations were advanced at Antalya location (30° 38’ E, 36° 53’ N, 32 m from sea level) from 2005 to 2008 crop seasons. Weeds were controlled pulling by hand during seedling period. Plants were grown without additional irrigation under rainfed conditions.

*2.3. Goodness of fit 3 to 1*

The rose-flowered mutant plants were counted in segregating rows of $M_2$ and results confirmed in $M_3$ generation. Chi-square ($\chi^2$) test was performed for goodness of fit of 3:1 ratio according to the Equation 1 (Steel & Torrie 1980).

$$\chi^2 = \Sigma(O-E)^2/E \qquad (1)$$

Where; $O$ and $E$, observed and expected values, respectively.

## 3. Results and Discussion

*3.1. Morphological characteristics of rose-flowered mutant*

Flowers of the rose-flowered mutant look like flowers of the genus *Rosa* L., whereas flowers of the parent cv. Sierra are cleistogamic papilionaceous. The mutant had many petals from 27 to 35 petals (Figure 1), while Sierra had five petals namely one standard, two wings and two keels (Figure 1). It was isolated from 200 Gy treatment.

Similarly, flowers of Sierra consisted of a stigma but flowers of the mutant contained ovary and style without stigma. Moreover, the female organ (gynoecium) was absent in rose-flowered mutant, while Sierra had 10 (9 fused+1 free) female organs. Flower structure of the rose-flowered mutant is quite different compared to flowers of Sierra since flowers of the mutant is open while flowers of Sierra is normal cleistogamous viz., closed (Table 1).

**Figure 1- Rose-flowered mutant with open flower, 27-35 petals and without stigma and stamens (left) and normal cleistogamous flower of Sierra (right)**

*Şekil 1- Sierrada dişi ve erkek organları bulunmayan 27-35 taç yapraklı gül-çiçekli mutant (sol) ve normal kleistogamik çiçek (sağ)*

**Table 1- Characteristics of rose-flowered mutant and its parent**

*Çizelge 1- Gül-çiçekli mutant ve ebeveynlerin karakteristikleri*

| *Characteristics* | *Parent (Sierra)* | *Rose-flowered mutant* |
|---|---|---|
| Flower color | White | White |
| Flower shape | Cleistogamous (closed) | Open |
| No. of petals | 5 | 27-35 |
| Stamens | 9+1 | Nil (0) |
| Stigma | Yes | Absent |

Open-flowered mutants in the cultivated chickpea (*Cicer arietinum* L.) and its progenitor (*C. reticulatum* Ladiz.) were reported prior to our study (Pundir & Reddy 1998; Srinivasan & Gaur 2012; Yildirim et al 2013). Previously reported open flower mutants were given as ICC 16341, ICC 16129 and OFM-3 by Srinivasan & Gaur (2012). Like flower shape, flower color mutations were reported in the cultivated chickpea (Gaur & Gour 2001; Atta et al 2003) and *C. reticulatum* Ladiz. (Toker

2009). In $M_2$, 15 plants, sister of rose-flowered mutants, were harvested as single plant. These 15 single plants were grown as single plant progeny in $M_3$. Of 15 rows, 9 rows in M3 were segregated as rose-flowered mutant and normal plants. A total of 89 plants in 9 segregated rows were counted as 69 normal and 20 rose-flowered in $M_3$.

*3.2. Inheritance and genetics of the rose-flowered mutant*

Chi-square test indicated that both of segregation in $M_3$ generation fit in well to the expected ratio of 3:1, indicating that the rose-flowered characteristic was governed by a single recessive gene (Table 2).

Results in the present study were in agreement with findings of previous reports (Pundir & Reddy 1998; Srinivasan & Gaur 2012) since open-flower trait was controlled by a single recessive gene. The gene symbol '*rs*' was designed for the induced rose-flowered characteristic. Results indicated that genotypic formula of the rose-flowered mutant and Sierra were assumed as '*rsrs*' and '*RsRs*', respectively. The new approaches could be used for all traits in mutants of crop plants. Srinivasan & Gaur (2012) pointed out that the genes controlling open-flower trait in ICC 16341, ICC 16129 and OFM-3 were '*ofl-1*', '*ofl-2*' and '*ofl-3*', respectively. These genes were non-allelic genes (Srinivasan & Gaur 2012).

**Table 2- Inheritance of rose-flowered trait**

*Çizelge 2- Gül-çiçekliliğin kalıtımı*

| *Parents* | *$M_3$* | | $\chi^2$ | *P* |
|---|---|---|---|---|
| | *Observed* | *Expected* | | |
| | No. of fertile plants (F): No. of sterile mutants (S) | F:S* | | |
| Sierra | 69:20 | 3:1 | 0.31 | 0.90-0.75 |

*, F is the induced fertile sib and S is the induced sterile mutant

In conclusion, a quite unique mutant and a new gene controlling rose-flowered trait viz., '*rs*' in the cultivated chickpea cv. Sierra was created with gamma rays in the present study. The present study is an alternative approach on inheritance studies if hybridization is impossible due to sterility.

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# Evaluation of Advanced Lentil Lines for Diversity in Seed Mineral Concentration, Grain Yield and Yield Components

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**ABSTRACT**

Lentil is one of the most important grain legumes, which plays a significant role in human nutrition and animal feed through the world. In developing countries, the prohibitively high cost of meat has rendered, lentil, with its high seed protein and essential amino acid content, important source of dietary protein. In this research, 181 lentil advanced lines ($F_7$ generation) of Karacadağ x Silvan and Karacadağ x Çağıl 2004 crosses were evaluated for grain yield, yield components and seed mineral concentrations in two diverse environments in Turkey. Considerable diversity was observed with regard to yield components and seed mineral concentrations in the advanced lentil lines. The greatest phenotypic diversity was observed in the biological yield, number of pods and weight of pods per plant, the number of seeds and weight of seeds per plant, and seed Ca, Zn and Fe concentrations. Grain yield per plant was significantly positively correlated with the biological yield per plant, number of pods per plant, weight of pods per plant, and number of seeds per plant. Plant grain yield and yield components were strongly positively correlated with seed potassium (K), calcium (Ca), magnesium (Mg) and zinc (Zn) concentrations but was negatively correlated with Fe concentration. In conclusion, promising lentil advanced lines for the grain yield, yield components and mineral concentrations could be evaluated for developing new lentil varieties and spesific breeding purposes.

Keywords: Lentil; Crosses; Mineral concentration; Yield components; Diversity

# İleri Kademedeki Mercimek Hatlarının Dane Mineral Madde Konsantrasyonu, Verim ve Verim Komponentleri Yönünden Değerlendirilmesi

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**ÖZET**

Mercimek, insan ve hayvan beslenmesi yönünden yemeklik dane baklagiller grubunun en önemli üyelerinden birisidir. Gelişmekte olan ülkelerde et fiyatının yüksek olması; yüksek protein içeriği ve amino asit kompozisyonu ile mercimeği protein kaynağı olarak ön plana çıkarmaktadır. Bu araştırmada, Karacadağ x Silvan ve Karacadağ x Çağıl 2004 mercimek melez kombinasyonlarına ilişkin ileri kademedeki ($F_7$) 181 adet mecimek hattı iki farklı lokasyonda yetiştirilerek, dane verimi, verim komponentleri ve danede mineral madde konsantrasyonu yönünden incelenmiştir. Verim komponentleri ve mineral madde konsantrasyonu yönünden ileri kademedeki mercimek hatları arasında önemli düzeyde varyasyonlar saptanmıştır. Biyolojik verim, bitkide bakla sayısı, bitkide bakla ağırlığı, bitkide tohum sayısı, bitki dane verimi, tohumda kalsiyum (Ca), çinko (Zn) ve demir (Fe) konsantrasyonu yönünden önemli varyasyonlar tespit edilmiştir. Bitki dane verimi ile biyolojik verim, bitkide bakla sayısı, bitkide bakla ağırlığı ve bitkide dane sayısı arasında önemli pozitif ilişkiler belirlenmiştir. Dane verimi ve verim komponentlerinin danede potasyum (K), kalsiyum (Ca), magnezyum (Mg) ve çinko (Zn) konsantrasyonları ile pozitif, demir (Fe) konsantrasyonu ile negatif ilişkili olduğu saptanmıştır. Sonuç olarak, incelenen kırmızı mercimek ileri melez hatları içerisinde dane verimi, verim komponentleri ve mineral madde konsantrasyonu yönünden ümitvar olanların, gelecekte çeşit adayı olabileceği ve ıslah çalışmalarında spesifik amaçlar için kullanılabileceği tespit edilmiştir.

Anahtar Kelimeler: Mercimek; Melezleme; Mineral içeriği; Verim komponentleri; Çeşitlilik



## 1. Introduction

Lentil (*Lens culinaris* Medik) is a diploid (2n= 2x= 14), self-pollinated (autogamous) and annual species of grain legume and is considered to be one of the most ancient crops, as researchers have traced it back to 7,000-8,000 BC (Cubero 1981; Lev-Yadun et al 2000). Building and improving an effective lentil breeding program, requires utilizing lentil genetic resources effectively and efficiently in order to develop valuable genotypic and phenotypic variations in promising new varieties (Gepts 2006; Singh et al 2014). In light of this, this research developed a utilization program comprised of lentil landraces of considerable plant trait diversity (Toklu et al 2009a, b) and, in the $F_7$ generation, assessed advanced lines of two cross combinations. Lentil is a major source of protein, minerals and vitamins in human diet (Khan 1987; Iqbal et al 2006; Karaköy et al 2012). In addition, its mineral- and carbohydrate-rich straw provides valuable animal fodder (Muehlbauer et al 2006). Pulses play an important role in the nutrition of low-income people in many developing countries, as they are high in protein, minerals, vitamins, calories, dietary fiber and carboydrate (Solanki et al 1999; Iqbal et al 2006; Upadhyaya et al 2011; Blair 2013). Several reports have shown that two-thirds of the world's population faces deficiencies of essential minerals and vitamins (WHO 1999; Welch & Graham 2004; White & Broadley 2009). It has been reported that approximately 170 million pre-school-aged children in developing countries are not getting enough protein (Iqbal et al 2006). Fe, Zn, Cu, Ca, Mg, I and Se are the most commonly lacking minerals in the human diet (White & Broadley 2009). Several researchers have reported that mineral malnutrition affects more than half of the world's population particularly in developing countries (Mayer et al 2008), and this problem could be solved through increased consumption of mineral-rich foods enhanced using biofortification (White & Broadley 2005; 2009; Shahzad et al 2014). In this context, biofortification is defined as the enrichment of the edible portion of plants containing micronutrients through agronomic intervention or plant breeding (Welch & Graham 2004; White & Broadley 2005). Limited research has been done on grain quality, as research on lentil has thus far primarily focused on grain yield and yield related traits. The utilization of plant genetic resources is one of the most effective ways to increase grain yield and quality in lentil. Identifying genotypes that produce high mineral concentrations and promising plant traits and using these genetic resources in breeding programs are the keys to successful crop improvement (White & Broadley 2005; Roy et al 2013). Therefore, this study was undertaken with a focus on mineral concentrations and promising plant traits, and to identify superior advanced lines for future breeding purposes including biofortification, grain yield and yield components.

## 2. Material and Methods

### *2.1. Growth conditions and research materials*

This research was conducted in two diverse environments: the Kozan Vocational School of Çukurova University, located in Kozan, Adana, Turkey, and the Sivas Vocational School of Cumhuriyet University located in Sivas, Turkey. The two locations have diverse soil and climatic conditions (Table 1); the soil at the Sivas location is silty clay with a pH of 7.28, 0.33 mmhos $cm^{-1}$ salt, and 344, 560, 3.99, 0.42, 4.68 and 1.23 mg $kg^{-1}$ K, Mg, Fe, Zn, Mn and Cu, respectively. The Kozan location is clay with a pH of 7.50, 0.20 mmhos $cm^{-1}$ salt, and 252, 490, 4.30, 0.70, 8.90 and 0.70 mg $kg^{-1}$ K, Mg, Fe, Zn, Mn and Cu, respectively. The research material consisted of RILs (recombinant inbred lines) derived from Karacadağ x Silvan cross with single seed descent (127 RILs in the $F_7$ generation) and Karacadağ x Çağıl 2004 cross (54 RILs in the $F_7$ generation) red lentil landraces and four check varieties (Şakar, Fırat 87, Kırmızı 51 and Kafkas). The experiments were arranged in an Augmented Block Design at both locations; the seeds of the parental genotypes, RILs and check varieties were sown by hand in 1-m-long rows with 20-cm row spacing and a 5-cm plant diameter. Seeds were sown in December 20, 2013 and harvested in June 5, 2014 at the Kozan location under rainfed conditions and, sown in April 25, 2014 at the Sivas location under irrigated conditions and harvested in August 15, 2014.

**Table 1- Geographical, soil and climatic specifications of the experimental sites**

*Çizelge 1- Denemelerin yürütüldüğü loksyonların coğrafi, toprak ve iklim yapısına ilişkin bazı veriler*

| *Features* | *Sivas* | *Kozan/ Adana* |
|---|---|---|
| *Meteorological features** | *(April-August)* | *(November-May)* |
| Total rainfall (mm) | 119.5 | 620.8 |
| Mean temperature (°C) | 18.1 | 14.3 |
| Mean humidity (%) | 52.2 | 58.9 |
| Altitude (m) | 1250 | 110 |
| *Soil features*** | | |
| Soil texture | Silty-clay | Clay |
| pH | 7.28 | 7.50 |
| Salt (mmhos $cm^{-1}$) | 0.33 | 0.20 |
| $CaCO_3$ (%) | 19.6 | 27 |
| K (mg $kg^{-1}$) | 344 | 252 |
| Mg (mg $kg^{-1}$) | 560 | 490 |
| Fe (mg $kg^{-1}$) | 3.99 | 4.30 |
| Zn (mg $kg^{-1}$) | 0.42 | 0.70 |
| Mn (mg $kg^{-1}$) | 4.68 | 8.90 |
| Cu (mg $kg^{-1}$) | 1.23 | 0.70 |

*, meteorological data provided by Turkish State Meteorological Service; **, soil features provided by Cumhuriyet University and Çukurova University soil analysis laboratories

### *2.2. Determination of agromorphological traits*

The traits of days to 50% flowering (DF) (days from sowing to appearance of 50% flowers), biological yield (recorded mean above-ground weight of each plant as g per plant), plant height (cm), the number of branches per plant, the number of pods per plant, the weight of pods per plant, the number of seeds per plant, and the 1000 seed weight and the weight of seeds per plant were identified from five randomly selected plants in each row.

### *2.3. Seed mineral concentration analysis*

For the mineral nutrient analysis, 0.3 g seed samples of each of the lentil genotypes were ground and then decomposed in a microwave digester using 2 mL of 35% $H_2O_2$ and 5 mL of 65% $HNO_3$ (Alcock 1987). Following the digestion, K, Ca, Mg, Zn, Fe, Cu and Mn were analyzed by using an inductively coupled plasma optical emission spectrometer (ICP-OES; Varian-Vista Pro). Reference leaf samples from the National Institute of Standards and Technology (Gaithersburg, MD, USA) were used to check the related elemental measurements.

Simple statistics, including the mean, range (minimum and maximum) and the coefficient of variation, were computed using the mean values for each plant characteristic using Microsoft Office Excel. The correlation coefficients were calculated by using JMP statistical software (SAS 2007).

## 3. Results and Discussion

Large phenotypic variation was detected in the advanced lentil lines for the agromorphological plant characteristics and seed mineral concentrations in both environments when compared to the check varieties (Table 2 and 3). For the lentil advanced lines, days to 50% flowering ranged from 106 to 110 days with a mean of 107.6 days at Kozan and ranged from 54 to 66 days with a mean of 57.6 days at Sivas. A greater number of days to 50% flowering was observed in Kozan in comparison to Sivas, depending on the growing period. Plants were grown during winter period in Kozan and during spring in Sivas. Spring sowings resulted in almost 100% earliness both of the cross combinations and the observed mean for flowering days. Biological yield in Kozan ranged from 0.77 to 7.66 g per plant, with a recorded mean of 3.61 g per plant. This trait ranged from 3.45 to 66.2 g per plant with a mean of 21.9 g per plant in Sivas (Table 2). Considerable variation in biological yield has been reported in prior studies (Ayub et al 2004; Bicer & Sakar 2008; Toklu et al 2009b). Biological yield is an important plant characteristic used in breeding programs for selection; therefore, these advanced lentil lines have the potential to increase biological yield utilized in breeding programs. Mean plant height was greater in Kozan when compared to Sivas for in cross combinations. This result showed that plant height is a trait highly affected by environmental conditions such as climate, soil type, altitude. Large diversity in phenotypic characters over locatios may be explained due to differences in environmental conditions (soil characteristics, agro-climatic features and rust diseases) and, spring and autumn sowings. Several researchers have reported greater diversity in plant height among lentil genotypes and exotic germplasm collections (Toklu et al 2009b; Mondal et al 2013). The mean number of branches per plant observed was 4.50 and 2.41 for advanced lentil lines (Table 2) and 2.80 and 1.98 for check varieties at Kozan and Sivas respectively. Bicer & Sakar (2008) reported that the number of branches per plant ranged from 1.4 to 2.8 among the different lentil genotypes, and Mondal et al (2013) reported significant variation in the number of branches per plant in lentil between mutant accessions and mother varieties. The number of pods per plant is directly connected to grain yield in lentil and varied from 12 to 74.3 with a mean of 37.5 at Kozan and 10.8 to 113.6 with a mean of 50.6 at Sivas for the advanced lentil lines. Greater diversity for this trait was observed among advanced lentil lines when compared to the check varieties (Table 2).

Several researchers also described high morphological diversity for the number of pods per plant (Toklu et al 2009b; Roy et al 2013; Mekonnen et al 2014). Due to great diversity in the yield components of these cross combinations could be evaluated for breeding and selection purposes. The weight of pods per plant exhibited a similar trend, as the number of pods per plant is due to the close relationship between two traits. A wide range of variability was detected for the weight of pods per plant in the advanced lentil lines at both locations. Most research shows that the weight of pods per plant is strongly correlated with grain yield (Sarwar et al 2010; 2013; Vanda et al 2013; Sharma et al 2014). Given this, the greater weight of pods per plant produced by these two cross combinations proves promising. The number of seeds also plays an important role in grain yield; therefore, this trait is crucial in improving high-yielding new varieties. The number of seeds per plant ranged from 1.33 to 34.6 with a mean of 9.45 and 3.60 to 87.4 with a mean of 36.5 at Kozan and Sivas, respectively. This is an indication of higher genotypic and phenotypic diversity for this trait; consequently, these advanced lines could be evaluated for number of seeds per plant to improve high-yielding new varieties and

**Table 2- Mean, range and coefficient of variation (CV) for grain yield and yield components of the advanced lentil lines in two diverse locations**

*Çizelge 2- İleri kademedeki mercimek hatları ve kontrol çeşitlerinde dane verimi ve verim komponentlerine ilişkin iki farklı lokasyonda saptanan ortalama, değişim sınırları ve varyasyon katsayıları*

| *Plant characteristic* | *Location* | *Advanced lentil lines* | | | *Check varieties* | |
|---|---|---|---|---|---|---|
| | | *Mean±SD* | *Range* | *CV (%)* | *Mean±SD* | *Range* |
| Days to 50% flowering | Kozan | 107.6±1.00 | 106.0-110.0 | 0.97 | * | * |
| | Sivas | 57.6±2.71 | 54.0-66.0 | 7.71 | 63.0±4.55 | 57.0-67.0 |
| Biological yield (g per plant) | Kozan | 3.61±1.31 | 0.77-7.66 | 36.4 | 3.40±1.41 | 1.74-4.93 |
| | Sivas | 21.9±12.7 | 3.45-66.2 | 58.2 | 22.8±3.82 | 17.2-25.9 |
| Plant height (cm) | Kozan | 38.1±4.55 | 27.4-50.4 | 11.9 | 39.8±4.19 | 36.4-45.8 |
| | Sivas | 25.3±3.53 | 14.0-39.4 | 14.0 | 36.0±2.96 | 33.4-39.6 |
| Number of branches per plant | Kozan | 4.50±1.46 | 1.80-11.6 | 32.5 | 2.80±0.23 | 2.60-3.00 |
| | Sivas | 2.41±0.44 | 1.00-4.00 | 18.2 | 1.98±0.39 | 1.60-2.50 |
| Number of pods per plant | Kozan | 37.5±12.3 | 12.0-74.3 | 32.9 | 15.5±2.95 | 12.4-19.4 |
| | Sivas | 50.6±22.6 | 10.8-113.6 | 44.6 | 72.3±15.1 | 58.2-93.6 |
| Weight of pods per plant (g) | Kozan | 0.36±0.26 | 0.05-1.44 | 72.8 | 0.15±0.09 | 0.06-0.26 |
| | Sivas | 9.15±5.61 | 1.40-25.8 | 61.3 | 8.48±4.25 | 2.45-11.55 |
| Number of seeds per plant | Kozan | 9.45±6.73 | 1.33-34.6 | 71.2 | 3.73±1.39 | 2.00-5.20 |
| | Sivas | 36.5±20.6 | 3.60-87.4 | 56.4 | 41.0±16.7 | 16.8-53.5 |
| 1000-seed weight (g) | Kozan | 31.2±8.24 | 12.0-51.7 | 26.4 | 19.3±10.4 | 10.0-34.2 |
| | Sivas | 31.4±6.60 | 12.5-44.0 | 21.0 | 27.7±2.80 | 23.6-29.8 |
| Weight of seeds per plant (g) | Kozan | 0.24±0.20 | 0.04-1.14 | 85.9 | 0.07±0.04 | 0.02-0.10 |
| | Sivas | 3.07±0.88 | 0.40-5.46 | 28.5 | 2.59±1.55 | 0.39-3.93 |

*, data could not obtained; SD, standard deviation; CV, coefficient of variation

in breeding programs. Similarly, Bicer & Sakar (2008), Toklu et al (2009b) and Mekonnen et al (2014) reported a high morphological diversity for the number of seeds per plant. The 1000-seed weight ranged from 12 to 51.7 g with a mean of 31.2 g at Kozan and 12.5 to 44 g with a mean of 31.4 g at Sivas. A higher phenotypic diversity was observed in the advanced lentil lines in comparison to the check varieties. Considerable 1000-seed weight variations were reported between newly developed lentil genotypes (Solanki et al 1999; Tyagi & Khan 2011). The weight of seeds per plant ranged from 0.04 to 1.14 g with a mean of 0.24 g at Kozan and 0.40 to 5.46 with a mean of 3.07 g at Sivas. A higher phenotypic diversity was observed for the advanced lentil lines when compared to the check varieties. Plant grain yield, along with grain quality, is one of the main objectives for plant breeders. Several researchers reported large variations in grain yield per plant for lentil genotypes (Solanki et al 1999; Sarwar et al 2010; Tyagi & Khan 2011; Vanda et al 2013; Mekonnen et al 2014; Sharma et al 2014).

These advanced lentil lines used in this study have the potential to increase yield in lentil.

A wide range of variability of seed K, Ca, Mg, Zn, Fe, Cu and Mn concentrations was found within the advanced lentil lines and check varieties (Table 3). Several researchers have reported that people need to consume at least 20 minerals and vitamins for balanced nutrition. Fe, Zn, Cu, Ca, Mg, I and Se are the most commonly lacking minerals in the human diet (White & Broadley 2009). In our research, the advanced red lentil lines investigated were found to have valuable phenotypic diversity for K, Ca, Mg, Zn, Fe, Cu, and Mn concentrations. Khan et al (1987) revealed valuable diversity for Ca, P, Fe, Zn, Mn, Cu, Ni and phytate contents among the improved lentil lines. Solanki et al (1999) reported considerable variation among the lentil genotypes for Ca, K, Fe and tannin contents, and Karaköy et al (2012) reported impressive variation in the micro- and macroelement concentrations in 39 lentil landraces. Breeding has proved to be the most affective method seed biofortification (White & Broadley 2005; 2009), with this in mind, crosses used in this study could provide plant breeders with a promising source of mineral rich seeds. Fe and Zn deficiencies are two of humanity's main nutritional problems. Biofortified crops are therefore gaining importance for human nutrition worldwide. In our research, Fe concentration ranged from 29.8 to 185.7 mg kg$^{-1}$ with a mean of 56.1 mg kg$^{-1}$ at Kozan and 19.9 to 142.5 mg kg$^{-1}$ with a mean of 45.7 mg kg$^{-1}$ at Sivas (Table 3). Great diversity in Fe concentration was observed in the advanced lentil lines when compared to the check varieties. Because

**Table 3- Mean, range and coefficient of variation (CV) for seed mineral concentrations of lentil advanced lines and check varieties in two diverse locations**

*Çizelge 3- İleri kademedeki mercimek hatları ve kontrol çeşitlerinde dane mineral madde içeriğine ilişkin iki farklı lokasyonda saptanan ortalama, değişim sınırları ve varyasyon katsayısı*

| *Plant characteristic* | *Location* | *Advanced lentil lines* | | | *Check varieties* | |
|---|---|---|---|---|---|---|
| | | *Mean±SD* | *Range* | *CV (%)* | *Mean±SD* | *Range* |
| K (mg 100 g$^{-1}$) | Kozan | 759.4±92.6 | 560.9-1121.1 | 12.2 | 947.9±37.9 | 903.9-991.4 |
| | Sivas | 907.2±91.2 | 667.7-1134.9 | 10.1 | 966.4±83.1 | 889.1-1061.5 |
| Ca (mg 100 g$^{-1}$) | Kozan | 42.4±11.7 | 12.6-93.9 | 27.5 | 48.0±3.99 | 43.8-53.4 |
| | Sivas | 61.5±21.7 | 25.1-172.4 | 35.2 | 56.1±3.41 | 51.6-59.8 |
| Mg (mg 100 g$^{-1}$) | Kozan | 125.9±17.7 | 100.6-213.1 | 14.0 | 165.6±2.45 | 163.5-169.2 |
| | Sivas | 146.8±9.67 | 122.2-196.7 | 6.59 | 141.9±11.7 | 130.5-155.8 |
| Zn (mg kg$^{-1}$) | Kozan | 45.2±8.09 | 30.6-96.7 | 17.9 | 41.8±2.32 | 39.7-44.7 |
| | Sivas | 50.4±11.8 | 23.7-87.2 | 23.3 | 62.2±7.22 | 53.6-70.9 |
| Fe (mg kg$^{-1}$) | Kozan | 56.1±15.3 | 29.8-185.7 | 27.4 | 41.3±1.90 | 38.7-42.8 |
| | Sivas | 45.7±13.8 | 19.9-142.5 | 30.2 | 49.2±4.45 | 42.8-53.1 |
| Cu (mg kg$^{-1}$) | Kozan | 11.7±1.77 | 8.5-17.5 | 15.1 | 12.0±1.88 | 10.1-14.6 |
| | Sivas | 11.9±2.40 | 5.52-23.1 | 20.1 | 13.9±1.46 | 12.6-16.0 |
| Mn (mg kg$^{-1}$) | Kozan | 19.1±3.05 | 12.8-27.2 | 16.0 | 17.2±1.58 | 15.0-18.7 |
| | Sivas | 16.5±3.41 | 8.24-36.2 | 20.6 | 15.9±0.94 | 14.5-16.7 |

SD, standard deviation; CV, coefficient of variation of the higher phenotypic diversity for seed Fe concentration, these crosses could be evaluated for biofortificaion of newly developed lentil varieties. Seed Zn concentration ranged from 30.6 to 96.7 mg $kg^{-1}$ with a mean of 45.2 mg $kg^{-1}$ at Kozan and 23.7 to 87.2 mg $kg^{-1}$ with a mean of 50.4 mg $kg^{-1}$ at Sivas. The valuable phenotypic diversity of both Fe and Zn concentraion in advanced lentil lines indicate the potential of these crosses to be used in seed mineral concentration studies.

The correlation coefficients between the yield components and mineral concentrations of advanced lentil lines are presented in Table 4. Days to 50% flowering was positively correlated with plant height, number of branches per plant, Fe and Mn concentrations but was negatively correlated with biological yield, number of pods per plant, weight of pods per plant, number of seeds per plant, weight of seeds per plant, and K, Ca, Mg, and Zn concentrations. Biological yield showed a positive and significant correlation with the number of pods per plant, weight of pods per plant, number of seeds per plant, 1000-seed weight, weight of seeds per plant, and K, Ca, Mg and Zn concentrations but were negatively correlated with plant height and number of branches per plant, Fe and Mn concentrations. Plant height showed a significant positive association with the number of branches per plant and Mn concentration and a significant negative association with the number of pods per plant, weight of pods per plant, number of seeds per plant, weight of seeds per plant, and K, Ca, Mg and Zn concentrations. The number of branches per plant showed a significant negative correlation with the weight of pods per plant, number of seeds per plant, weight of seeds per plant, and K, Ca and Mg concentrations in seeds. The number of pods per plant showed a positive significant correlation with the weight of pods per plant, number of seeds per plant, weight of seeds per plant, 1000-seed weight, Ca, Mg and Zn concentrations. The weight of pods per plant showed a positive significant correlation with the number of seeds per plant, 1000-seed weight, weight of seeds per plant, and K, Ca, Mg and Zn concentrations in seeds. The number of seeds per plant was positively correlated with the 1000-seed weight, weight of seeds per plant and K, Ca, Mg and Zn concentrations. 1000-seed weight was negatively correlated with seed K and Mg concentrations but was positively correlated with weight of seeds per plant. The weight of seeds per plant was positively correlated with K, Ca, Mg and Zn concentrations while negatively correlated with Fe and Mn concentrations. Seed K concentration was positively correlated with Ca, Mg, Zn and Cu concentration but was negatively correlated with Fe concentration. Seed Ca concentration showed a positive significant correlation with Mg and Zn concentrations but was negatively with Fe concentration. Seed Mg concentration was positively correlated with seed Zn and Cu concentration but were negatively correlated with seed Fe and Mn concentrations. Seed Zn concentration was positively correlated to seed Fe, Cu and Mn concetrations. Fe concentration showed positive significant association with Cu and Mn concentrations. Cu concentration was positively correlated to seed Mn concentration. Sarwar et al (2010) reported that seed yield showed a positive phenotypic correlation with the grain filling period, plant height, branches per plant, pods per plant and harvest idex, and improvement within this type of lentil population is possible by selecting plants with a relatively long grain filling period, increased number of pods and high harvest index. The results of our research showed a positive significant correlation between plant grain yield and biological yield, number of pods per plant, weight of pods per plant and number of seeds per plant. These findings are in accordance with the findings of Sarwar et al (2010), Kayan & Olgun (2012), Sarwar et al (2013), and Sharma et al (2014), who reported that the biological yield, number of pods, seeds per plant and harvest index are the yield components that most improve grain yield in lentil. The strong, significant negative correlation between plant grain yield and days to flowering indicate the importance of the grain filling period in lentil. Abo-Hegazy et al (2012) also revealed a negative correlation between plant grain yield and days to 50% flowering. In the last decade, mineral malnutrition is considered to be among the most serious global challenges relevance

**Table 4- Correlation coefficients between the agromorphological characteristics and micronutrient concentrations of advanced lentil lines**

*Çizelge 4- İleri kademedeki mercimek hatlarında agromorfolojik karakterler ile dane mineral madde konsantrasyonları arasındaki korelasyon katsayıları*

| *Plant trait* | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* | *9* | *10* | *11* | *12* | *13* | *14* | *15* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1- Days to flowering | 1 | | | | | | | | | | | | | | |
| 2- Biological yield | -0.72** | 1 | | | | | | | | | | | | | |
| 3- Plant height | 0.84** | -0.45** | 1 | | | | | | | | | | | | |
| 4- No. of branches per plant | 0.69** | -0.41** | 0.64** | 1 | | | | | | | | | | | |
| 5- No. of pods per plant | -0.35** | 0.68** | -0.10* | 0.04 | 1 | | | | | | | | | | |
| 6- Weight of pods per plant | -0.75** | 0.83** | -0.49** | -0.46** | 0.69** | 1 | | | | | | | | | |
| 7- Number of seeds per plant | -0.60** | 0.83** | -0.33** | -0.35** | 069** | 0.92** | 1 | | | | | | | | |
| 8- 1000-seed weight | -0.02 | 0.17** | 0.08 | -0.04 | 0.11* | 0.19** | 0.17** | 1 | | | | | | | |
| 9- Weight of seeds per plant | -0.91** | 0.82** | -0.70** | -0.61** | 0.50** | 0.89** | 0.83** | 0.09** | 1 | | | | | | |
| 10- K | -0.62** | 0.38** | -0.50** | -0.49** | 0.08 | 0.39** | 0.27** | -0.18** | 0.53** | 1 | | | | | |
| 11- Ca | -0.47* | 0.40** | -0.41** | -0.32** | 0.40** | 0.42** | 0.37** | 0.01 | 0.46** | 0.14* | 1 | | | | |
| 12- Mg | -0.59** | 0.41** | -0.52** | -0.41** | 0.21** | 0.42** | 0.40** | -0.12* | 0.59** | 0.57** | 0.42** | 1 | | | |
| 13- Zn | -0.24** | 0.22** | -0.25** | -0.14** | 0.20** | 0.14** | 0.09* | 0.02 | 0.19** | 0.30** | 0.29** | 0.28** | 1 | | |
| 14- Fe | 0.34** | -0.22** | 0.33** | 0.19** | -0.08 | -0.29** | -0.24** | 0.06 | -0.33** | -0.12* | -0.11* | -0.21** | 0.31** | 1 | |
| 15- Cu | -0.06 | 0.06 | -0.09 | -0.06 | -0.03 | -0.06 | -0.05 | 0.06 | -0.02 | 0.28** | -0.04 | 0.14* | 0.60** | 0.45** | 1 |
| 16- Mn | 0.37** | -0.11* | 0.39** | 0.17** | -0.04 | -0.19 | -0.14** | 0.08 | -0.31** | -0.11 | 0.05 | -0.12* | 0.12* | 0.53** | 0.22** |

*, significant at $P<0.05$; **, significant at $P<0.01$

to human nutrition and health (Grusak 2002; Welch & Graham 2004; White & Broadley 2005; 2009). Plant breeding efforts including the utilization of genetic resources and additional agricultural approaches reported among the most effective factors to overcome this problem (Graham et al 2007; Mayer et al 2008). In our study, we observed great variations among the lentil advanced lines for researched mineral elements. Our results are in accordance with above explanations and promising lentil lines could be used to improve new lentil varieties and spesific breeding purposes.

## 4. Conclusions

In conclusion, utilizing genetic resources in breeding and crop improvement is one of the most valuable ways to increase agricultural production in lentil and to improve food security for the world's population. In our study, we found considerable variations among the researched plant traits both agromorphological and nutrient-related traits in lentil advanced lines. This valuable variation could be used to develop new lentil varieties and different breeding purposes. Another issue is the importance of agromorphological and molecular characterization of lentil genetic resources for important plant characteristics. The two crosses used in this study were selected in accordance with the results of previous agromorphological and molecular caharacterization studies (Toklu et al 2009a, b), and parental genotypes were chosen. These results also showed that the improvement of biofortified lentil lines is possible using genetic resources.

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# The Effects of Water Temperature on Discharge and Uniformity Parameters of Emitters with Different Discharges, Types and Distances

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**ABSTRACT**

The research was conducted on emitter testing bench established in Irrigation laboratory, Suleyman Demirel University, Isparta, Turkey. In the study, discharge equations ($q= kH^x$), standard temperature discharge index (TDI, standard temperature is 20 °C) and uniformity parameters such as coefficient of manufacturing variation (CV), standard uniformity (Us), Christiansen uniformity (Cu) and emission uniformity (CUE) of in-line emitters with different discharges ($D_1$: 2.4 L $h^{-1}$ and $D_2$: 4.0 L $h^{-1}$), types ($T_B$: Pressure compensating, $T_T$: Non-pressure compensating) and distances ($A_1$: 20 cm, $A_2$: 33 cm and $A_3$: 50 cm) under different water temperatures (20, 30, 40 and 50 °C) were determined. Effects of different pressures (from 80 to 200 kPa) on discharge of the emitters were also investigated. Discharges of non-pressure compensating emitters were increased by increasing pressure (r≈ 0.99). Although discharge was stable under high or recommended pressure in pressure compensating emitters, there was an increasing trend in emitter discharge under low pressure like non-pressure compensating emitters. Linear regressions were obtained between discharge and water temperature in non-pressure compensating and pressure compensating emitters (r≈ 0.99). Emitter discharge increased due to water temperature increase approximately 5 and 3% in non-pressure compensating and pressure compensating emitters, respectively. TDI values of non-pressure compensating emitters increased between 0.04 and 0.06 with increasing water temperature. In pressure compensating emitters, TDI values decreased 0.02 in $D_1A_1T_B$ emitter, did not change in $D_1A_2T_B$ emitter, and increased between 0.01 and 0.02 in other four emitters with increasing water temperature. Cv, Us, Cu and CUE values of the emitters under different water temperatures ranged between 0.023-0.044, 95.6-97.7%, 96.6-98.1% and 89.3-96.0%, respectively. Significant differences were obtained for each of these parameters in different water temperatures, emitter types and emitter distances. Generally, uniformity parameters improved in high water temperatures and the highest values of uniformity parameters were obtained from $A_2$ emitter distance in the tested emitters (P<0.01).

Keywords: Discharge; Emitter; Pressure; Uniformity; Water temperature

# Farklı Debi, Tip ve Aralıklara Sahip Damlatıcıların Debilerine ve Eş Su Dağılımlarına Su Sıcaklığının Etkisi

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**ÖZET**

Bu araştırma Isparta Süleyman Demirel Üniversitesi Sulama laboratuarında kurulan damlatıcı test düzeneğinde yürütülmüştür. Çalışmada, farklı su sıcaklıkları (20, 30, 40 ve 50 °C) altında, farklı damlatıcı debilerine ($D_1$: 2.4 L $h^{-1}$, $D_2$: 4.0 L $h^{-1}$), damlatıcı tiplerine ($T_B$: Basınç düzenleyicili, $T_T$: Basınç düzenleyicisiz) ve damlatıcı aralıklarına ($A_1$: 20 cm, $A_2$: 33 cm, $A_3$: 50 cm) sahip 12 farklı içten geçik damlatıcının debi eşitlikleri ($q= kH^x$), standart sıcaklık debi indeksleri (TDI, standart sıcaklık 20 °C olarak alınmıştır) ve yapım faklılığı katsayısı (Cv), standart eş su dağılımı (Us), Christiansen eş su dağılım katsayısı (Cu) ve damlatıcı eş su dağılımı (CUE) gibi eş su dağılım parametreleri belirlenmiştir. Ayrıca, farklı işletme basınçlarının (80-200 kPa) damlatıcı debilerine olan etkileri incelenmiştir. Basınç düzenleyicisiz damlatıcı debileri artan işletme basıncı ile artmıştır (r≈ 0.99). Basınç düzenleyicili damlatıcı debileri ise yüksek veya önerilen basınçlarda sabit kalırken, düşük basınçlarda basınç düzenleyicisizlerde olduğu gibi artış göstermiştir. Hem basınç düzenleyicisiz hem de basınç düzenleyicili damlatıcılarda debi ve su sıcaklığı arasında doğrusal ilişki elde edilmiştir (r≈ 0.99). Su sıcaklığının artmasıyla debilerdeki artış basınç düzenleyicisiz damlatıcılarda yaklaşık % 5, basınç düzenleyicili damlatıcılarda ise yaklaşık % 3 olarak belirlenmiştir. Basınç düzenleyicisiz damlatıcıların TDI değerleri sıcaklık artışıyla 0.04 ile 0.06 arasında artmıştır. Basınç düzenleyicili damlatıcılarda ise TDI değerleri sıcaklık artışıyla, $D_1A_1T_B$'de 0.02 azalmış, $D_1A_2T_B$'de değişmemiş, ancak diğer dört damlatıcıda 0.01 ile 0.02 arasında artış göstermiştir. Farklı sıcaklıklar altında elde edilen Cv, Us, Cu ve CUE değerleri sırasıyla 0.023-0.044, % 95.6-97.7, % 96.6-98.1 ve % 89.3-96.0 arasında değişmiştir. Bu parametrelerin farklı su sıcaklıkları, damlatıcı tipleri ve damlatıcı aralıkları arasında istatistiksel olarak önemli farklar bulunmuştur. Test edilen damlatıcılarda genel olarak, eş su dağılım parametreleri yüksek su sıcaklıklarında yükselirken, en yüksek değerler $A_2$ damlatıcı aralığında elde edilmiştir (P<0.01).

Anahtar Kelimeler: Debi; Damlatıcı; Basınç; Eş su dağılımı; Su sıcaklığı



# 1. Introduction

Nowadays, global warming and rapid population growth have negative impact on water sources and increase water requirement for both urban and industrial areas in the world and Turkey. For this reason, irrigation water must be used more efficiently, especially, in countries like Turkey where approximately 73% of the total water consumption is used for agricultural irrigation. One of the most important reasons for excessive water use in agriculture is the using of surface irrigation systems with low efficiency (Yildirim 2012). Drip irrigation has an important potential with high irrigation efficiency, low energy consumption and water loss. Effective use of drip irrigation systems is depending on correct design of the system. Emitter is the most important elements of the system for efficient operation. High efficiency in drip irrigation systems depends on uniformity of emitter discharge. The most of the designs focus on pressure-emitter discharge relationships of the emitters because of variations in operating pressure in field condition due to land slope and head losses in pipes for the uniformity. However, emitter discharge and uniformity of drip irrigation systems are also influenced by other factors such as manufacturing variability, lateral diameter, emitter distance, clogging and water temperature changes (Ozekici & Sneed 1995; Rodriguez-Sinobas et al 1999; Clark et al 2005; Dutta 2008). While emitter clogging can be controlled by proper water filtration and system maintenance, manufacturing variability and temperature are often uncontrolled and variable parameters that can influence the discharge of individual emitters and the distribution uniformity of drip irrigation systems. Some water physical properties such as viscosity, density and emitter flow passage could be affected by temperature changes. Therefore, temperature changes cause changes in both friction loss and discharge (Peng et al 1986; Rodriguez-Sinobas et al 1999). In the field condition, drip irrigation laterals and emitters used in surface or near surface in the field may have full or partial exposure to the sun in warm and hot climates. Some researchers reported that drip lateral temperatures and soil temperatures during the day ranged from 26 to 42 °C and from 24 to 66 °C, respectively (Parchomchuk 1976; Nakayama & Bucks 1985; Abu-Gharbieh 1997). Under these conditions, buried drip irrigation laterals can act as a heat exchanger and absorb heat from the soil, thereby increasing the temperature of the water, resulting in a changed emitter discharge. Parchomchuk (1976) indicated that emitter discharge rates could increase about 53% when water temperature increased from 20 to 60 °C in microtube and spiral path emitters. Dogan & Kırnak (2010) concluded that when water temperature increased from 20 to 50 °C, flow rate changes due to irrigation water temperature increase varied from -7.5 to 16.1% and from -7.4 to 20.9% at pressure compensating emitters and non-pressure compensating emitters, respectively. Senyigit et al (2012) also claimed that the non-pressure compensating in-line emitter discharge increased with increasing temperature. The objective of this study was to evaluate the effects of different water temperatures and pressures on emitter discharge and the effects of different water temperatures on standard temperature discharge index and uniformity parameters.

## 2. Material and Methods

The study was conducted on emitter testing bench established in Irrigation Laboratory, Süleyman Demirel University, Isparta, Turkey in 2013 (Figure 1). Laterals were placed in the emitter testing bench without inclination. Graduated cylinders (1000 mL) with divisions every 10 mL located under each of the emitters were used to determine the emitter discharge. The pressure values were measured by manometers installed to the emitter testing bench and supply water was provided by a 216 L reservoir that had a small pump having 3.4 $m^3 h^{-1}$ discharge at 4.2 bar to pressurize the water. The water in the reservoir was heated by two resistances each of which has a capacity of 1500 Watts and the water temperature was tracked both by temperature sensor screen and by measurements from emitter output with a digital thermometer accurate to ±1 °C. Variation of temperature determined was less than 1 °C in each test. In the study, 12 different in-line emitters which are commonly used and produced by different manufacturers were used. Some physical properties of the emitters were shown in Table 1. In order to determine the effects of different water temperatures and pressures on discharge equations and the effects of different water temperatures on standard temperature discharge index (TDI), coefficient of manufacturing variation (CV), standard uniformity (Us), Christiansen uniformity (Cu) and emission uniformity (CUE) of different emitters, water temperatures of 20, 30, 40 and 50 °C and pressure values of 80, 90, 100, 110, 120, 130, 140, 150,160, 170, 180, 190 and 200 kPa were used.

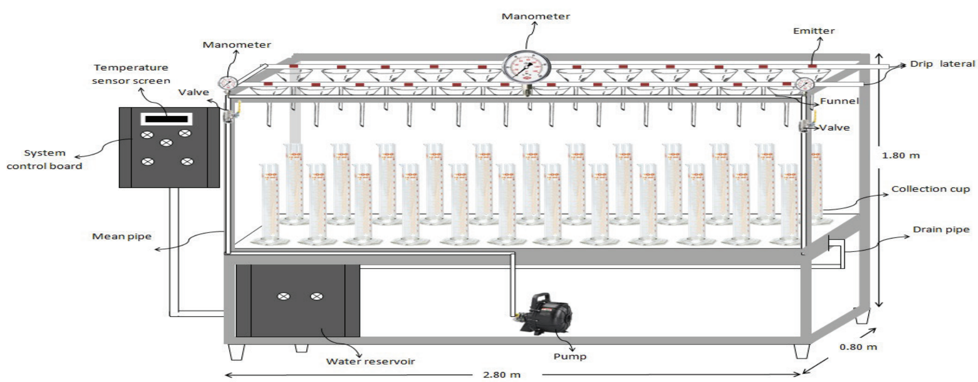


**Figure 1- Emitter testing bench**

*Şekil 1- Damalatıcı test düzeneği*

**Table 1- Some physical properties of the tested emitters**

*Çizelge 1- Damlatıcıların kimi fiziksel özellikleri*

| *Emitters* | *Manufacturer recommended emitter discharge ($L\ h^{-1}$)* | *Lateral diameter (mm)* | *Emitter distance (cm)* | *Emitter number* |
|---|---|---|---|---|
| $D_1A_1T_T$ | 2.4 | 16 | 20 | 24 |
| $D_1A_2T_T$ | 2.4 | 16 | 33 | 16 |
| $D_1A_3T_T$ | 2.4 | 16 | 50 | 10 |
| $D_1A_1T_B$ | 2.4 | 16 | 20 | 24 |
| $D_1A_2T_B$ | 2.4 | 16 | 33 | 16 |
| $D_1A_3T_B$ | 2.4 | 16 | 50 | 10 |
| $D_2A_1T_T$ | 4 | 16 | 20 | 24 |
| $D_2A_2T_T$ | 4 | 16 | 33 | 16 |
| $D_2A_3T_T$ | 4 | 16 | 50 | 10 |
| $D_2A_1T_B$ | 4 | 16 | 20 | 24 |
| $D_2A_2T_B$ | 4 | 16 | 33 | 16 |
| $D_2A_3T_B$ | 4 | 16 | 50 | 10 |

Each test was conducted by measuring the discharge of the emitters in testing bench under a constant temperature and different pressures. Before emitter discharge measurements, the system was operated for about 5 minutes to stabilize pressure. Emitter discharges were measured for 300 seconds, then collected water from each emitter was measured as volumetric and those values were converted to $L\ h^{-1}$. For the next test, the temperature was changed from sensor screen and waited least 30-40 minutes to equilibrate the temperature. After reaching to the desired temperature, the same measurements were repeated (Rodriguez-Sinobas et al 1999; Clark et al 2005).

Coefficients (*k*) and exponents (*x*) of emitter discharge and correlation coefficients were determined using regression test procedures (ASABE 2003) by emitter discharge equation (Equation 1).

$$q = kH^x \tag{1}$$

Where; $q$, emitter discharge ($L\ h^{-1}$); $H$, pressure (kPa); $k$, emitter coefficient; $x$, emitter exponent.

Standard temperature discharge index (TDI), standard variation (S), coefficient of manufacturing variation (CV), standard uniformity (Us), Christiansen uniformity (Cu) and emission uniformity (CUE) were calculated using Equation 2-7 (Christiansen 1942; Wu & Gitlin 1979; Bralts & Edwards 1986; ASABE 2003).

$$TDI = \frac{(qt^0)}{(qt^0_{20})} \tag{2}$$

$$S = \left[\frac{\sum_{i=1}^{n}(q_i - q_{mean})^2}{n-1}\right]^{1/2} \tag{3}$$

$$CV = \frac{S}{q_{ort}} \tag{4}$$

$$U_s = 100(1 - CV) \tag{5}$$

$$Cu = 100(1 - \frac{\Delta q_o}{q_{mean}}) \tag{6}$$

$$CUE = 100\left[1 - \frac{1.27CV}{\sqrt{n}}\right]\frac{q_{min}}{q_{mean}} \tag{7}$$

Where; $qt^0$, emitter discharge at the test water temperature ($L\ h^{-1}$); $qt^0_{20}$, emitter discharge at the 20 $^oC$ ($L\ h^{-1}$); $S$, standard variation; $q_i$, emitter discharge ($L\ h^{-1}$); $q_{mean}$, average emitter discharge ($L\ h^{-1}$); $n$, total number of emitters; $\Delta q_o$, absolute deviation of the average (L $h^{-1}$); $q_{min}$, minimum discharge obtained from minimum pressure (L $h^{-1}$).

The effect of various pressures and water temperatures on uniformity parameters of emitters with different discharges, types and distances were analyzed by a factorial design analysis of variance and Tukey's test were used to determine the differences.

## 3. Results and Discussion

### *3.1. Discharge-pressure relationship*

Discharges, emitter coefficients and exponents in discharge equation (q= $kH^x$) and $R^2$ values according to regression analyses from tested non-pressure compensating and pressure compensating emitters at different temperatures and pressures, were given in Table 2. Regression analyses of discharge and pressure relationships of all emitters were generally significant at 0.001 level. It was observed that the discharges of all non-pressure compensating emitters increased by increasing pressure (r≈ 0.99). The x values of the non-pressure compensating emitters were found to be close to 0.5 which showed that the flow was fully turbulent. Contrary to non-pressure compensating emitters, although discharge was stable under high or recommended pressure in pressure compensating emitters, there was an increasing trend in emitter discharge under low pressure like non-pressure compensating emitters. The x values were obtained near 0 as expected, this showed that the manufacturers emitters data to be compatible with the pressure compensating properties. This finding is confirmed by the findings of other previous studies (Rodriguez-Sinobas et al 1999; Clark et al 2005; Dogan & Kirnak 2010; Senyigit et al 2012). In addition, although discharge-pressure curves of the pressure compensating emitters remained constant at high or recommended pressures except $D_1A_1T_B$, increased in the low pressure as non-pressure compensating emitters. This finding is in agreement with the findings of Dutta (2008).

### *3.2. Water temperature-emitter discharge and standard temperature discharge index relationships*

Linear regressions were obtained between emitter discharge and water temperature in non-pressure compensating and pressure compensating emitters (r≈ 0.99). Average emitter discharges strongly increased with increasing water temperature at non-

**Table 2- Emitter coefficients, exponents and $R^2$ values of non-pressure compensating and pressure compensating emitters at different water temperatures**

*Çizelge 2- Basınç düzenleyicili ve basınç düzenleyicisiz damlatıcıların damlatıcı, katsayıları ve $R^2$ değerleri*

| | *20°C* | | | *30°C* | | | *40°C* | | | *50°C* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Emitters* | *x* | *k* | *$R^2$* | *x* | *k* | *$R^2$* | *x* | *k* | *$R^2$* | *x* | *k* | *$R^2$* |
| $D_1A_1T_T$ | 0.52 | 0.21 | 0.996*** | 0.52 | 0.21 | 0.998*** | 0.52 | 0.22 | 0.998*** | 0.50 | 0.24 | 0.997*** |
| $D_1A_2T_T$ | 0.51 | 0.22 | 0.996*** | 0.50 | 0.24 | 0.992*** | 0.49 | 0.24 | 0.995*** | 0.46 | 0.29 | 0.998*** |
| $D_1A_3T_T$ | 0.52 | 0.24 | 0.993*** | 0.50 | 0.26 | 0.998*** | 0.52 | 0.24 | 0.998*** | 0.51 | 0.26 | 0.998*** |
| $D_2A_1T_T$ | 0.52 | 0.35 | 0.992*** | 0.51 | 0.38 | 0.998*** | 0.52 | 0.37 | 0.998*** | 0.51 | 0.40 | 0.998*** |
| $D_2A_2T_T$ | 0.50 | 0.44 | 0.998*** | 0.50 | 0.45 | 0.996*** | 0.51 | 0.44 | 0.996*** | 0.47 | 0.53 | 0.999*** |
| $D_2A_3T_T$ | 0.52 | 0.45 | 0.998*** | 0.52 | 0.45 | 0.999*** | 0.49 | 0.52 | 0.999*** | 0.48 | 0.54 | 0.998*** |
| $D_1A_1T_B$ | 0.02 | 2.66 | 0.575*** | 0.01 | 2.27 | 0.185* | 0.03 | 2.04 | 0.504*** | 0.05 | 1.85 | 0.860*** |
| $D_1A_2T_B$ | 0.08 | 1.64 | 0.740*** | 0.10 | 1.47 | 0.932*** | 0.10 | 1.48 | 0.925*** | 0.13 | 1.31 | 0.952*** |
| $D_1A_3T_B$ | 0.22 | 0.82 | 0.992*** | 0.24 | 0.76 | 0.998*** | 0.22 | 0.81 | 0.990*** | 0.25 | 0.73 | 0.982*** |
| $D_2A_1T_B$ | 0.09 | 2.58 | 0.756*** | 0.12 | 2.23 | 0.805*** | 0.15 | 1.97 | 0.914*** | 0.13 | 2.19 | 0.857*** |
| $D_2A_2T_B$ | 0.13 | 2.02 | 0.954*** | 0.14 | 1.93 | 0.939*** | 0.15 | 1.79 | 0.981*** | 0.16 | 1.75 | 0.990*** |
| $D_2A_3T_B$ | 0.10 | 2.37 | 0.866*** | 0.13 | 2.13 | 0.887*** | 0.14 | 1.99 | 0.944*** | 0.13 | 2.12 | 0.934*** |

*, significant at 0.05 level; ***, significant at 0.001 level

pressure compensating emitters and slightly increased with increasing water temperature at pressure compensating emitters. The rate of emitter discharge increase due to increased water temperature (from 20 to 50 °C) was approximately 5 and 3% at non-pressure compensating and pressure compensating emitters, respectively (Figure 2). Similarly, Dogan & Kirnak (2010) claimed that water temperature generally tend to increase discharge of non-pressure compensating and pressure compensating emitters. Some other researchers also explained the relationship between water temperature and discharge with linear regression similar to our study (Parchomchuk 1976; Dogan & Kirnak 2010).

Standard temperature discharge index (TDI) values were obtained with emitter discharge measured at different water temperatures and then regression analyses were performed (Figure 3). TDI values except $D_1A_2T_B$ showed linear relationships among different water temperatures, this result is also in agreement with previous findings (Zur & Tal 1981; Dogan & Kirnak 2010). TDI values of non-pressure compensating emitters increased between 0.04 and 0.06 with increasing water temperature. In pressure compensating emitters, TDI values decreased in $D_1A_1T_B$ emitter as 0.02 and constant in $D_1A_2T_B$ emitter, but increased between 0.01 and 0.02 in other four emitters with increasing water temperature. The results are consistent with some previous findings by Rodriguez-Sinobas et al (1999) and Dogan & Kirnak (2010). As a result, water temperature is an important factor to affect changing of TDI values depending on the emitter type. Clark et al (2005) reported similar results which indicated that highly undesirable discharge distributions in drip irrigation systems could be provided with emitter exposed to sunlight or very warm water conditions.

CV values were obtained as lower than 0.05 for all emitters and varied from 0.023-0.044 and 0.031-0.043 at non-pressure compensating and pressure compensating emitters, respectively (Table 3). While the lowest CV values in non-pressure compensating

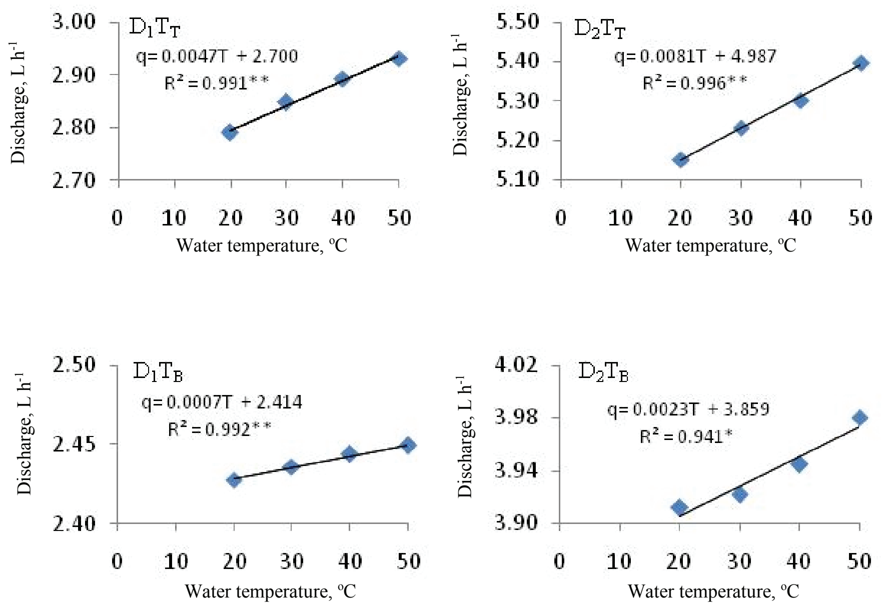


**Figure 2- Water temperature-discharge relationships of the non-pressure compensating and pressure compensating emitters with different discharges**

*Şekil 2- Farklı debilere sahip basınç düzenleyicili ve basınç düzenleyicisiz damlatıcılarda su sıcaklığı-debi ilişkisi*

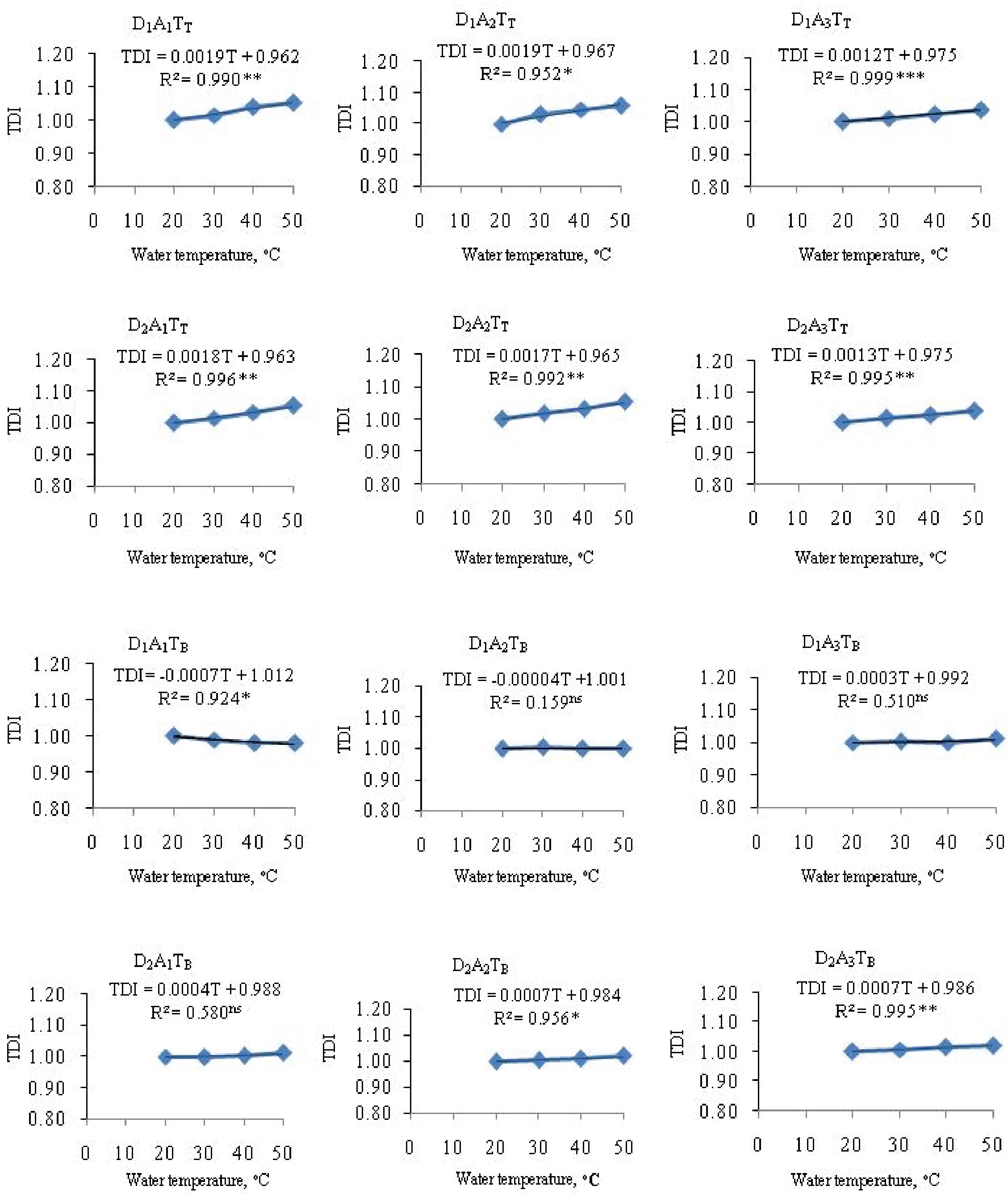


**Figure 3- Water temperature-standard temperature discharge index (TDI) relationships of the emitters**

*Şekil 3- Damlatıcıların su sıcaklığı-standart sıcaklık debi indeks ilişkileri* emitters with $D_1$ were obtained at 40 and 50 °C water temperatures, CV values were not affected from changes in water temperature for other emitters (P<0.01). However, CV value of non-pressure compensating emitter was lower than pressure compensating emitter's at 50 °C in both $D_1$ and $D_2$. Our results except decreased CV values in high water temperatures in non-pressure compensating emitters with $D_1$ are similar with Clark et al (2005) and Dogan & Kirnak (2010) who indicated that there was no relationship between CV and water temperature. In addition, the lowest CV values between the means of emitter distances in various water temperatures were obtained from $A_2$ for emitters with both $D_1$ and $D_2$ (P<0.01). Mean Us values of all emitters were obtained higher than 96% which was described as "excellent" class according to ASAE (2002). The Us values changed between 95.6 and 97.4% at non-pressure compensating emitters, while those values changed between 95.7 and 96.9% at pressure compensating emitters (Table 3). The effects of water temperatures on Us were found to be similar to those found for CV since Us is the function of CV.

**Table 3- Cv and Us values of the emitters with different discharges, types and distances under different water temperatures**

*Çizelge 3- Farklı debi, tip ve aralıklara sahip damlatıcıların farklı su sıcaklıklarında Cv ve Us değerleri*

| *CV* | | | | | | |
|---|---|---|---|---|---|---|
| *Emitters* | | *Water temperature (°C)* | | | | *Mean* |
| | | *20* | *30* | *40* | *50* | |
| $D_1$ | $T_T$ | 0.036 ABa | 0.038 Bb | 0.033 Aa | 0.034 Aa | 0.036 |
| | $T_B$ | 0.035 Ab | 0.035 Aa | 0.035 Aa | 0.037 Ab | 0.035 |
| | Mean | 0.036 | 0.037 | 0.034 | 0.036 | |
| $D_2$ | $T_T$ | 0.033 Aa | 0.032 Aa | 0.032 Aa | 0.030 Aa | 0.032 |
| | $T_B$ | 0.035 Aa | 0.035 Aa | 0.033 Aa | 0.036 Ab | 0.035 |
| | Mean | 0.034 | 0.034 | 0.033 | 0.034 | |
| $D_1$ | $A_1$ | 0.037 | 0.037 | 0.033 | 0.036 | 0.036 b |
| | $A_2$ | 0.029 | 0.029 | 0.029 | 0.028 | 0.029 a |
| | $A_3$ | 0.041 | 0.044 | 0.041 | 0.043 | 0.042 c |
| | Mean | 0.036 | 0.037 | 0.034 | 0.036 | |
| $D_2$ | $A_1$ | 0.038 | 0.038 | 0.035 | 0.038 | 0.037 b |
| | $A_2$ | 0.027 | 0.027 | 0.028 | 0.027 | 0.027 a |
| | $A_3$ | 0.037 | 0.036 | 0.033 | 0.035 | 0.035 b |
| | Mean | 0.034 | 0.034 | 0.032 | 0.034 | |
| *Us* | | | | | | |
| *Emitters* | | *Water temperature (°C)* | | | | *Mean* |
| | | *20* | *30* | *40* | *50* | |
| $D_{1w}$ | $T_T$ | 96.4 Aba* | 96.2 Bb | 96.7 Aa | 96.6 Aa | 96.4 |
| | $T_B$ | 96.5 Aa | 96.5 Aa | 96.6 Aa | 96.3 Ab | 96.5 |
| | Mean | 96.4 | 96.3 | 96.6 | 96.4 | |
| $D_2$ | $T_T$ | 96.7 Aa | 96.8 Aa | 96.8 Aa | 97.0 Aa | 96.8 |
| | $T_B$ | 96.5 Aa | 96.5 Aa | 96.7 Aa | 96.4 Ab | 96.5 |
| | Mean | 96.6 | 96.6 | 96.8 | 96.6 | |
| $D_1$ | $A_1$ | 96.3 | 96.3 | 96.7 | 96.4 | 96.4 b |
| | $A_2$ | 97.1 | 97.1 | 97.1 | 97.2 | 97.1 a |
| | $A_3$ | 95.9 | 95.6 | 95.9 | 95.7 | 95.8 c |
| | Mean | 96.4 | 96.3 | 96.6 | 96.4 | |
| $D_2$ | $A_1$ | 96.2 | 96.2 | 96.5 | 96.2 | 96.3 b |
| | $A_2$ | 97.3 | 97.3 | 97.2 | 97.3 | 97.3 a |
| | $A_3$ | 96.3 | 96.4 | 96.7 | 96.5 | 96.5 b |
| | Mean | 96.6 | 96.6 | 96.8 | 96.6 | |

*, capital Latin letters show differences between the columns, small Latin letters show differences between the rows

Generally, Cu values ranged from 97.0 to 97.5% in all emitters under different water temperatures (Table 4). While Cu values did not provide the condition as Cu≥ 98% suggested by Perold (1977), Cu≥ 95% condition recommended by Wu & Gitlin (1979) was provided in almost all emitters. While there was no statistical difference between Cu values at different water temperatures in both non-pressure compensating and pressure compensating emitters, Cu value of non-pressure compensating emitter was higher than pressure compensating emitter's at only 50 °C water temperature for both $D_1$ and $D_2$ (P<0.01). Furthermore, the highest Cu values between the means of emitter distances at various water temperatures were obtained in $A_2$ for the emitters with both $D_1$ and $D_2$ (P<0.01). CUE values classified as "good- excellent" class according to ASAE (2002) stayed between 87 and 94% (Table 4). However, CUE values were "excellent" class in $A_2$ emitter distance of both non-pressure compensating and pressure compensating emitters. The highest CUE values at non-pressure compensating emitters with $D_1$ were obtained from 40 and 50 °C water temperatures (P<0.01), while those values were not affected by water temperature at pressure compensating emitters. In addition, means CUE

**Table 4- Cu and CUE values of the emitters with different discharges, types and distances under different water temperature**

*Çizelge 4- Farklı debi, tip ve aralıklara sahip damlatıcılıarın Cu ve CUE değerleri*

| | | *Cu* | | | | |
|---|---|---|---|---|---|---|
| *Emitters* | | *Water temperature (°C)* | | | | *Mean* |
| | | *20* | *30* | *40* | *50* | |
| $D_1$ | $T_T$ | 97.2 Aa* | 97.1 Aa | 97.4 Aa | 97.4 Aa | 97.3 |
| | $T_B$ | 97.3 Aa | 97.2 Aa | 97.2 Aa | 97.0 Ab | 97.2 |
| | Mean | 97.2 | 97.2 | 97.3 | 97.2 | |
| $D_2$ | $T_T$ | 97.4 Aa | 97.4 Aa | 97.5 Aa | 97.7 Aa | 97.5 |
| | $T_B$ | 97.5 Aa | 97.4 Aa | 97.5 Aa | 97.3 Ab | 97.4 |
| | Mean | 97.5 | 97.4 | 97.5 | 97.5 | |
| $D_1$ | $A_1$ | 97.1 | 97.1 | 97.5 | 97.2 | 97.2 b |
| | $A_2$ | 97.7 | 97.8 | 97.7 | 97.8 | 97.7 a |
| | $A_3$ | 96.8 | 96.6 | 96.7 | 96.6 | 96.7 c |
| | Mean | 97.2 | 97.2 | 97.3 | 97.2 | |
| $D_2$ | $A_1$ | 97.0 | 97.0 | 97.2 | 97.1 | 97.1 c |
| | $A_2$ | 97.9 | 97.7 | 97.8 | 98.0 | 97.9 a |
| | $A_3$ | 97.3 | 97.4 | 97.5 | 97.4 | 97.4 b |
| | Mean | 97.5 | 97.4 | 97.5 | 97.5 | |
| | | *CUE* | | | | |
| *Emitters* | | *Water temperature (°C)* | | | | *Mean* |
| | | *20* | *30* | *40* | *50* | |
| $D_1$ | $T_T$ | 92.1Bb | 91.2Cb | 93.5Ab | 92.8ABa | 92.4 |
| | $T_B$ | 93.3Ba | 93.3Ba | 94.2Aa | 93.3Ba | 93.5 |
| | Mean | 92.7 | 92.3 | 93.9 | 93.1 | |
| $D_2$ | $T_T$ | 93.6 | 95.3 | 93.8 | 94.1 | 93.7a |
| | $T_B$ | 92.6 | 92.9 | 93.3 | 92.4 | 92.8b |
| | Mean | 93.1 | 93.2 | 93.5 | 93.3 | |
| $D_1$ | $A_1$ | 91.5 | 91.5 | 93.2 | 92.4 | 92.2b |
| | $A_2$ | 94.4 | 94.3 | 94.7 | 95.0 | 94.6a |
| | $A_3$ | 92.1 | 91.0 | 93.4 | 92.2 | 92.2b |
| | Mean | 92.7 | 92.3 | 93.9 | 93.1 | |
| $D_2$ | $A_1$ | 91.3 | 91.0 | 91.7 | 91.8 | 91.5c |
| | $A_2$ | 95.5 | 95.5 | 95.1 | 94.9 | 95.3a |
| | $A_3$ | 92.5 | 93.1 | 93.9 | 93.0 | 93.1b |
| | Mean | 93.1 | 93.2 | 93.5 | 93.3 | |

*, capital Latin letters show differences between the columns, small Latin letters show differences between the rows

value of non-pressure compensating emitters (93.7%) was higher than pressure compensating emitter's (92.8%) in $D_2$ according to CUE values under different water temperatures (P<0.01).

## 4. Conclusions

In the present study, the effects of different water temperatures and pressures on emitter discharges and the effects of different water temperatures on standard temperature discharge index and uniformity parameters were tested using 12 different in-line emitters with different discharges, types and distances. Study results showed that emitter discharges of non-pressure compensating emitters were increased linearly by increasing pressure. Although discharge-pressure curves were a constant under high or recommended pressure in compensating emitters, the curves rose like non-pressure compensating emitters under low operating pressure.

Mean emitter discharges of all emitters in the experiment were increased with water temperature and linear relationships were observed between discharge and water temperature. In addition, TDI values except $D_1A_2T_B$ showed linear relationships among different water temperatures**.** It can be concluded that water temperature had an important effect on changing of TDI values depending on the emitter type.

Significant differences were obtained between the values of uniformity parameters of emitters with different discharges, types and distances under different water temperatures (P<0.01). While uniformity parameters generally improved in high water temperature (40 and 50 $^oC$) in non-pressure compensating emitters, the data indicated that no significant effect of water temperature on uniformity parameters in pressure compensating emitters. In addition, the highest uniformity parameters values were obtained from $A_2$ emitter distance in the tested emitters. However, in general, there was no significant difference between the non-pressure compensating and pressure compensating emitters with regard to uniformity parameters except Cu.

While the most of manufacturers provide x and k coefficients values of the emitter discharge equation at standard temperature (20 $^oC$), the effects of different temperature on emitter discharge were not considered. According to our results, providing the response data of different water temperatures on emitter discharges by manufacturers to designers will be useful strategy to organize more accurate project and efficient drip irrigation system. In addition, drip irrigation system users should also measure water temperature and make associated correction during operation in the field for high performance.

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# Determination of Forage Yield and Quality Characteristics of Annual Ryegrass (*Lolium multiflorum* Lam.) Lines

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**ABSTRACT**

In the present study, we examined forage yield and quality features of annual ryegrass (*Lolium multiflorum* Lam.) lines developed by using half-sib family selection breeding method. The study was conducted in a randomized complete block design with three replications between 2009 and 2011 years in Samsun, Turkey. Based on the average of the results of two years, significant differences were found for all parameters. In the studied lines and varieties, dry matter yields were found between 6.66 and 9.37 t ha$^{-1}$, crude protein contents 11.46-13.81%, crude protein yields 0.80-1.18 t ha$^{-1}$, acid detergent fiber 31.41-34.75%, neutral detergent fiber 48.77-52.80%, total digestible nutrient contents 56.49-60.80%, total digestible nutrient yields 376.35-556.42 t ha$^{-1}$ and relative feed values 109.33-122.83. Annual ryegrass lines 4, 5, 6, 10 and 11 were selected for further regional yield assessments due to their superior yield and quality attributes.

Keywords: Annual ryegrass; Dry matter yield; Crude protein; Total digestible nutrient; Relative feed value

# Tek Yıllık Çim (*Lolium multiflorum* Lam.) Hatlarının Verim ve Kalite Özelliklerinin Belirlenmesi

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**ÖZET**

Bu çalışmada yarı kardeş aile seleksiyonu ıslah yöntemiyle geliştirilen tek yıllık çim hatlarının yem verim ve kalite özelikleri araştırılmıştır. Araştırma tesadüf blokları deneme deseninde üç tekerrürlü olarak 2009-2011 yılları arasında Samsun/Türkiye'de yürütülmüştür. İki yıllık ortalama sonuçlara göre incelenen tüm parametrelerde önemli farklılıklar bulunmuştur. İncelenen hat ve çeşitlerde kuru madde verimleri 6.66-9.37 t ha$^{-1}$, ham protein oranları % 11.46-13.81, ham protein verimleri 0.80-1.18 t $ha^{-1}$, asit deterjan lif oranları % 31.41-34.75, nötral deterjan lif oranları % 48.77-52.80, toplam sindirilebilir besin oranları % 56.49-60.80, toplam sindirilebilir besin verimleri 376.35-556.42 t $ha^{-1}$ ve nispi yem değerleri 109.33-122.83 arasında belirlenmiştir. Üstün verim ve kalite özellikleri nedeniyle 4, 5, 6, 10 ve 11 numaralı yıllık çim hatları bölge verim denmeler için seçilmişlerdir.

Anahtar Kelimeler: Tek yıllık çim; Kuru madde verimi; Ham protein; Toplam sindirilebilir besin; Nispi yem değeri



## 1. Introduction

Annual ryegrass (*Lolium multiflorum* Lam.) has been one of the most important forage grass species being cultivated in many parts of the world (Pivorienė & Pašakinskienė 2007; Lopes et al 2009) due to its high productivity and forage quality (Simić et al 2009). Annual ryegrasses can contain high levels of digestible nutrients for many ruminants to increase their genetic capacity for production. Rich nutritious content of annual ryegrass may be conserved for three or more months before digestibility declines (Lippke & Elis 1997). Water-soluble carbohydrate ratio is quite high in the leaves of annual ryegrass (Sandrin et al 2006) and dry matter digestibility can reach up to 80% in the early stage of development (Balasko et al 1995). In later stages of maturation of annual ryegrass, CP and digestibility decrease while ADF and NDF rates increase (Callow et al 2000; Aganga et al 2004). It is highly adaptable to different environmental and soil conditions (Evers et al 1997), and tolerant to intense and frequent grazing (Lemus 2009). Annual ryegrass can be used for grazing and sources of herbage or silage due to easy establishing and long production period with high productivity (Aganga et al 2004).

Forage production in Turkey is insufficient to meet the need of high-quality roughage, and the forage gap is compensated by using low-quality forage such as cereal straws (Koc et al 2012). To solve this problem, it is necessary to employ new varieties of forage crops, especially annual species, and to increase the production of forage. In the world, many annual ryegrass varieties have been improved for the production of high yield and quality; however, only two varieties (Efe 82 and Rambo) have been registered in Turkey.

The objectives of this study were to investigate yield and quality characteristics of annual ryegrass lines and to determine the new candidate varieties for registration.

## 2. Material and Methods

Annual ryegrass (*Lolium multiflorum* Lam.) seeds were collected from natural grassland vegetation in the Black Sea coastal area of Turkey. Seeds were sown in 2002 for the half sib family selection breeding process in city of Samsun in located the same coastal area. Annual ryegrass plants were observed and selected in terms of features such as flowering status, and leaf and stem characteristics for two years. At the end of this process, a total of fourteen quintet groups were created by using the half sib family selection breeding method in 2004. These groups were isolated in order to prevent cross-pollination for four years. When enough seeds were obtained, the yield trial was established with a total of 19 accessions, fourteen annual ryegrass lines and five standard cultivars (St-1; Caramba, St-2; Trinova, St-3; Teenna, St-4; Bellem and St-5; Orxy) in 2009.

Field studies were conducted during two growing seasons (2009-2010 and 2010-2011) in Samsun, Turkey (41° 13' N, 36° 30' E). The soil of the study area was neutral (pH 6.8), clay loam, medium in phosphorus (92 mg $kg^{-1}$), rich in potassium (384 mg $kg^{-1}$), with 1.99% organic matter content. The monthly total precipitation and average temperature for growing season (November through September) were 810 mm and 12.7 °C in 2009-2010, 870 mm and 11.4 °C in 2010-2011. Long-term average total precipitation and temperature of this period were 601 mm and 11.5 °C, respectively.

The study was carried out in a randomized complete block design with three replications. The amount of seed was 20 kg ha$^{-1}$. Each plot consisted of six rows, 4 m in length. The row spacing was 20 cm. The annual ryegrass lines and cultivars were sown by hand in November. The plots were harvested three times (on May 27, June 26, and September 3 in 2010, and on May 26, June 22, and September 5 in 2011) to determine dry matter yield at the 50% flowering stage. After drying for 48 hours at 70 $^{o}$C, the weighed samples were passed through a 1 mm sieve and crude protein content was measured by the Kjeldahl method (AOAC 1990). Acid detergent fiber (ADF) and neutral detergent fiber (NDF) concentrations were determined by using the standard laboratory procedures of Ankom Technology (ANKOM 2005). The total digestible nutrient (TDN) content and the relative feed value (RFV) were calculated according to the methods of Moore & Undersander (2002). The total digestible nutrient yield (TDNY) was calculated by multiplying dry matter yield (DMY) with the TDN value. All data were subjected to analysis of variance using SAS (SAS 1998) and differences between means were compared using Duncan's test at the 0.05 probability level (Steel & Torrie 1997).

## 3. Results and Discussion

### *3.1. Dry matter yield, crude protein content and yield*

Annual ryegrass lines differed (P≤0.01) consistently in dry matter yield (Table 1). Dry matter yield (DMY) varied from 5.36 to 9.18 t ha$^{-1}$ in 2010 and from 5.58 to 10.52 t ha$^{-1}$ in 2011. The average value of dry matter yield (8.25 t ha$^{-1}$) in 2011 was higher than in 2010 (7.12 t ha$^{-1}$). This was due to the fact that the total precipitation in 2011 was higher

**Table 1- Dry mater yields, crude protein contents and crude protein yields of annual ryegrass lines**

*Çizelge 1- Tek yıllık çim hatlarının kuru madde verimleri, ham protein oranları ve ham protein verimleri*

| *Lines* | *DMY (t ha$^{-1}$)* | | | *CP (%)* | | | *CPY (t ha$^{-1}$)* | | |
|---|---|---|---|---|---|---|---|---|---|
| | *2010* | *2011* | *Mean* | *2010* | *2011* | *Mean* | *2010* | *2011* | *Mean* |
| 1 | 6.40 c-f* | 8.32b-e | 7.36 cde | 14.36 | 12.43 | 13.40 ab | 0.91 a-e | 1.03 b-e | 0.97 bcd |
| 2 | 5.93 ef | 8.25 cde | 7.09 de | 13.88 | 13.42 | 13.65 a | 0.82 cde | 1.10 a-d | 0.96 bcd |
| 3 | 5.36 f | 8.38 b-e | 6.87 de | 12.16 | 11.55 | 11.86 bc | 0.64 e | 0.96 b-f | 0.80 d |
| 4 | 8.24 ab | 10.50 a | 9.37 a | 13.52 | 11.94 | 12.73 abc | 1.11 ab | 1.25 ab | 1.18 a |
| 5 | 6.74 b-f | 9.60 ab | 8.17 bc | 12.13 | 13.49 | 12.81 abc | 0.83 b-e | 1.29 a | 1.06 ab |
| 6 | 7.99 abc | 10.52 a | 9.25 a | 11.68 | 11.23 | 11.46 c | 0.93 a-d | 1.18 abc | 1.05 ab |
| 7 | 6.25 def | 9.39 a-d | 7.82 bcd | 11.56 | 11.46 | 11.51 c | 0.72 de | 1.07 a-d | 0.89 bcd |
| 8 | 6.27 def | 9.51 abc | 7.89 bcd | 12.21 | 10.89 | 11.55 c | 0.76 cde | 1.03 b-e | 0.89 bcd |
| 9 | 7.64 a-d | 8.64 b-e | 8.14 bc | 12.13 | 11.59 | 11.86 bc | 0.92 a-d | 1.00 b-f | 0.96 bcd |
| 10 | 9.18 a | 8.36 b-e | 8.77 ab | 12.50 | 11.24 | 11.87 bc | 1.14 a | 0.94 c-h | 1.04 abc |
| 11 | 7.95 abc | 8.68 bcd | 8.32 bc | 12.26 | 13.03 | 12.65 abc | 0.97 a-d | 1.13 a-d | 1.05 abc |
| 12 | 6.01 ef | 7.36 efg | 6.69 e | 13.64 | 11.84 | 12.74abc | 0.81 cde | 0.87 d-h | 0.84 d |
| 13 | 6.89 b-f | 7.00 fg | 6.95 de | 13.62 | 11.30 | 12.46 abc | 0.94 a-d | 0.79 e-h | 0.86 dc |
| 14 | 7.86 a-d | 5.58 h | 6.72 e | 12.02 | 13.23 | 12.63 abc | 0.95 a-d | 0.74 gh | 0.84 d |
| St-1 | 6.94 b-f | 6.38 gh | 6.66 e | 13.52 | 11.07 | 12.29 abc | 0.93 a-d | 0.70 h | 0.82 d |
| St-2 | 7.67 a-d | 6.98 fg | 7.33 cde | 12.04 | 11.15 | 11.60 c | 0.91 a-e | 0.77 fgh | 0.84 d |
| St-3 | 8.23 ab | 6.35 gh | 7.29 cde | 12.02 | 11.09 | 11.56 c | 0.98 a-d | 0.71 gh | 0.85 d |
| St-4 | 7.27 bcd | 8.08 de | 7.67 cde | 14.18 | 13.43 | 13.81 a | 1.03 abc | 1.08 a-d | 1.05 ab |
| St-5 | 6.49 cef | 8.81 bcd | 7.65 cde | 11.65 | 12.43 | 11.77 bc | 0.75 cde | 1.04 a-e | 0.90 bcd |
| Mean | 7.12 B+ | 8.25 A | 7.68 | 12.69 A | 11.96 B | 12.33 | 0.90 B | 0.98 A | 0.94 |
| CV (%) | 11.77 | 8.31 | 9.96 | 10.20 | 9.65 | 9.95 | 15.85 | 13.50 | 14.63 |

*, means followed by the same letter in a column are not significantly different according to the Duncan test at the P≤0.05 level; +, overall means followed by the same capital letter are not significantly different at the P≤0.05 level

than in 2010. The increase in the total amount of precipitation had a positive effect on DMY. Based on the average of two years, DMY varied from 6.66 to 9.37 t $ha^1$, and high values were determined for line 4 (9.37 t $ha^{-1}$), line 6 (9.25 t $ha^{-1}$), and line 10 (8.77 t $ha^{-1}$). Higher values of DMY were obtained from line 10, 4, St-3, 6, 11, 14, St-2 and 9 than the other lines in 2010. In the second year of the study, line 6, 4, 5, 8 and 7 provided higher values of DMY than the others. Although Line 10 and 4 were in the same statistical groups in the first year of the study, these lines were categorized in different groups in the second year of the study. So, the effects of years on lines were different in both years and year x line interaction was found statistically significant (P≤0.01).

Marais & Goodenough (2000) obtained 12.6 t $ha^{-1}$ DMY from annual ryegrass. Redfearn et al (2005) reported that DMY in annual ryegrass was 7.8-11.9 t $ha^{-1}$. Butler et al (2007) found that DMY of annual ryegrass was 4.55-10.51 t $ha^{-1}$. The dry matter yield obtained in this study was lower than values reported by Marais & Goodenough (2000). These discrepancies likely resulted from differences in ecological conditions and genotypes. Dry matter yields obtained in the current study were within the range of values reported by Redfearn et al (2005) and Butler et al (2007), although the ecological conditions and cultivars or lines examined were different. According to our results, there were significant differences between annual ryegrass cultivars and lines. Our findings were different from Redfearn et al (2002) in this regard because they argued that there were no differences between dry matter yields of annual ryegrass varieties.

There were no statistically significant differences among the crude protein contents in both years of the study, and the year x line interaction was statistically insignificant (Table 1). Crude protein (CP) content varied from 11.56 to 14.36% in 2010 and from 10.89 to 13.49% in 2011. The average CP content in the first year of the study, which was determined as 12.69%, was higher than the average CP content in the second year (11.96%) of the study (P≤0.01). A statistically significant difference (P≤0.01) was found between two-year average CP ratios of lines and standard cultivars. According to the two-year averages, higher values of CP content were obtained from lines St-4, 2, 1, 5, 12, 4, 11, 14, 13, and St-1 (12.29-13.81%) than the others. CP contents ranging from 13.4 to 17.4% have been reported by others (Meissner 1996; Johnston & Bowman 1998; Ferret et al 1999; Tran et al 2009). Sürmen et al (2013) expressed that the quality of forage might be altered due to differences in temperature and precipitation.

Effects of year, line, and year x line interactions on crude protein yield (CPY) were significant (Table 1). Crude protein yields for lines were 0.64-1.14 t $ha^{-1}$, 0.70-1.29 t $ha^{-1}$ and 0.80-1.18 t $ha^{-1}$ in 2010, 2011 and as the average, respectively. The average value of CPY (0.98 t $ha^{-1}$) in 2011 was higher than in 2010 (0.90 t $ha^{-1}$). In 2011, the increase in dry matter yield due to greater rainfall had a positive effect on crude protein yield, being related to CP content and DMY (Albayrak & Güler 2005). Based on the averaged values over two years, higher values of CPY were obtained from lines 4, 5, St-4, 6, 11, and 10 (1.04-1.18 t $ha^{-1}$) than the others. The lines in the same statistical groups in the first year of the study (e.g. lines 4 and 10) were categorized in different groups in the second year of the study, as the effects of years on lines were statistically different in both years indicating significant year x line interaction (P≤0.01).

### *3.2. Acid detergent fiber and neutral detergent fiber contents*

Lower ADF values were obtained from lines 12, 4, 7, 3, 10, 1, St-5, 13, St-1 and 9 (30.62-32.72%) in the first year (P≤0.05), although there were no statistical differences among the annual ryegrass lines (30.95-36.63%) in the second year (Table 2). There was a statistically significant difference between the two-year averages of ADF ratios (P≤0.05). The average ADF value (32.61%) in 2010 was lower than the average ADF value (34.59%) in 2011 (P≤0.01). According to the two-year average, lower ADF contents were determined for line 1, St-5, 4, 3, 2, 12, 5, 10, 7, and 8 than the other lines.

**Table 2- Acid detergent fiber and neutral detergent fiber contents of annual ryegrass lines**

*Çizelge 2- Tek yıllık çim hatlarının asit deterjan lif ve nötral deterjan lif içerikleri*

| *Lines* | *ADF (%)* | | | *NDF (%)* | | |
|---|---|---|---|---|---|---|
| | *2010* | *2011* | *Mean* | *2010* | *2011* | *Mean* |
| 1 | 31.87 a-e* | 30.95 | 31.41 c | 49.32 b-e | 48.22 | 48.77 d |
| 2 | 33.08 a-d | 32.99 | 33.04 abc | 49.90 bcd | 53.66 | 51.78 ab |
| 3 | 31.58 b-e | 33.28 | 32.43 bc | 49.72 bcd | 54.14 | 51.93 ab |
| 4 | 31.17 de | 33.54 | 32.36 bc | 50.22 bc | 52.81 | 51.52 abc |
| 5 | 33.75 ab | 32.71 | 33.23 abc | 51.67 ab | 51.88 | 51.77 ab |
| 6 | 33.26 a-d | 35.70 | 34.48 ab | 52.96 a | 52.65 | 52.80 a |
| 7 | 31.44 cde | 35.14 | 33.29 abc | 49.46 b-e | 51.88 | 50.67 a-d |
| 8 | 33.12 a-d | 33.95 | 33.54 abc | 49.47 b-e | 51.64 | 50.56 a-d |
| 9 | 32.72 a-e | 34.94 | 33.83 ab | 47.46 de | 52.94 | 50.20 bcd |
| 10 | 31.69 b-e | 34.83 | 33.26 abc | 46.96 e | 52.07 | 49.52 bcd |
| 11 | 34.00 a | 34.56 | 34.28 ab | 50.25 bc | 52.40 | 51.33 abc |
| 12 | 30.62 e | 35.78 | 33.20 abc | 49.24 b-e | 51.65 | 50.45 a-d |
| 13 | 32.03 a-e | 35.21 | 33.62 ab | 48.63 cde | 49.80 | 49.22 cd |
| 14 | 33.00 a-d | 36.49 | 34.75 a | 49.36 b-e | 51.03 | 50.20 bcd |
| St-1 | 32.06 a-e | 36.63 | 34.35 ab | 48.93 cde | 49.33 | 49.13 cd |
| St-2 | 33.37 a-d | 34.72 | 34.04 ab | 50.05 bcd | 51.79 | 50.92 a-d |
| St-3 | 33.68 abc | 35.35 | 34.51 ab | 51.02 abc | 51.50 | 51.26 abc |
| St-4 | 33.46 abc | 35.54 | 34.50 ab | 51.12 abc | 49.01 | 50.07 bcd |
| St-5 | 31.87 a-e | 30.95 | 31.41 c | 49.31 b-e | 48.22 | 48.77 d |
| Mean | 32.61 B+ | 34.59 A | 33.60 | 49.82B | 51.53 A | 50.67 |
| CV (%) | 3.49 | 5.75 | 4.83 | 2.72 | 3.97 | 3.42 |

*, means followed by the same letter in a column are not significantly different according to the Duncan test at the P≤0.05 level; +, overall means followed by the same capital letter are not significantly different at the P≤0.05 level

The differences among NDF values of accessions in the first year and averaged values of NDF over two years were statistically significant (P≤0.01), but effects of this factor on the NDF content in the second year was not statistically significant. (Table 2). Low NDF contents in 2010 were achieved in lines 10, 9, 13, St-1, 12, St-5, 1, 14, 7 and 8, while NDF contents in 2011 ranged from 48.22 to 54.14%. According to the averaged values over two years, lines 1, St-5, St-1, 13, 10, St-4, 9, 14, 12, 8, 7 and St-2 had low NDF content. The year x line interaction was statistically significant (P≤0.05). Line 10 placed in the group of low NDF values in 2010, although no significant differences existed between lines in 2011, this line showed a high NDF content in the second year.

It was reported that ADF contents of annual ryegrass ranged from 30.3 to 39.9% and NDF from 43.1 to 60.6% (Meissner 1996; Johnston & Bowman 1998; Ferret et al 1999; Tran et al 2009). The ADF and NDF contents of annual ryegrasses in present study were similar to results other studies.

### *3.3. Total digestible nutrient content, total digestible nutrient yield, and relative feed value*

Effects of the lines on the TDN content in 2010 and in the combined analysis of two years were statistically significant while TDN content values of the lines in 2011 were not statistically significant different from each other (Table 3). The total digestible nutrient contents for lines were determined between 57.45 and 61.81% in 2010. In the first year of the study, lines 12, 4, 7, 3, 10, 1, 13, St-2 and 9 were in the same statistical group with higher TDN values in the first year of the study. The total digestible nutrient values in the second year varied between 54.06 and 61.40%. The average value of the first year (59.25%) was significantly higher (P≤0.01) than that of the second year (556.69%). Based on the average of two years, higher TDN contents were determined for line 1, 4, 3, 2, 12, 5, 10, 7, and 8 than the other lines. The TDN refers to the nutrients available for livestock and is related to the ADF concentration of the forage. In our study, significant differences were found among annual ryegrass cultivars and lines in digestibility. However, Redfearn et al (2002) reported that there were not any significant differences in digestibility of annual ryegrass varieties. Our results differed from findings of Redfearn et al (2002) in this aspect.

The differences among the total digestible nutrient yield (TDNY) values of the lines and cultivars were statistically significant (P≤0.01) (Table 3). The total digestible nutrient yields varied from 324.54 to 554.49 t ha$^{-1}$ in 2010 and from 312.49 to 609.74t ha$^{-1}$ in 2011. Average TDNY (468.49 t ha$^{-1}$) in the second year of the study was higher than average TDNY (421.67 t ha$^{-1}$) in the first year (P≤0.01). According to the averaged values over two years, TDNY varied from 376.35 to 556.42 t ha$^{-1}$ (P≤0.01) and the higher TDNY values were obtained from lines 4, 6, and 10 than the others. The first statistical group consisted of 4,

**Table 3- Total digestible nutrient content, total digestible nutrient yield, and relative feed value of annual ryegrass lines**

*Çizelge 3- Tek yıllık çim hatlarının toplam sindirilebilir besin oranları, toplam sindirilebilir besin verimleri ve nispi yem değerleri*

| *Lines* | *TDN (%)* | | | *TDNY (t ha$^{-1}$)* | | | *RFV (%)* | | |
|---|---|---|---|---|---|---|---|---|---|
| | *2010* | *2011* | *Mean* | *2010* | *2011* | *Mean* | *2010* | *2011* | *Mean* |
| 1 | 60.20 a-e* | 61.40 | 60.80 a | 384.81 cde | 509.49 bcd | 447.15 c-h | 120.67 bcd | 125.00 | 122.83 a |
| 2 | 58.65 b-e | 58.75 | 58.70 abc | 347.32 e | 485.85 b-e | 416.59 d-ı | 118.00 c-g | 109.67 | 113.83 bc |
| 3 | 60.59 a-d | 58.39 | 59.49 ab | 324.54 e | 489.36 b-e | 406.95 e-ı | 120.33 b-e | 108.33 | 114.33 bc |
| 4 | 61.11 ab | 58.05 | 59.58 ab | 503.10 ab | 609.74 a | 556.42 a | 119.67 b-f | 110.67 | 115.17 bc |
| 5 | 57.77 de | 59.12 | 58.45 abc | 391.23 cde | 567.50 ab | 479.37 bcd | 113.00 h | 114.00 | 113.50 bc |
| 6 | 58.41 b-e | 55.26 | 56.84 bc | 466.55 a-d | 581.29 ab | 523.92 ab | 110.67 h | 108.00 | 109.33 c |
| 7 | 60.76 abc | 55.99 | 58.37 abc | 379.88 cde | 525.96 a-d | 452.92 c-h | 121.33 a-d | 110.33 | 115.83 b |
| 8 | 58.60 b-e | 57.51 | 58.06 abc | 366.93 de | 547.30 abc | 457.12 c-g | 118.33 c-g | 112.67 | 115.50 bc |
| 9 | 59.11 a-e | 56.25 | 57.68 bc | 451.77 bcd | 486.77 b-e | 469.27 b-f | 124.67 ab | 108.67 | 116.67 b |
| 10 | 60.44 a-d | 56.39 | 58.42 abc | 554.49 a | 471.45 c-f | 512.97 abc | 127.33 a | 110.67 | 119.00 ab |
| 11 | 57.45 e | 56.73 | 57.09 bc | 456.83 bcd | 491.73 b-e | 474.28 b-e | 115.67 d-h | 110.00 | 112.83 bc |
| 12 | 61.81 a | 55.17 | 58.49 abc | 371.45 de | 405.67 e-h | 388.56 ghı | 123.00 abc | 110.00 | 116.50 b |
| 13 | 59.99 a-e | 55.89 | 57.94 bc | 414.36 b-e | 393.40 f-ı | 403.88 f-ı | 122.33 abc | 115.00 | 118.67 ab |
| 14 | 57.92 cde | 56.22 | 57.07 bc | 455.86 bcd | 312.49 ı | 384.18 hı | 114.33 e-h | 113.67 | 114.00 bc |
| St-1 | 58.74 b-e | 54.25 | 56.49 c | 406.96 b-e | 345.75 hı | 376.35 ı | 119.00 b-g | 110.33 | 114.67 bc |
| St-2 | 59.96 a-e | 54.06 | 57.01 bc | 459.22 bcd | 377.49 ghı | 418.35 d-ı | 121.33 a-d | 114.00 | 117.67 ab |
| St-3 | 58.27 b-e | 56.53 | 57.40 bc | 479.24 abc | 359.93 ghı | 419.59 d-ı | 117.00 c-g | 111.33 | 114.17 bc |
| St-4 | 57.87 cde | 55.72 | 56.79 bc | 419.93 b-e | 450.73 d-g | 435.33 d-ı | 114.33 e-h | 111.00 | 112.67 bc |
| St-5 | 58.16 cde | 55.46 | 56.81 bc | 377.26 de | 489.50 b-e | 433.38 d-ı | 114.00 fgh | 125.00 | 115.00 bc |
| Mean | 59.25 A+ | 56.69 B | 57.97 | 421.67 B | 468.49 A | 445.08 | 118.68 A | 112.07 B | 115.38 |
| CV(%) | 2.48 | 4.53 | 3.61 | 12.11 | 10.57 | 11.30 | 2.71 | 5.04 | 3.98 |

*, means followed by the same letter in a column are not significantly different according to the Duncan test at the P≤0.05 level; +, overall means followed by the same capital letter are not significantly different at the P≤0.05 level

6, 10 and St-3 lines in the first year, while 4, 5, 6, 7, and 8 lines occurred in the first group in the second year. The effects of years on lines were different in both years and therefore, year x line interaction was statistically significant (P≤0.01).

In 2010, the differences among the RFV values (127.33-110.67%) were statistically significant and higher values of RFV were obtained from lines 10, 9, 12, 13, 7, and St-2 than the others (Table 3). In the second year of the study, the differences among the RFV values were insignificant and they ranged from 108.00 to 125.00%. The average RFV value of the first year (118.68%) was significantly higher than that of the second year (112.07%) (P≤0.01). According to the results of the combined analysis of two years data, higher average values of RFV were obtained from lines 1, 10, 13 and St-2 compared to the others. The effects of the years on lines caused a statistically significant year x line interaction (P≤0.01). As a matter of fact, in 2010, the differences of RFV values among the lines were statistically significant. However, there was no statistical difference recorded in 2011.

RFV values of forages are classified by Kapper (2004) as prime (higher than 151%), premium (150-125%), good (124-103%), fair (102-87%), poor (86-75%), and rejected (less than 75%). Based on the average of the two years, the annual ryegrass lines had relative feed values ranging from 109.33 to 122.83 and they can be categorized as good quality (Table 3).

## 4. Conclusions

In this study, fourteen annual ryegrass lines were compared with five standard varieties for yield and quality characteristics. Present results indicated that some of the lines had similar or superior yield and quality characteristics than standard varieties. Therefore, lines 4, 5, 6, 10, and 11 were selected for further regional yield assessments due to their high dry matter yield, crude protein yield, digestible nutrient content, and digestible nutrient yield capacities. Some of these candidate lines may be registered as cultivars for Black Sea region in the near future.

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# Yaygın Fiğ-Tahıl Karışımlarında Ot Verimi, Bazı Kalite Özellikleri ve Rekabetin Belirlenmesi

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**ÖZET**

Yaygın fiğ (*Vicia sativa* L.) yalın ekildiğinde, bitkiler çiçeklenmeden sonra yatmaktadır. Bu yüzden genellikle tahıllarla birlikte ekilir. Karışımda kullanılan türler ve ekim oranı, türler arasındaki rekabetten dolayı karışımın ot verimini etkilemektedir. Araştırma, yaygın fiğ ile tritikale ve yulaf karışımlarının ot verimi, kalite ve türler arasındaki rekabeti belirlemek amacıyla 2 yıl süreyle Doğu Karadeniz Bölgesi koşullarında (Ordu) yürütülmüştür. Türler arasındaki rekabeti belirlemek için agresivite, rekabet oranı ve LER değeri kullanılmıştır. Türler yalın olarak ve 3 farklı yaygın fiğ-tahıl karışımı (sırasıyla 75:25, 50:50 ve 25:75) olarak sonbaharda ekilmiştir. Hasat, fiğde alt baklaların dolum döneminde yapılmıştır. Bu dönemde tritikale çiçeklenme yulaf ise süt olum döneminde olmuştur. Araştırma sonucunda karışımların kuru ot, ham protein ve sindirilebilir kuru madde verimleri her iki yılda da yalın ekimlerden üstün bulunmuştur. Bununla birlikte karışımların verimleri yıllara göre değişkenlik göstermiş, ancak 50:50 tritikale-fiğ karışımı diğer karışımlara göre daha stabil bir verim sağlamıştır. Agresivite ve rekabet oranı değerleri, sonbahar ve kış yağışlı geçtiğinde tahılların yaygın fiğe göre daha rekabetçi olduğunu göstermiştir. Tüm yaygın fiğ-tahıl karışımları, yalın ekimlerden üstün (LER> 1) olmuş, fakat 50:50 yaygın fiğ-tritikale veya yulaf karışımlarının (LER= 1.4) en yüksek yararı sağladığı belirlenmiştir. Bu nedenle 50:50 yaygın fiğ-tritikale veya yulaf karışımları benzer bölgeler için tavsiye edilebilir bulunmuştur.

Anahtar Kelimeler: Rekabet; Kuru ot; Karışım; Yulaf; Tritikale; Fiğ

# Determination of Forage Yield, Some Quality Properties and Competition in Common Vetch-Cereal Mixtures

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**ABSTRACT**

Common vetch (*Vicia sativa* L.) plant is lodged after flowering when planted alone, thus, it is generally sown with cereals. Species used in mixture and seeding ratio in the mixture affect hay yield due to competition between crops.

A two year field study was conducted to determine the effects of mixture common vetch with oat and triticale on hay yield, quality and competition between the species in Eastern Black Sea Region (Ordu). Aggressivity, competitive ratio and LER were used to assess competition between mixture component. Species was sown monocrops and in common vetch-cereal mixture in three seeding ratios (75:25, 50:50, 25:75, respectively). The plots were harvested vetch was at the lowest pod filling stage, at that time triticale was at flowering and oat was at milk-dough stage. The results of the study showed that hay, crude protein and digestible dry matter yield of mixtures were higher than monocrops. Additionally, yield of mixtures changed with year, but, 50:50 triticale: vetch had more stable yield. Furthermore, A and CR values indicated cereals were more competitive than common vetch when it was rainy in fall and winter. All common vetch- cereal intercrops have yield advantage (LER> 1), but, sowing 50:50 mixtures of common vetch: triticale or oat (LER= 1.4) were found to be the most profitable. 50:50 mixtures of common vetch: triticale or oat should be suggested in similar regions.

Keywords: Competition; Hay; Intercrop; Oat; Triticale; Vetch



## 1. Giriş

Birçok yem bitkisi türünün rahatlıkla yetiştirilebileceği ülkemizde, ekim nöbeti planlamalarının yapılmaması, çiftçilerimizin yem bitkileri tarımında modern teknikleri bilmemeleri ve işletmelerin genellikle küçük ve parçalı olması vb. faktörlerden dolayı, tarla tarımı içerisinde çok yıllık yem bitkileri türlerine çok fazla yer verilememekte, çiftçilerimiz daha çok tek yıllık yem bitkilerini tercih etmektedir. Ülkemizde yaklaşık 500000 ha alanda fiğ yetiştirilmektedir (TÜİK 2014). Fiğler protein, mineral maddeler ve vitaminler bakımından oldukça zengin olduğundan, yoğun hayvancılığın kaba yem gereksiniminin karşılanmasında önemli bir yere sahiptir (Kuşvuran et al 2011). Fiğler içinde de yaygın fiğ ön plana çıkmaktadır. Yaygın fiğ serin mevsim yem bitkisi ve tek yıllık olması nedeniyle, özellikle sahil bölgelerimizde kışlık ara ürün olarak yetiştirilmektedir. Böylece çiftçi ana ürün deseninde değişiklik yapmadan, üretime yem bitkilerini dâhil edebilmektedir.

Yaygın fiğ yetiştiriciliğinde çiçeklenmeden sonraki dönemde gövdenin yatması önemli bir problemdir. Bu sebepten fiğler genellikle tahıllarla karışık olarak ekilmektedir. Karışık ekimde çevresel kaynaklar daha etkili kullanılabilmekte ve yalın ekime göre daha üstün verim elde edilebilmektedir (Lithourgidis et al 2011a). Ayrıca karışımdan elde edilen yemin protein/karbonhidrat oranı daha dengeli olmaktadır (Tuna & Orak 2007). Ancak karışık ekimlerde tür içi ve türler arasında su, ışık ve besin maddesi yönünden rekabet söz konusudur. Bu nedenle karışık ekimden beklenen yararın sağlanabilmesi için uygun bitki türleri ve çeşitlerini (Lithourgidis et al 2011a) ve en uygun karışım oranını belirlemek (Erol et al 2009; Atis et al 2012; Dordas et al 2012; Uzun & Aşık 2012) gerekmektedir. Bu çalışma, yaygın fiğ-tahıl karışımlarının ot verimi ve bazı kalite özelliklerini belirlemek ve karışımda yer alan türler arasındaki rekabeti incelemek amacıyla yürütülmüştür.

## 2. Materyal ve Yöntem

Araştırma, Ordu Üniversitesi Ziraat Fakültesi Deneme alanında (40º 58´ N, 37º 56´ E, 5 m rakım), 2012-2013 ve 2013-2014 yetiştirme sezonlarında yürütülmüştür. Deneme yerlerinden 0-30 cm derinlikten alınan toprak örneklerine ait analiz sonuçları incelendiğinde her iki yılda da araştırma alanı toprağının killi-tınlı bünyede, potasyumca zengin (430 ve 930 kg $K_2O$ $ha^{-1}$), fosforca fakir (55.3 ve 20.8 kg $P_2O_5$ $ha^{-1}$) ve kireçsiz olduğu belirlenmiştir. Ayrıca 1. yıl deneme alanı toprağı organik madde bakımından zengin iken (% 3.88), 2. yıl orta seviyede (% 2.25) bulunmuştur. Toprak reaksiyonu ise sırasıyla; hafif asit (6.7) ve hafif alkali (7.9) olarak belirlenmiştir

Denemenin yürütüldüğü 2012-2013 yetiştirme sezonunda toplam 643.8 mm, 2013-2014 yetiştirme sezonunda ise toplam 392.2 mm yağış düşmüştür. 2.

yetiştirme sezonunda özellikle tahılların kardeşlenme dönemleri olan ocak ve şubat ayları ilk yıla göre oldukça kurak geçmiştir. Vejetasyon süresinde düşen toplam yağış miktarı uzun yıllar ortalamasıyla karşılaştırıldığında, ilk yılın daha yağışlı ikinci yılın ise oldukça kurak geçtiği görülmektedir. Bununla birlikte her iki dönem de uzun yıllar ortalamasına göre daha sıcak geçmiştir. Aylık ortalama oransal nem değerlerinin 2012-2013 yetiştirme sezonunda uzun yıllar ortalamasına benzerlik gösterdiği, 2013-2014 yetiştirme sezonunda ise uzun yıllar ortalamasına göre daha düşük olduğu görülmektedir (Çizelge 1).

Araştırmada yaygın fiğ (*Vicia sativa* L.*)*'in Albayrak çeşidi, tritikale (*Triticosecale wittmark*)'nin Tatlıcak 97 çeşidi ve yulaf (*Avena sativa* L.)'ın Sarı çeşidi kullanılmıştır. Denemeler, tesadüf blokları deneme desenine göre 3 tekrarlamalı olarak kurulmuş ve parsellerde 4 m boyunda, 20 cm sıra aralığında, 8 sıra yer almıştır. Denemede yalın yaygın fiğ, tritikale ve yulaf parsellerinin yanında, yaygın fiğ-tahıl karışımları (sırasıyla 75:25, 50:50, 25:75) ekilmiştir. Bu durumda denemede toplam 9 işlem yer almıştır. Ekim ilk yıl sonbahar yağışlarından dolayı 22 Kasım 2012, 2. yıl ise 1 Kasım 2013 tarihinde elle yapılmıştır. Yalın ekimde, yaygın fiğ 200 tohum $m^{-2}$ (Yücel et al 2006), yulaf 500 tohum $m^{-2}$ (Kahraman et al 2012) ve tritikale ise 500 tohum $m^{-2}$ (Mut et al 2006) canlı tohum olacak şekilde ekilmiştir. Karışımlarda kullanılacak tohumluk miktarı, yalın ekimde kullanılacak tohumluk miktarı ile karışım oranı dikkate alınarak hesaplanmıştır. Karışık ekimde tohumlar aynı sıraya ekilmiştir. Her iki yılda da ekimden önce 45 kg N $ha^{-1}$ olacak şekilde azotlu gübreleme yapılmıştır (Aydın & Tosun 1993; Tan & Serin 1995). Fosforlu gübreleme ise ilk yıl 60 kg $P_2O_5$ $ha^{-1}$, 2. yıl 100 kg $P_2O_5$ $ha^{-1}$ olacak şekilde yapılmıştır. Deneme alanında görülen yabancı otlar her iki yılda da çapalanarak yok edilmiştir. Her iki yılda da sulama yapılmamıştır. Parsellerin yanlarından birer sıra ve başlarından 50 cm kenar tesiri bırakıldıktan sonra, fiğlerde alt baklaların dolduğu dönemde 1. yıl 17 Mayıs, 2. yıl ise 10 Mayıs'ta ot hasadı yapılmıştır. Hasat zamanında tritikalenin çiçeklenme, yulafın ise süt olum döneminde olduğu belirlenmiştir. Her parselde biçilen yeşil ot, fiğ ve tahıl olmak üzere türlere ayrılarak tartılmış ve her bir tür için bulunan sonuç dekara çevrilerek yeşil ot verimleri belirlenmiştir. Ardından bileşenlerine ayrılan yeşil ottan her tür için 0.5 kg yeşil ot alınmış ve örnekler 70 $^oC$'de sabit ağırlığa ulaşıncaya kadar kurutularak örneklerin kuru ot oranları belirlenmiştir. Her bitki türünde belirlenen yeşil ot verimi ile kuru ot oranı çarpılarak türlerin kuru ot verimi hesaplanmıştır. Belirlenen kuru ot verimlerinin toplanmasıyla dekara kuru ot verimi bulunmuştur. Her parselden ayrı ayrı alınan fiğ ve tahıl örneklerinin ADF, NDF ve ham protein oranı Foss Nır Sytems Model 6500 Win ISI II v 1.5 cihazında IC-0904FE kalibrasyon

**Çizelge 1- Ordu iline ait bazı iklim faktörleri**

*Table 1- Some climatic properties in Ordu*

| *Aylar** | *Ortalama sıcaklık (°C)* | | | *Toplam yağış (mm)* | | | *Ortalama oransal nem (%)* | | |
|---|---|---|---|---|---|---|---|---|---|
| | *2012-2013* | *2013-2014* | *UYO* | *2012-2013* | *2013-2014* | *UYO* | *2012-2013* | *2013-2014* | *UYO* |
| Kasım | 15.4 | 12.1 | 11.8 | 201.3 | 47.0 | 123.7 | 74.2 | 62.0 | 71.1 |
| Aralık | 10.7 | 6.4 | 8.8 | 138.8 | 175.1 | 113.6 | 68.4 | 59.1 | 68.2 |
| Ocak | 9.4 | 9.5 | 6.7 | 112.6 | 20.2 | 98.9 | 63.7 | 65.7 | 68.3 |
| Şubat | 10.2 | 9.1 | 6.7 | 52.3 | 14.5 | 82.0 | 68.8 | 63.5 | 69.8 |
| Mart | 11.1 | 11.4 | 8.0 | 90.0 | 81.1 | 79.7 | 65.4 | 67.3 | 73.9 |
| Nisan | 13.0 | 12.7 | 11.4 | 21.9 | 20.4 | 69.2 | 72.4 | 69.8 | 76.2 |
| Mayıs | 17.9 | 16.0 | 15.7 | 26.9 | 33.9 | 53.9 | 73.1 | 75.1 | 77.1 |
| Ort./Top. | 12.5 | 11.0 | 9.8 | 643.8 | 392.2 | 621 | 69.4 | 66.0 | 72.0 |

*, veriler Ordu Meteoroloji İstasyon Müdürlüğü'nden alınmıştır; UYO, uzun yıllar ortalaması

programı kullanılarak belirlenmiş ve karışımlarda tartılı oranları hesaplanmıştır. Her bir parsel için belirlenen ham protein oranı ile kuru ot verimlerinin çarpımı sonucu ham protein verimi elde edilmiştir. Ot örneklerinde belirlenen ADF oranları üzerinden sindirilebilir kuru madde miktarı (%) Eşitlik 1 ile hesaplanmış (Horrocks & Vallentine 1999), elde edilen değer ile kuru ot verimi çarpılarak sindirilebilir kuru madde verimi (SKMV) belirlenmiştir.

Sindirilebilir kuru madde miktarı (SKM, %)= 88.9 - (0.779 x % *ADF*) (1)

Bununla birlikte bitkiler arasındaki rekabeti belirlemek amacıyla aşağıda belirtilen özellikler de incelenmiştir.

Karışık ekimde birim alandan elde edilen verimin, bitkiler yalın yetiştirildiğinde de alınabilmesi için gerekli alan miktarını gösteren Alan Eşdeğerlik Oranı (LER) değeri Eşitlik 2, 3 ve 4'e göre hesaplanmıştır (Kızılşimşek & Erol 2000).

$$LER=(LERf+LERt) \quad (2)$$

$$LERf = \frac{Yfc}{Yf} \quad (3)$$

$$LERt = \frac{Ytv}{Yt} \quad (4)$$

Burada; *Yf* ve *Yt*, sırasıyla yaygın fiğ ve tahılın yalın ekim verimleri; *Yfc* ve *Ytv* ise sırasıyla, karışımlarda yaygın fiğ ve tahıl verimlerini ifade etmektedir.

Hesaplama sonucunda elde edilen LER değeri <1 olduğunda karışık ekimin gereksiz, LER= 1 olduğunda karışımın saf ekimden farksız, LER> 1 ise karışık ekimin yalın ekimden üstün olduğu anlaşılmaktadır (Boz 2006).

Karışımlarda türler arasındaki rekabeti belirlemek üzere kullanılan agresivite (A) Eşitlik 5 ve 6'ya ve rekabet oranı (RO) değerleri Eşitlik 7 ve 8'e göre hesaplanmıştır.

$$A_t = \left(\frac{Y_{ti}}{Y_t Z_{ti}}\right) - \left(\frac{Y_{fi}}{Y_f Z_{fi}}\right) \quad (5)$$

$$A_f = \left(\frac{Y_{fi}}{Y_f Z_{fi}}\right) - \left(\frac{Y_{ti}}{Y_t Z_{ti}}\right) \quad (6)$$

Burada; $Z_{ti}$, karışımda tahılın ekim oranı; $Z_{fi}$, ise karışımda yaygın fiğin karışım oranını ifade etmektedir.

Eğer $A_t$= 0 ise, her iki türün eşit rekabet gücüne sahip olduğu, $A_t$ pozitif ise tahılın baskın tür olduğu ve $A_t$ negative ise tahılın baskılanan tür olduğu varsayılmıştır (Dhima et al 2007; Lithourgidis et al 2011b).

$$RO_t = \left(\frac{LER_t}{LER_f}\right)\left(\frac{Z_{fi}}{Z_{ti}}\right) \quad (7)$$

$$RO_f = \left(\frac{LER_f}{LER_t}\right)\left(\frac{Z_{ti}}{Z_{fi}}\right) \quad (8)$$

Araştırmada incelenen tüm özellikler için elde edilen verilere Kolmogorov-Simirnov testi uygulanarak verilerin normal dağılış gösterdiği belirlenmiştir. Ayrıca işlem varyanslarının homojenlik kontrolü ise Levene testi ile yapılmış ve varyansların homojen olduğu belirlenmiştir. Bunun üzerine verilere tesadüf blokları deneme desenine göre yıllar üzerinden birleştirilerek varyans analizi yapılmış ve ortalamalar arasındaki farklar Tukey çoklu karşılaştırma testi kullanılarak değerlendirilmiştir (Gülümser et al 2006). Varyans analizi, Minitab 13.0 istatistik paket programında yapılmıştır.

## 3. Bulgular ve Tartışma

Her iki yılda ekim zamanları ve iklim koşullarının farklı olması (Çizelge 1), çeşitlerin ve karışımların gelişme seyrini ve farklı koşullara tepkilerini değiştirdiğinden, yapılan varyans analizi sonucunda; toplam kuru ot verimi bakımından yıl x işlem interaksiyonu istatistiki olarak (P<0.01) önemli bulunmuştur (Çizelge 2). İkinci yıl tahılların kardeşlenme dönemi olan ocak şubat aylarının oldukça kurak geçmesi (Çizelge 1) tahıllarda kardeşlenmeyi olumsuz etkilemiştir. Ayrıca tahılların vernalizasyon ihtiyacını karşıladıkları dönemde sıcaklık değerlerinin düzensiz olması, tahılların strese girmesi ve sapa kalkma döneminde gecikmelere yol açmıştır. Bununla birlikte ilk yıl deneme arazisi toprağında bulunan organik madde yüksek iken (% 3.88) ikinci yılda orta seviyede (% 2.25) bulunmuştur. Organik madde seviyesinin yüksek olması tahılların gelişimini artırırken fiğlerde aynı etki görülmemektedir. Bunun sonucu olarak ilk yıl yüksek olan organik madde tahıl gelişimine ikinci yıla göre daha fazla katkıda bulunmuş ve tüm bunların etkisi ile her iki yılda tahılların gelişim oranında farklılık görülmüştür. Bu farklılıklar tahılların karışımdaki fiğ bitkisine olan rekabetini de etkilemiş böylece fiğin verimi değişmiş sonuçta işlemlerden elde edilen verimler yıllara göre değişmiştir. Araştırmada en yüksek kuru ot verimi 8713.7 kg $ha^{-1}$ ile 2. yıl 50:50 fiğ-yulaf karışımından elde edilirken, aynı yıl yalın tahıl parselleri ve ilk yıl yalın fiğ parseli hariç, diğer işlemlerin tamamı istatistiki olarak aynı grupta yer almıştır. En düşük kuru ot verimi ise ile 3627.0 kg $ha^{-1}$ ile ilk yıl yalın ekilen fiğ parselinden elde edilmiştir. Her iki yılda da karışımların verimleri yalın tahıllardan yüksek olmuştur. Bununla birlikte karışımlar içerisinde de 50:50 fiğ-tritikale karışımının kuru ot verimi bakımından yıllar itibariyle daha stabil olduğu görülmüş, yalın tritikaleye göre ilk yıl yaklaşık % 26 ikinci yıl ise % 85, yalın fiğe göre ise sırasıyla iki kat ve % 25 daha fazla kuru ot elde edilmiştir (Çizelge 2). Genellikle ekolojik kaynakların etkili kullanılması, simbiyotik olarak bağlanan azotun tahıllara transferi nedeniyle karışık ekilen parsellerin yalın ekimlere göre daha yüksek kuru ot verimine sahip olduğu bilinmektedir (Ledgard 1991). Ancak karışık ekimlerde türler arası ve tür içi rekabetten veya allelopatik etkilerden dolayı karışımda kullanılan türlere ve karışım oranlarına bağlı olarak verim kayıpları olabildiği bildirilmektedir (Lithourgidis et al 2011a). Bu nedenle de farklı ekolojilerde farklı tahıl tür ve karışım oranlarında yetiştirilen yaygın fiğ-tahıl karışımlarından farklı kuru ot verimleri elde edilmiştir. Örneğin; Yılmaz (1997), Hatay koşullarında en yüksek kuru ot verimini 75:25 fiğ-yulaf karışımından, Tuna & Orak (2007), Tekirdağ koşullarında 25:75 fiğ-yulaf karışımından, Erol et al (2009), Kahramanmaraş koşullarında 55:45 fiğ-yulaf karışımından elde ettiklerini bildirmişlerdir. Lithougidis et al (2006), Yunanistan ekolojik koşullarında, yaygın fiğ-tritikale karışımlarından, yaygın fiğ-yulaf karışımlarına göre % 18 daha az verim alındığını bildirilmiştir. Araştırıcıların sonuçlarından farklı olarak bu çalışmada aynı oranda yulaf ve tritikale içeren yaygın fiğ-tahıl karışımlarından birbirine yakın verimler elde edilmiştir.

İkinci yıl elde edilen otun içerisinde fiğ oranının daha yüksek olması (Çizelge 2) ham protein oranı ve ham protein verimi bakımından yıl x işlem interaksiyonunun istatistiki olarak (P<0.01) önemli

**Çizelge 2- Yalın ve farklı karışım oranlarında ekilmiş yaygın fiğ ve tahılların kuru ot verimi (kg $ha^{-1}$)**

*Table 2- Hay yield for monocrops and mixtures of common vetch with cereal in different seeding ratio (kg $ha^{-1}$)*

| *İşlemler* | *Ekim oranı* | *Fiğ* | | *Tahıl* | | *Toplam* | | |
|---|---|---|---|---|---|---|---|---|
| | | *2012-2013* | *2013-2014* | *2012-2013* | *2013-2014* | *2012-2013* | *2013-2014* | *Ort.* |
| Tritikale | 100 | - | - | 6134.9 | 4510.6 | 6134.9$^{a-d*}$ | 4510.6$^{cd}$ | 5322.8 |
| Tritikale:fiğ | 75:25 | 754.0 | 5962.0 | 5674.6 | 1709.8 | 6428.6$^{a-d}$ | 7671.9$^{abc}$ | 7050.3 |
| Tritikale:fiğ | 50:50 | 1333.3 | 7035.3 | 6373.0 | 1308.0 | 7706.3$^{abc}$ | 8343.3$^{a}$ | 8024.8 |
| Tritikale:fiğ | 25:75 | 1992.1 | 5590.9 | 5531.7 | 916.7 | 7523.8$^{abc}$ | 6507.6$^{a-d}$ | 7015.7 |
| Fiğ | 100 | 3627.0 | 6671.3 | - | - | 3627.0$^{d}$ | 6671.3$^{a-d}$ | 5149.2 |
| Yulaf:fiğ | 75:25 | 841.3 | 5658.4 | 6206.3 | 2492.6 | 7047.6$^{a-d}$ | 8151.0$^{ab}$ | 7599.3 |
| Yulaf:fiğ | 50:50 | 1523.8 | 6909.6 | 5373.0 | 1804.1 | 6896.8$^{a-d}$ | 8713.7$^{a}$ | 7805.3 |
| Yulaf:fiğ | 25:75 | 1984.1 | 6615.7 | 4222.2 | 1191.9 | 6206.3$^{a-d}$ | 7807.6$^{abc}$ | 7007.0 |
| Yulaf | 100 | - | - | 6198.4 | 4704.3 | 6198.4$^{a-d}$ | 4704.3$^{bcd}$ | 5451.4 |
| Yıl | | | | | | ** | | |
| İşlem | | | | | | ** | | |
| Yıl x işlem | | | | | | ** | | |

*, aynı harflerle gösterilen ortalamalar arasında 0.01 düzeyinde farklılık yoktur; **, P<0.01

çıkmasına neden olmuştur (Çizelge 3). Baklagiller, tahıllara göre daha fazla ham protein içerirler. Ayrıca tahılların gelişme devresi ham protein oranı üzerine etkilidir (Tan & Serin 1997). Bu çalışmada tiritikale yulafa göre daha erken gelişme döneminde hasat edilmiştir. Bu nedenle her iki yılda da en düşük ham protein oranı yalın yulaf parselinde (sırasıyla % 9.39, % 9.67) belirlenmiştir. En yüksek ham protein oranı ise ikinci yıl yalın fiğde (% 16.93) belirlenirken, aynı yıl 75:25 fiğ-tritikale ve 25:75 fiğ-tritikale parsellerinden elde edilen otun ham protein oranı ile yalın fiğ otunun ham protein oranı arasında istatistiki olarak farklılık bulunmamıştır. Bu durum sözü edilen karışımlardan elde edilen otun içerisinde fiğin yüksek oranda yer almasından kaynaklanmaktadır (Çizelge 2). Karışık ekim parsellerinde fiğ oranının artması genellikle ham protein oranını artırmıştır (Çizelge 3). Aynı zamanda karışık ekim genellikle kuru ot verimini de artmıştır (Çizelge 2). Bunun sonucu olarak elde edilen ham protein verimi artmıştır (Çizelge 3). Araştırma sonucunda en yüksek ham protein verimi (1296.8 kg ha$^{-1}$) ikinci yıl 50:50 fiğ-tritikale parselinden elde edilmesine rağmen, ikinci yıl yalın ekilen tahıl parselleri hariç diğer karışımların tamamı ile 50:50 fiğ-tritikale karışımı arasında istatistiki olarak farklılık bulunmamıştır. En düşük ham protein verimi (448.8 kg ha$^{-1}$) ise aynı yıl yulaf parselinden elde edilmiştir (Çizelge 3).

Yapılan varyans analizi sonucunda, otun ADF ve NDF oranı bakımından işlemler arasında istatistiki olarak önemli (sırasıyla; $P<0.01$ ve $P<0.05$) düzeyde farklılık olduğu belirlenmiştir. Araştırmada en yüksek ADF oranı % 39.24 ile yalın yulafta, en düşük oran ise % 34.40 ile yalın fiğde belirlenmiştir (Çizelge 4). Yalın tahıl otu ile tahıl-fiğ karışımlarından elde edilen otun ADF değerleri karşılaştırıldığında, otun içerisinde fiğ oranındaki artışla birlikte ADF oranının sürekli azalmadığı belirlenmiştir (Çizelge 4). Bu durum muhtemelen türler arası rekabetten kaynaklanmaktadır. Nitekim, Lithourgidis et al (2006) ve Budaklı Çarpıcı & Çelik (2014) de benzer şekilde karışımda baklagil oranının artmasına bağlı olarak otun ADF içeriğinin her zaman düşmediğini bildirmektedirler. Bununla birlikte kaba yemler ADF içeriğine göre kalite sınıflarına ayrılmaktadır. Araştırmada tüm karışımlardan elde edilen ot, ADF içeriği bakımından iyi sınıfta (ADF % 36-40) yer almıştır.

Çizelge 4'te görüldüğü üzere, en düşük NDF oranı yalın fiğ parsellerinde belirlenirken (% 56.76), diğer işlemler arasında önemli bir farklılık tespit

**Çizelge 3- Yalın ve farklı karışım oranlarında ekilmiş yaygın fiğ ve tahılların ham protein oranı ve verimi**

*Table 3- Crude protein ratio and yield for monocrops and mixtures of common vetch with cereal in different seeding ratio*

| *İşlemler* | *Ekim oranı* | *Ham protein oranı (%)* | | | *Ham protein verimi (kg ha$^{-1}$)* | | |
|---|---|---|---|---|---|---|---|
| | | *2012-2013* | *2013-2014* | *Ort.* | *2012-2013* | *2013-2014* | *Ort.* |
| Tritikale | 100 | $11.04^{cd*}$ | $11.30^{cd}$ | 11.71 | $674.4^{c-f}$ | $498.3^{ef}$ | 586.4 |
| Tritikale:fiğ | 75:25 | $11.24^{cd}$ | $15.98^{a}$ | 13.61 | $717.6^{c-f}$ | $1219.5^{ab}$ | 968.6 |
| Tritikale:fiğ | 50:50 | $10.69^{cd}$ | $15.59^{ab}$ | 13.14 | $825.3^{b-f}$ | $1296.8^{a}$ | 1061.1 |
| Tritikale:fiğ | 25:75 | $11.82^{cd}$ | $16.14^{a}$ | 13.98 | $884.9^{a-e}$ | $1051.2^{abc}$ | 968.1 |
| Fiğ | 100 | $15.30^{ab}$ | $16.93^{a}$ | 16.12 | $555.0^{ef}$ | $997.5^{a-d}$ | 776.3 |
| Yulaf:fiğ | 75:25 | $10.41^{cd}$ | $12.87^{bc}$ | 11.64 | $732.0^{c-f}$ | $1060.9^{abc}$ | 896.5 |
| Yulaf:fiğ | 50:50 | $10.90^{cd}$ | $15.12^{ab}$ | 13.01 | $742.8^{c-f}$ | $1184.0^{ab}$ | 963.4 |
| Yulaf:fiğ | 25:75 | $11.85^{cd}$ | $15.53^{ab}$ | 13.69 | $681.9^{c-f}$ | $1204.2^{ab}$ | 943.1 |
| Yulaf | 100 | $9.39^{d}$ | $9.67^{d}$ | 9.53 | $590.9^{def}$ | $448.8^{f}$ | 519.9 |
| Yıl | | ** | | | | ** | |
| İşlem | | ** | | | | ** | |
| Yıl x işlem | | ** | | | | ** | |

*, her bir özellikte aynı harflerle gösterilen ortalamalar arasında 0.01 düzeyinde farklılık yoktur; **, P<0.01

**Çizelge 4- Yalın ve farklı karışım oranlarında ekilmiş yaygın fiğ ve tahılların ADF ve NDF oranları**

*Table 4- ADF and NDF ratio for monocrops and mixtures of common vetch with cereal in different seeding ratio*

| *İşlemler* | *Ekim oranı* | *ADF (%)* | | | *NDF (%)* | | |
|---|---|---|---|---|---|---|---|
| | | *2012-2013* | *2013-2014* | *Ort.* | *2012-2013* | *2013-2014* | *Ort.* |
| Tritikale | 100 | 37.79 | 36.94 | 37.36[abcz] | 61.04 | 61.95 | 61.49[a] |
| Tritikale:fiğ | 75:25 | 37.63 | 35.18 | 36.40[bcd] | 61.60 | 57.56 | 59.58[ab] |
| Tritikale:fiğ | 50:50 | 37.54 | 36.77 | 37.15[abc] | 62.05 | 62.74 | 62.39[a] |
| Tritikale:fiğ | 25:75 | 37.03 | 35.00 | 36.01[cd] | 62.26 | 57.48 | 59.87[ab] |
| Fiğ | 100 | 34.10 | 34.71 | 34.40[d] | 56.28 | 57.24 | 56.76[b] |
| Yulaf:fiğ | 75:25 | 37.43 | 38.03 | 37.73[abc] | 60.84 | 58.68 | 59.76[ab] |
| Yulaf:fiğ | 50:50 | 39.12 | 38.38 | 38.74[ab] | 62.06 | 62.16 | 62.11[a] |
| Yulaf:fiğ | 25:75 | 36.61 | 37.36 | 36.98[abcd] | 62.02 | 60.25 | 61.13[a] |
| Yulaf | 100 | 37.90 | 40.60 | 39.24[a] | 62.09 | 62.75 | 62.42[a] |
| Yıl | | ns | | | ns | | |
| İşlem | | ** | | | * | | |
| Yıl x işlem | | ns | | | ns | | |

[Z], her bir özellikte aynı harflerle gösterilen ortalamalar arasında 0.01 ve 0.05 düzeyinde farklılık yoktur; *, P<0.05; **, P<0.05; ns, not significant

edilmemiştir. Baklagillerde ince hücre çeperine sahip doku miktarı buğdaygillerden daha fazladır. NDF oranı hücre çeperi hakkında bilgi verdiğinden, baklagillerde tahıllara göre daha düşüktür (Tan & Menteşe 2003). Karışık ekim parsellerinde fiğ oranı arttıkça NDF oranının düştüğü belirtilmiştir (Erol et al 2009). Bu çalışmada da benzer şekilde karışımdaki fiğ oranı arttığında otun NDF oranı azalmış, ancak bu azalış ekim oranı ile parelellik sergilememiştir. Bu durum muhtemelen rekabetten kaynaklanmıştır. Bunun yanında fiğin aynı oranda karışım oluşturduğu tahıl türleri arasındaki NDF oranındaki farklılık muhtemelen tahılların hasat zamanında farklı gelişme döneminde olmasından kaynaklanmıştır.

Yapılan varyans analizi sonucunda, otun sindirilebilir kuru madde (SKM) oranı bakımından işlemler arasında istatistiki olarak önemli (P<0.01) düzeyde farklılık olduğu belirlenmiş, sindirilebilir kuru madde verimi (SKMV) bakımından ise yıl x işlem interaksiyonu istatistiki olarak (P<0.01) önemli bulunmuştur. En yüksek SKM oranı yalın fiğde (% 62.1) belirlenirken, 75:25 tritikale-fiğ, 25:75 tritikale-fiğ ve 25:75 yulaf-fiğ karışımlarından elde edilen SKM oranı ile yalın fiğ arasında istatistiki olarak fark bulunmamıştır. En düşük SKM oranı ise yalın yulafta (% 58.3 ) belirlenmiştir (Çizelge 5).

SKM oranı ADF değerinden hesaplandığından, ADF oranını etkileyen etmenler SKM oranını da değiştirmiştir. İşlemlerden elde edilen SKM verimi incelendiğinde, her iki yılda da karışımların yalın ekimlerden daha yüksek sindirilebilir kuru madde verimi sağladığı belirlenmiştir. En yüksek SKM verimi ikinci yıl 50:50 yulaf-fiğ karışımından elde edilirken bunu aynı yıl 50:50 tritikale-fiğ ve 75:25 yulaf-fiğ karışımları takip etmiştir (Çizelge 5). Sözü edilen karışımların kuru ot verimleri yüksek olduğundan (Çizelge 2), SKM verimleri de yüksek olmuştur.

Karışık ekim parsellerinin alan eşdeğerlik oranlarına bakıldığında tüm karışımların yalın ekimden üstün olduğu görülmektedir (LER> 1.0) (Şekil 1). Bu durum, bitkilerin çevresel kaynaklardan yalın ekime göre daha etkin faydalandıklarını göstermektedir (Albayrak et al 2004). Karışımda bulunan fiğ ve tahılların farklı kök ve gövde yapısına sahip olması, besin ihtiyaçlarının farklı olması, iklim şartlarına tepkilerinin farklı olması, fiğin tahıllara N sağlaması gibi nedenlerle karışık ekimden elde edilen verim türlerin yalın ekimlerine göre üstün olmuştur. Karışımlar içerisinde de en

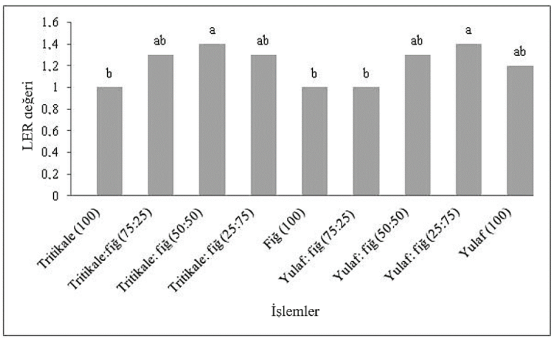
**Çizelge 5- Yalın ve farklı karışım oranlarında ekilmiş yaygın fiğ ve tahılların sindirilebilir kuru madde oranı (SKM) ve verimi (SKMV)**

*Table 5- Dry matter digestibility ratio and yield for monocrops and mixtures of common vetch with cereal in different seeding ratio*

| *İşlemler* | *Ekim oranı* | *SKM (%)* | | | *SKMV (kg ha$^{-1}$)* | | |
|---|---|---|---|---|---|---|---|
| | | *2012-2013* | *2013-2014* | *Ort.* | *2012-2013* | *2013-2014* | *Ort.* |
| Tritikale | 100 | 59.5 | 60.1 | 59.8$^{bcd*}$ | 364.4$^{abc}$ | 269.5$^{bc}$ | 317.0 |
| Tritikale:fiğ | 75:25 | 59.6 | 61.5 | 60.5$^{abc}$ | 383.4$^{abc}$ | 472.1$^{ab}$ | 427.8 |
| Tritikale:fiğ | 50:50 | 59.7 | 60.3 | 60.0$^{bcd}$ | 460.5$^{ab}$ | 503.4$^{a}$ | 482.0 |
| Tritikale:fiğ | 25:75 | 60.1 | 61.6 | 60.9$^{ab}$ | 452.4$^{ab}$ | 400.9$^{abc}$ | 426.7 |
| Fiğ | 100 | 62.3 | 61.9 | 62.1$^{a}$ | 226.3$^{c}$ | 412.7$^{abc}$ | 319.5 |
| Yulaf:fiğ | 75:25 | 59.7 | 59.3 | 59.5$^{bcd}$ | 421.7$^{abc}$ | 483.5$^{a}$ | 452.6 |
| Yulaf:fiğ | 50:50 | 58.4 | 59.0 | 58.7$^{cd}$ | 401.7$^{abc}$ | 513.9$^{a}$ | 457.8 |
| Yulaf:fiğ | 25:75 | 60.4 | 59.8 | 60.1$^{a-d}$ | 375.0$^{abc}$ | 466.3$^{ab}$ | 420.7 |
| Yulaf | 100 | 59.4 | 57.3 | 58.3$^{d}$ | 368.4$^{abc}$ | 269.7$^{bc}$ | 319.1 |
| Yıl | | ns | | | | ns | |
| İşlem | | ** | | | | ** | |
| Yıl x işlem | | ns | | | | ** | |

*, her bir özellikte aynı harflerle gösterilen ortalamalar arasında 0.01 düzeyinde farklılık yoktur; **, P<0.01; ns, not significant

yüksek avantaj (LER= 1.4) 50:50 fiğ-tritikale ve yulaf karışımlarından sağlanmıştır (Şekil 1). Elde edilen sonuçlar Erol et al (2009)'ın bulgularıyla benzerlik göstermektedir.




**Şekil 1- Farklı işlemlerde belirlenen LER değeri**

*Figure 1- LER values in different treatments*

Agresivite ve rekabet oranı değerleri incelendiğinde, türlerin rekabet özelliğinin yıllara göre önemli (P<0.01) değişim gösterdiği anlaşılmaktadır. İlk yıl tüm karışım oranlarında tahıllar baskın tür (Ac pozitif) olmasına rağmen, ikinci yıl yaygın fiğ baskın (Av pozitif) olmuştur (Çizelge 6). Agresivite özelliğine benzer olarak tahılların rekabet oranı (CRc) değeri ilk yıl yaygın fiğin rekabet oranı (CRv) değerinden yüksek olurken, ikinci yıl tam tersi durum söz konusu olmuştur (Çizelge 7). Bu durum araştırmanın yürütüldüğü yıllarda çevre şartlarındaki farklılıkların fiğ ve tahıl gelişimine olan etkisinin farklı olmasından kaynaklanmıştır. Daha önce yapılmış araştırmalarda farklı sonuçlar elde edilmiştir. Örneğin; Atis et al (2012), buğday:yaygın fiğ karışımlarında yaygın fiğin baskın tür olduğunu bildirmesine rağmen, Dordas et al (2012) ise tahıl:baklagil karışımlarında tahılın baskın tür olduğunu bildirmiştir. Bununla birlikte Ac ve Av değerleri bakımından karışımlar arasında önemli (P<0.01) farklılık olduğu belirlenmiştir (Çizelge 6). Karışımlarda tahılın ekim oranı azaldıkça agresivitesi artmış, fiğde ise tam tersi durum belirlenmiştir. Benzer durum rekabet oranı değerleri için de belirlenmiştir (Çizelge 7). Tahıllar kardeşlenme özellikleri sayesinde ekim oranındaki azalmayı tolere edebilmekte ve sık ekime oranla seyrek ekimde kardeşler daha gür gelişebilmektedir. Ayrıca karışımda fiğ arttıkça muhtemelen fiğden tahıla geçen N miktarı da artmıştır. Tüm bu nedenlerle tahıllarda ekim oranı azaldıkça agresivite artmıştır. Ayrıca karışımlarda tritikale yulafa göre daha rekabetçi görünmektedir (Çizelge 7). Bu durum muhtemelen türlerin kardeşlenme özellikleri, ana sap uzunluğu gibi farklılıklardan kaynaklanmıştır. Tritikale yulafa göre daha az kardeşlenmektedir, bu nedenle muhtemelen tür içi rekabet daha az olmuştur. Ayrıca çalışmada, tritikale yulafa göre daha uzun boylu olduğundan (veri verilmemiştir) muhtemelen fiğde daha fazla ışık rekabetine sebep olmuştur. Elde edilen sonuçlar, karışımlarda türler arasındaki rekabetin karışımlarda kullanılan türlere ve ekim oranlarına bağlı olarak değiştiği bildiren Dhima et al (2007) ve Lithourgidis et al (2011b)'ın sonuçları ile uyumludur.

## 4. Sonuçlar

Yaygın fiğ-tahıl karışımlarının ot verimi, bazı kalite özellikleri ve karışımlarda bitkiler arasındaki rekabetin belirlenmesi amacıyla iki yıl süreyle yürütülen bu çalışma sonucunda; karışımların kuru ot, ham protein ve sindirilebilir kuru madde verimlerinin her iki yılda da yalın ekimlerden üstün olduğu belirlenmiştir. Ancak karışımların verimleri yıllara göre değişkenlik göstermiş, 50:50 fiğ-tritikale karışımı diğer karışımlara göre daha stabil bir verim sağlamıştır. Bununla birlikte otun ADF içeriği bakımından değerlendirildiğinde, tüm

**Çizelge 6- Farklı karışım oranlarında ekilmiş yaygın fiğ ve tahılların agresivite değerleri**

*Table 6- Aggressivity for mixtures of common vetch with cereal in different seeding ratio*

| *İşlemler* | *Ekim oranı* | *Ac* | | | *Av* | | |
|---|---|---|---|---|---|---|---|
| | | *2012-2013* | *2013-2014* | *Ort.* | *2012-2013* | *2013-2014* | *Ort.* |
| Tritikale:fiğ | 75:25 | 0.0040 | -0.0314 | -0.0137 [d*] | -0.0040 | 0.0314 | 0.0137 [a] |
| Tritikale:fiğ | 50:50 | 0.0144 | -0.0152 | -0.0004 [bc] | -0.0144 | 0.0152 | 0.0004 [bc] |
| Tritikale:fiğ | 25:75 | 0.0290 | -0.0024 | 0.0133 [a] | -0.0290 | 0.0024 | -0.0133 [d] |
| Yulaf:fiğ | 75:25 | 0.0045 | -0.0275 | -0.0115 [d] | -0.0045 | 0.0275 | 0.0115 [a] |
| Yulaf:fiğ | 50:50 | 0.0091 | -0.0128 | -0.0018 [d] | -0.0091 | 0.0128 | 0.0018 [b] |
| Yulaf:fiğ | 25:75 | 0.0196 | -0.0031 | 0.0083 [ab] | -0.0196 | 0.0031 | -0.0083 [cd] |
| Ort. | | 0.0134 [A] | -0.0154 [B] | | -0.0134 [B] | 0.0154 [A] | |
| Yıl | | ** | | | ** | | |
| İşlem | | ** | | | ** | | |
| Yıl x işlem | | ns | | | ns | | |

*, her bir özellikte aynı harflerle gösterilen ortalamalar arasında 0.01 düzeyinde farklılık yoktur; **, P<0.01; ns, not significant

**Çizelge 7- Farklı karışım oranlarında ekilmiş yaygın fiğ ve tahılların rekabet oranı değerleri**

*Table 7- Competition rate for mixtures of common vetch with cereal in different seeding ratio*

| *İşlemler* | *Ekim oranı* | *CRc* | | | *CRv* | | |
|---|---|---|---|---|---|---|---|
| | | *2012-2013* | *2013-2014* | *Ort.* | *2012-2013* | *2013-2014* | *Ort.* |
| Tritikale:fiğ | 75:25 | 1.58 [bcdz] | 0.20 [d] | 0.89 | 0.70 | 9.19 | 4. 94 |
| Tritikale:fiğ | 50:50 | 3.05 [bc] | 0.29 [d] | 1.67 | 0.34 | 4.22 | 2.28 |
| Tritikale:fiğ | 25:75 | 5.55 [a] | 0.83 [cd] | 3.19 | 0.21 | 1.43 | 0.82 |
| Yulaf:fiğ | 75:25 | 1.52 [bcd] | 0.20 [d] | 0.86 | 0.69 | 5.39 | 3.04 |
| Yulaf:fiğ | 50:50 | 2.15 [bcd] | 0.42 [d] | 1.29 | 0.49 | 4.07 | 2.28 |
| Yulaf:fiğ | 25:75 | 3.84 [ab] | 0.76 [d] | 2.30 | 0.27 | 1.46 | 0.87 |
| Ort. | | | | | 0.45 [B] | 4.29 [A] | |
| Yıl | | ** | | | ** | | |
| İşlem | | ** | | | ns | | |
| Yıl x işlem | | * | | | ns | | |

[Z], aynı harflerle gösterilen ortalamalar arasında 0.01 düzeyinde farklılık yoktur; *, P<0.01; **, P<0.05; ns, not significant karışımların otu iyi sınıfta yer almıştır. LER değeri bakımından ise en üstün karışımlar 50:50 fiğ-tritikale ve 50:50 fiğ-yulaf olmuştur. Bu nedenlerle benzer ekolojilerde 50:50 fiğ-tritikale ve 50:50 fiğ-yulaf karışımlarının yetiştirilmesi önerilebilir.

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# Physico-Chemical Characteristic and Fatty Acids Compositions of Cottonseed Oils

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**ABSTRACT**

In this study, three cotton genotypes of species *Gossypium hirsutum* L., Cukurova 1518, PAUM 15 and BA 119 were investigated for their some physicochemical properties of oils such as free fatty acids, peroxide value, iodine value, unsaponifiable matter, total carotenoid and tocopherol contents and fatty acids composition in Cukurova region in Turkey. Seed oil content ranged 17.2-19.6% and PAUM 15 was found to be genotype with the highest oil content. The range of other physicochemical properties and their values are as follows; free fatty acids 1.7-2.8%, peroxide value 5.3-6.0 meq $O_2$ kg$^{-1}$, unsaponifiable matters 2.1-2.3%, iodine value 102-110, total carotenoid content 119-140 mg kg$^{-1}$, total tocopherol content 887-920 mg kg$^{-1}$, linoleic acid 52.00-55.82%, palmitic acid 24.85-25.63%, oleic acid 14.06-17.00%, stearic acid 3.01-3.13% in the cottonseed oils. PAUM 15 was determined to be more suitable for food consumption as edible oil due to its highest oil content and quality characteristics than the others genotypes.

Keywords: Cottonseed oil; Fatty acids; Physicochemical properties

# Pamuk Yağlarının Fiziko-Kimyasal Özellikleri ve Yağ Asitleri Kompozisyonu

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**ÖZET**

Bu çalışmada, Türkiye'nin Çukurova Bölgesi koşullarında, *Gossypium hirsutum* L. türüne ait, Çukurova 1518, PAUM 15 ve BA 119 pamuk genotiplerinden elde edilen yağların serbest yağ asitleri, peroksit sayısı, iyot ayısı, sabunlaşmayan madde miktarı, toplam karotenoid, toplam tokoferol içerikleri gibi bazı fizikokimyasal analizleri ile yağ asitleri kompozisyonu araştırılmıştır. Tohumlarda yağ içeriği % 17.2-19.6 arasında değişmiştir. Elde edilen yağlarda serbest yağ asitleri % 1.7-2.8, peroksit sayıları 5.3-6.0 meq $O_2$ kg$^{-1}$, sabunlaşmayan maddeler % 2.1-2.3, iyot sayıları 102-110, toplam karotenoid içerikleri 119-140 mg $kg^{-1}$, toplam tokoferol içerikleri 887-920 mg $kg^{-1}$ aralığında değişmiştir. Linoleik asit, palmitik asit, oleik asit ve stearik asit oranlarının, sırasıyla % 52.0-55.82; % 24.85-25.63, % 14.06-17.0 ve % 3.01-3.13 aralığında değiştiği saptanmıştır. PAUM 15 genotipinin en yüksek yağ verimi ve yağ kalitesine sahip olmasından dolayı diğer genotiplere kıyasla yemeklik yağ olarak tüketime daha uygun olabileceği belirlenmiştir.

Anahtar Kelimeler: Pamuk yağı; Yağ asitleri; Fizikokimyasal özellikler



## 1. Intruduction

Cotton is one of the most important commercial crops of Turkey and is the single largest natural source of fibre. It plays a dominant role in industrial economy as the backbone of textile industry. 65% of country's textile products are exported, and 80% of these products consist of cotton weaving (Mert et al 2015). However cottonseeds contain oil significant amount. Oil content of cottonseeds changes between 12-25% (Kohel 1998; Mert et al 2004). Oil is obtained from cottonseeds as by products that meet an important part of Turkey oil consumption. Cottonseed oil is the second most common oil being used today besides sunflower oil. As the most important vegetable oil source in Turkey, sunflower is first ranked with 1.38 million tons, followed by cottonseed with 1.28 million tons, soybean 180,000 ton, peanut 141,000 tons and rapeseed 101,000 tons (Kolsarıcı et al 2015).

Cottonseed oil is usually used in vegetable oil mixtures (Metin et al 2003), cooking and salad oil, in the preparation of margarine, shortening, mayonnaise and sauces, also to less extend in canned fish and smoked meat (Gümüşkesen 1999; Karaosmanoğlu et al 1999; Sekhar & Rao 2011).

Crude cottonseed oil, which has an aroma resembling peanut and walnut, has a blurry appearance (Paralı 2003). Color of crude cottonseed oil can vary from brunette yellow to dark red due to significant amount of color pigment passing to oil during extraction (O'Brien 1998; Orhevba & Efomah 2012). In addition triglycerides, nonglyceride components such as gossypol, phospholipids, sterols, pigments, tocopherols and carbohydrates are found in this oil with the amount of about 2% (O'Brien 1998). Cottonseed oil also has a rich source of minerals, it includes vitamin B and oil soluble vitamins such as A, D, E, K (Lukonge 2005; Sawan et al 2006).

The important component of cottonseed oil is tocopherols, natural antioxidants. However, amount of tocopherols that present in oil declines significantly during the refining process. Therefore crude cottonseed oil when compared to refined cottonseed oil and soybean oil is rich in terms of amount of tocopherol and, more resistant to oxidation (Saxena et al 2011; Sekhar & Rao 2011). Fatty acid composition of cottonseed oil is the one of important properties (Lukonge 2005; Ping et al 2009). Cottonseed oil has a 2:1 ratio of polyunsaturated to saturated fatty acid. It is described as naturally hydrogenated because its fatty acid profile generally consists of 70% unsaturated fatty acids, including 18% mono-unsaturated (oleic) and 52% poly-unsaturated (linoleic), and 26% saturated (primarily palmitic and stearic) acids. These make the oil stable for frying without the need for additional processing or the formation of trans-fatty acids (Sekhar & Rao 2011). As with other vegetable oils quality of cottonseed oil usually comes from fatty acid composition and unsaponifiable matters mentioned. Their amount and oil yield varies depending on genotype, ecological conditions of region process and storage conditions (Baydar & Turgut 1999; Reddy & Aruna 2009).

The objective of this study was to determine crude seed oil yield, fatty acid composition and typical characteristic properties in the seed oil of three different cotton genotypes grown in Cukurova Region.

## 2. Material and Methods

This study was conducted at the Cotton Research and Application Center of Cukurova University, Adana, in 2006-2007 cotton growing season. The experiment was set in a randomized complete block design with three replications. Cukurova 1518, PAUM 15 and BA 119 cotton genotypes (*Gossypium hirsutum* L.) were used as plant materials.

The plants and rows spacing were kept at 20 and 70 cm, respectively. Plots were fertilized with 80 kg $ha^{-1}$ N and 80 kg $ha^{-1}$ $P_2O_5$ before planting using diammonium phosphate (DAP) fertilizer, and an additional nitrogen (as urea) dose of 80 kg $ha^{-1}$ was top dressed 50 days after planting. Other inputs like irrigation and insecticides were applied at proper time and as when required. All other cultural practices including weeding were uniformly adopted in whole experiment throughout the growing period to minimize the environmental variations.

In order to remove of cottonseed lints completely delintation process was performed to seeds. Analysis such as seed index (the weight of 100 seeds in g), hull (%), kernel (%), seed moisture content (%), seed oil content (%) in seed and free fatty acid (%), peroxide value, unsaponifiable matter, iodine value, total carotenoid and tocopherol contents, fatty acid profiles in cottonseed oil were carried out. All tests were performed in triplicate.

In order to determine oil content cottonseeds were crushed in blender and dried at 103±2 °C till the constant weight. Crude oils of seeds were extracted with the soxhlet method for 6 h. Recovered crude oils were taken to a rotary evoparator at 35 °C (Anderson 2004). Obtained oil samples were filtered and stored at 4°C in dark glass bottles prior to analyses.

Determination of free fatty acidity, peroxide value, unsaponifiable matter and iodine value were carried out following the analytical methods described in IUPAC (1991).

Carotenoid compounds were determined at 470 nm, in cyclohexane using the specific extinction values by the method of Minguez-Mosquera et al (1991). The carotenoid contents are expressed as mg lutein per kg of oil.

Total tocopherols were evaluated by the method of Wong et al (1988). 200 mg of the oil sample was weighed accurately into a 10 mL volumetric flask. 5 mL of toluene were added by pipette and the oil was taken into solution. 3.5 mL of 2.2'-dipyridine and 0.5 mL of $FeCl_3.6H_2O$ were added in that order. This solution is made up to 10 mL with 95% aqueous ethanol. After kept for 1 min, the absorbance was measured at 520 nm against a blank solution. The tocopherol contents were expressed as mg $kg^{-1}$ α-tocopherol.

For the determination of fatty acid composition, the methyl esters were prepared by vigorous shaking of a solution of oil in n-heptane (0.1 g in 2 mL) with 2 N methanolic potassium. The analysis of fatty acid composition was performed by using a Shimadzu GC apparatus (Model 14 B) equipped with a hydrogen flame ionization detector (FID) and a capillary column DB-23 of 60 m length x 0.25 mm i.d. and 0.25 µm of film thickness (Agilent J & W, US). Helium was used as carrier gas and the temperatures of injector, oven and detector were 270, 230 and 280 ºC, respectively. The results were expressed as peak area (relative) percent. The injection volume was 1 µL (IOOC 2001).

Statistical analysis was carried out by using SAS software and procedures (SAS 2005). Data were analysed according to PROC GLM procedures. The means were compared using Duncan's multiple comparison tests at 5% significance level.

## 3. Results and Discussion

The whole seeds compositions of three cotton genotypes are shown in Table 1. Seed index in cotton genotypes ranged from 9.6 (Cukurova 1518) to 10.3 (PAUM 15) g. Sharma et al (2009) reported seed index range of 3.69 to 5.38 g for *G.arboreum* and 6.01 to 7.71 g for *G.hirsutum*, whereas Agarwal et al (2003) observed a range of 4.65-9.41 g in upland cotton. The values for hull percentage and kernel ranged from 36-40% and 60-64%, respectively. Depending on the genotype, species and ecological factors, hull contributed about 30-50% to the weight of cotton seed (Sundaram 1974). These values are in agreement with those reported by Sharma et al (2009). Seed oil contents were found 17.2% in BA 119, 17.8% in Cukurova 1518 and 19.6% in PAUM 15. Sharma et al (2009) observed seed oil content varied from 14.4% to 18.7% in desi cotton entries, whereas in American cotton, its value ranged from 15.8% to 20.2%. Gotmare et al (2004) have reported seed oil content ranging from 17.61% to 19.54% in six races of *G. arboreum*. Our results are in agreement with those obtained by these researchers. This situation supported by findings of Ikurior & Fetuga (1987) and Sun et al (1987) which indicate that genotypes and regional variation affects oil content of cotton seed.

Free fatty acids (FFA) content (%), peroxide values (meq $O_2$ $kg^{-1}$), iodine number (g), unsaponification matter (%), total carotenoid (mg $kg^{-1}$), total tocopherol (mg $kg^{-1}$) for cottonseed oils are shown in Table 2. The FFA content of cotton seed oil ranged from 1.7% (PAUM 15) to 2.8% (Cukurova 1518). Free fatty acids (generated as a result of hydrolysis of triglycerides) are good indicator of oil quality (Sharma et al 2009). O'Brien (2001) and Sharma et al (2009) have reported that FFA content range for crude cottonseed oil was 0.43 to 0.70% and 0.5 to 0.6%, respectively whereas Orhevba & Efomah (2012) specify this value as 5.7%. These differences might be due to genotype, region grown, climate, storage in unsuitable conditions (high moisture content) (O'Brien 1998).

The peroxide value which is used as an indicator of oxidation of oils was found to be 5.3-6.0 meq $kg^{-1}$ indicating that the oil is fresh. This is because fresh oils usually have peroxide values below 10 meq $kg^{-1}$ (Orhevba & Efomah 2012).

In cottonseed oils amount of unsaponifiable matters varied between 2.1-2.3% and it was determined it did not change according to genotypes. The iodine value which gives the degree of unsaturation in vegetable oils was found to be 102, 104, 110 g 100 $g^{-1}$ for cottonseed oil PAUM 15, Cukurova 1518 and BA 119, respectively.

**Table 1- Composition of whole seeds of cotton varieties**

*Çizelge 1- Pamuk çeşitlerinin tohum özellikleri*

| *Variety* | *Seed index (g)* | *Hull (%)* | *Kernel (%)* | *Seed moisture content (%)* | *Oil (%)* |
|---|---|---|---|---|---|
| Cukurova 1518 | $9.6^{b*}$ | $36^{b}$ | $64^{a}$ | $7.7^{a}$ | $17.8^{b}$ |
| PAUM 15 | $10.3^{a}$ | $38^{ab}$ | $62^{ab}$ | $6.7^{b}$ | $19.6^{a}$ |
| BA 119 | $9.8^{ab}$ | $40^{a}$ | $60^{b}$ | $6.8^{b}$ | $17.2^{b}$ |
| Mean | 9.9 | 38 | 62 | 7.1 | 18.2 |
| Range | 9.6-10.3 | 36-40 | 60-64 | 6.8-7.7 | 17.2-19.6 |

*, in each column values with different letters are statistically different (P<0.05)

**Table 2- Physicochemical characteristics of cottonseed oil**

*Çizelge 2- Pamuk yağının fizikokimyasal özellikleri*

| *Variety* | *Free fatty acid (% oleic)* | *Peroxide value (meq $O_2$ $kg^{-1}$)* | *Unsaponifiable matter (%)* | *Iodine value* | *Total carotenoid (mg $kg^{-1}$)* | *Total tocopherol (mg $kg^{-1}$)* |
|---|---|---|---|---|---|---|
| Cukurova 1518 | $2.8^{a*}$ | 5.7 | 2.3 | $104^{b}$ | $140^{a}$ | $904^{b}$ |
| PAUM 15 | $1.7^{c}$ | 5.3 | 2.2 | $102^{b}$ | $119^{b}$ | $920^{a}$ |
| BA 119 | $2.3^{b}$ | 6.0 | 2.1 | $110^{a}$ | $127^{b}$ | $886^{c}$ |
| Mean | 2.2 | 5.6 | 2.2 | 105.3 | 128.6 | 903.3 |
| Range | 1.7-2.8 | 5.3-6.0 | 2.1-2.3 | 102-110 | 119-140 | 886-920 |

*, in each column values with different letters are statistically different (P<0.05)

Similar results were obtained by Sharma et al (2009) and O'Brien (2001) who reported that iodine value range for cotton seed oil was 98-113 and 101-113, respectively. In other study, cotton seed oil iodine value was very low (97.4) (Orhevba & Efomah 2012). Degree of unsaturation of oil varies depending on genotype obtained oil, climate and geographical factors and oil processing method. As degree of unsaturation (number of double bonds) of oil and iodine value increases, sensitivity to oxidation that is peroxide value increases (Orhevba & Efomah 2012). It seems that the lowest iodine value between cotton genotypes had by PAUM 15 genotype which also has the lowest peroxide value.

It was determined carotenoid contents of cottonseed oil changed between 119-140 mg $kg^{-1}$. The oil obtained from Cukurova 1518 was highest content of carotenoid and BA 119 genotype followed this. Carotenoid content of oil is related to colour of oil and oxidative stability (O'Brien 1998).

Total tocopherol content of cotton seed oils ranged from 886 to 904 mg $kg^{-1}$. While highest tocopherol content was determined in the oil obtained from PAUM 15, lowest content of tocopherol was determined in BA 119. That tocopherol content varied according to cotton genotypes. Tocopherol is significant feature because it has antioxidant structure which prevents oil to oxidation and it has vitamin E property which increases nutritional value of oil (Psomiadou & Tsimidou 2002).

The fatty acids composition for cottonsseed oils are shown in Table 3. The linoleic, palmitic, oleic and stearic acids were the principal fatty acids for all genotypes analyzed. The values of miristic, palmitoleic, linolenic, arachidic did not exceed 1%. It was determined content of oleic acid varied between 14.06-17.00% in cotton seed oil according to genotypes. Highest oleic and linoleic acid contents were found oils obtained from genotypes of BA 119 (17.00%) and PAUM 15 (55.82%), respectively. Sharma et al (2009) have reported highest oleic and linoleic acid contents of 24.81% and 52.78% in cotton genotypes, respectively. Obtained results support the results of Lukonge (2005) that indicate there was a negative correlation between oleic acid and linoleic acid. Specifically, the oxidative stability of cottonseed oil can be lower than for other vegetable oils such as olive oil and canola oil because of its high concentration of linoleic acid (Dowd et al 2010). Highest palmitic and stearic acid contents were detected oils in BA 119 (25.63%) and Cukurova 1518 (3.13%), respectively. The concentration of palmitic acid (16:0), a saturated fatty acid, is higher in cottonseed oil (~24%) than in many other vegetable oils. Higher levels of saturated fatty acids contribute functionality in food systems (Dowd et al 2010). BA 119 genotype has high oleic acid content revealed it is more resistant to oxidation than other genotypes. The results obtained are in accordance with O'Brien (1998) and Baydar & Turgut (1999) who reported that indicate fatty acid composition of seeds vary according to genotype and environmental factors.

**Table 3- Fatty acids profiles of cottonseed oil of cotton varieties (%)**

*Çizelge 3- Pamuk çeşitlerine ait tohum yağlarının yağ asiti profilleri (%)*

| *Fatty acids* | *Cukurova 1518* | *PAUM 15* | *BA 119* | *Mean* | *Range* |
|---|---|---|---|---|---|
| Myristic (C14:0) | 0.79 | 0.78 | 0.80 | 0.79 | 0.78-0.80 |
| Palmitic (C16:0) | 25.52 | 24.85 | 25.63 | 25.33 | 24.85-25.63 |
| Palmitoleic (C16:1) | 0.55 | 0.54 | 0.57 | 0.55 | 0.54-0.57 |
| Stearic (C18:0) | 3.13 | 3.01 | 3.12 | 3.08 | 3.01-3.13 |
| Oleic (C18:1) | 15.11 | 14.06 | 17.00 | 15.39 | 14.06-17.00 |
| Linoleic (C18:2) | 54.01 | 55.82 | 52.00 | 53.94 | 52.00-55.82 |
| Linolenic (C18:3) | 0.14 | 0.14 | 0.12 | 0.13 | 0.12-0.14 |
| Arachidic (C20:0) | 0.29 | 0.30 | 0.31 | 0.30 | 0.29-0.31 |

## 4. Conclusions

The major findings of the current study are: 1) that genotype differences in characteristics of cottonseed oil exist under field conditions, 2) highest oil content and amount of tocopherol obtained from 'PAUM-15' while the highest oleic and linoleic acid content was found in 'BA119' and 'PAUM 15', respectively, 3) the highest carotenoid content was found oil obtained from 'Cukurova 1518', 4) that the genotype PAUM-15 has larger genetic potential for cottonseed oil %, linoleic acid content and total tocopherol among genotypes investigated, 5) due to genotype x environment interactions, genotypes should be evaluated in more than a single environment.

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# The Piosphere Effects of Livestock Grazing on Rangeland Vegetation in Ahir Mountain of Kahramanmaras Region

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**ABSTRACT**

Excessive grazing pressure on rangeland vegetation reduces the basal area value of vegetation and also changes the botanic composition. This study examined the piosphere effects of livestock grazing on rangeland vegetation based on distance from a natural water source. The piosphere effects were evaluated around Karagöl Lake, which is a natural water-source in Mediterranean region of Turkey. The changes in vegetation were determined within three different sites where sample plots were located at 0-1000 m, 1000-3000 m and 3000-5000 m away from the lake. The mean values of basal area in the study area were 10.71%, 14.46%, and 22.16% for three sites, respectively. The average oven-dry hay yield was 639.0 kg $ha^{-1}$, 1542.9 kg $ha^{-1}$, and 2146.3 kg $ha^{-1}$, respectively. The vegetation similarity indices of the sites indicated that the botanic composition changed with respect to increasing distance from the lake. The lowest similarity index was encountered between the site one and site three (30.31%).

Keywords: Piosphere; Rangeland; Basal area; Hay yield; Botanic composition

# Kahramanmaraş Yöresi Ahır Dağı Meralarında Piospher'in Vejetasyon Yapısı Üzerindeki Etkileri

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**ÖZET**

Mera vejetasyonları üzerinde oluşan aşırı otlatma baskısı, vejetasyonun bitki ile kaplı alan değerinin azalmasına ve botanik kompozisyonun değişmesine neden olmaktadır. Yapılan bu araştırmada Türkiye'nin Akdeniz bölgesinde yer alan, doğal su kaynaklarından biri olan Karagöl gölüne olan mesafeye göre piosferin vejetasyon üzerindeki etkileri incelenmiştir. Bunun için çalışma alanında yer alan doğal su kaynaklarından biri olan Karagöl gölünün piosfer etkisi araştırılmıştır. Vejetasyonda meydana gelen değişiklikler Karagöl gölü çevresinden 0-1000 m, 1000-3000 m ve 3000-5000 m uzaklıkta seçilen üç deneme alanı alınarak belirlenmiştir. Araştırma alanında ortalama bitki ile kaplı alan değerleri sırasıyla % 10.71, % 14.46 ve % 22.16 olarak belirlenmiştir. Göl çevresinde ortalama fırın kurusu ot verimi sırasıyla 63.90 kg da$^{-1}$, 154.29 kg da$^{-1}$ ve 214.63 kg da$^{-1}$ olarak tespit edilmiştir. Vejetasyonun benzerlik indeksi değerlerine göre göl çevresinden uzaklaştıkça vejetasyonun farklılaştığı belirlenmiştir. En düşük benzerlik oranının birinci ve üçüncü deneme alanları arasında olduğu tespit edilmiştir.

Anahtar Kelimeler: Piosfer; Mera; Bitki ile kaplı alan; Ot verimi; Botanik kompozisyon



# 1. Introduction

Rangelands are a type of land on which the natural vegetation is dominated by grasses, forbs and shrubs and the land is managed as a natural ecosystem (SRM 2015). Rangeland areas play important role in terms of both biological diversity and grazing, due to having wide range of plant species. In addition, rangeland vegetation is important in preventing erosion and runoff (Gökkuş & Koç 2001).

The total area of rangelands occupies 3.5 billion ha in world (FAO 2008). In Turkey, the area of rangelands is about 14.6 million hectares, while it was 50 million hectares in 1923 (TSI 2011). Within the same period, the number of animals grazing on rangelands increased from 20.3 million to 29.9 million cattle units (TSI 2011). Thus, rangelands continually decreased while the number of grazing animals per unit area increased, which led to ever-increasing grazing pressure on rangelands. The vegetation structures of rangelands were deteriorated and productivity decreased due to increasing grazing pressure. Grazing pressure also reduced the density of vegetation coverage and emerged active surface erosion. Due to excessive, non-uniform, and untimely (i.e. while plants are not mature enough for grazing and soil is humid) grazing, deterioration process of vegetation has been accelerated in last decades.

Unplanned grazing practices in Turkey resulted in non-uniform grazing which led to much greater grazing pressure in rangeland areas, especially rangeland sites located around water sources. Grazing animals on rangelands tend to stay around water sources because these animals are continuously in need of drinking water (Stoddart et al 1975). Grazing density around water sources decreases circumferentially away from the center (Andrew 1988; Pickup 1989; Pickup & Chevings 1994; Pickup et al 1998). The higher grazing density around water sources causes reduction in the basal area, changes in botanic composition and extinction of many plant species. The animal communities around a water source also result in soil compaction and consequently increased runoff.

The term "piosphere" is used to define grazing pressure in areas surrounding water sources, especially in arid rangelands areas (Lange 1969; Andrew 1988; Thrash 1998; 2000; James et al 1999). The origin of the term "piosphere" comes from Latin; "pios"= to drink and "phere"= round or ball. Tongway et al (2003) revealed that the piosphere effect can be noticed even at a distance of 1-3 km from water. ICARDA (2002) observed deterioration in vegetation within a radius of 2-5 km around well shafts due grazing practices. Therefore, the distance from water sources can be used to define grazing pressure; because the closer the water sources the greater the grazing pressure (Ludwig et al 2001).

This study examined the piosphere effect of grazing pressure on rangeland vegetation according to distance from a natural water source. Karagöl Lake located in rangelands of Ahır Mountain in Kahramanmaras region was considered as the center of piosphere. This region has an arid climate and study area has been subject to significant amount of non-uniform grazing. In the study, the basal area, hay yields and similarity indices between plant communities were analyzed in the study area.

# 2. Material and Methods

## *2.1. Study area*

The rangelands of Ahır Mountain are located in the East Meditarrenean region of Turkey, average altitude 1650 m, 25 km away from Kahramanmaras province. The study area is located between latitudes 37° 39' 38"-37° 38' 15" N and longitudes 36° 56' 20"-37° 03' 14" E (Figure 1). Karagöl Lake, located in the rangeland, has the water surface area of 15.5 ha the study area has transitional characteristics between continental and Mediterranean climates. Generally, summers are hot and dry; winters are cold and snowy. Annual precipitation is about 700 mm. Precipitation generally occurs in winter and spring. Annual average temperature is 16.7 °C with maximum and minimum temperatures of 45.2 °C (July) and -9.6 °C (February), respectively (TSMS 2012). When considering the vegetation period, it can be seen that the study area has arid climatic characteristics. The soils of the study area are generally of sandy, sandy loam, and sandy clay loam that form on the bedrocks of sandstone, limestone, and mudstone. The flora of the study area is dominated by herbaceous plants such as *Gundelia tournefortii* var. *armata, Bromus tectorum, Astragalus akmanii, Carduus nutans, Marrubium globosum* subsp. *globosum, Anthemis kotschyana, Achillea kotschiyana, Galium verum* subsp. *verum, Hypericum scabrum,* and *Allium trachycoleum*.

### 2.2. Methods

A preliminary survey was carried out in the area to identify potential study sites. It was observed that some features (i.e. basal area, botanic composition, etc.) of vegetation differed depending on the distance from Karagöl Lake. Random sampling method was used for determining vegetation characteristics in the study area. All sample plots were taken from same altitude (1620-1670 m), slope (10-20%) and aspect (south). The piosphere effects of livestock grazing on rangeland vegetation were evaluated for three different sites where five sample plots with 1000 m radius were located based on their proximity to the lake. In the first site, Plot I centralized the Karagöl Lake. In the second site, Plot II and III were located on west and east of Plot I, respectively. Then, Plot IV and V were located on west of Plot II and east of Plot III, respectively (Figure 2). Within each plot, 7

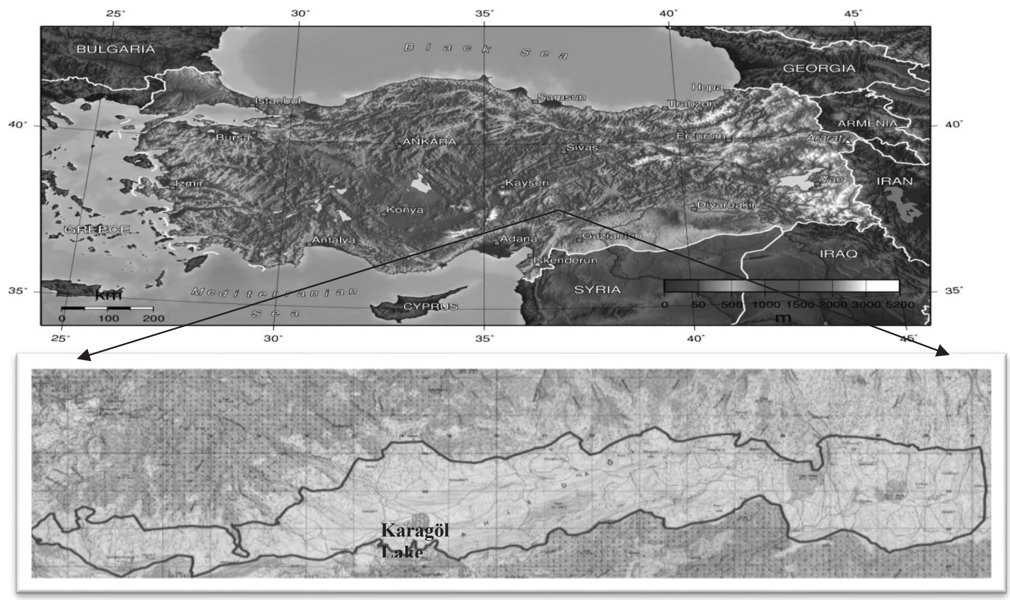


**Figure 1- The location of the study area**

*Şekil 1- Araştırma alanının yeri*

sampling areas occupying an area of 1000 m$^2$ (20 m x 50 m) were chosen to determine the basal area, hay yield, and similarity index. All of the vegetation measurements were conducted between 1st July and 15th August in 2012. One-way analysis of variance was applied to determine whether or not there were significant differences in the effect of distance from the lake on vegetation characteristics. Statistical analysis of the data was conducted by using SPSS (version 18.0).

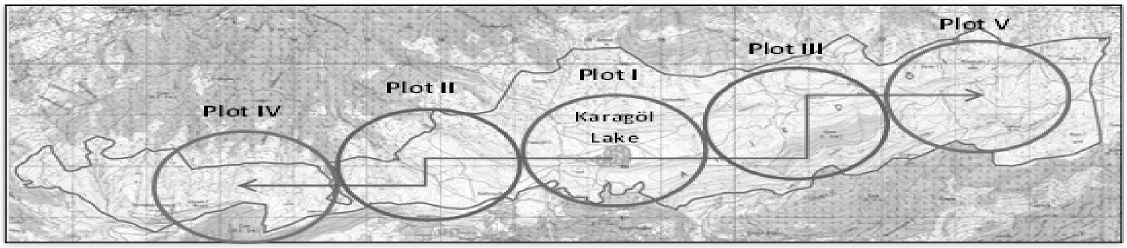


**Figure 2- Sample plots located in study sites**

*Şekil 2- Çalışma alanı örnekleme noktalarının yeri*

The loop transect method suggested by Parker & Harris (1959) was used to evaluate changes in rangelands vegetation in the study area (Figure 3). In each sampling area, 6 loop transects were conducted to estimate basal area (in %). Thus, 42 loop transects from each plot and total of 210 loop transects from the whole study area were conducted.

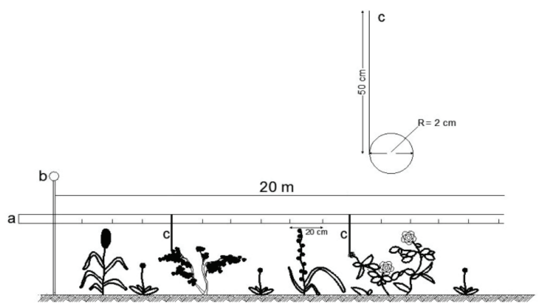


**Figure 3- Application of loop transect method; a, marked rope (20 m); b, steel pins; c, loops**

*Şekil 3- Lup yöntemi ile çalışma; a, işaretli ip (20 m); b, tesbit çubuğu; c, lup aracı*

In application of loop transect method, 20 meter long rope was marked at each 20 cm intervals to locate loops along each loop transect. Total of 100 loops were located on marked rope which was anchored on the ground at both end points by using steel pins. The loop consisted of a 50 cm of handle attached to an observation ring with about 2 cm (¾ inches) diameter. During the measurements, each loop was observed through rings to evaluate existence of plants and dominant species were considered if more than one plant exists.

To determine the hay yield in the study area, total of 175 quadrat samples (1 m x 1 m) were implemented in the study area, where 5 quadrat samples were used in each sampling area (Okatan 1987). The herbaceous within the quadrats were mowed at 5 cm height above the ground surface and then dried in a drying oven at 78 °C to determine oven dried hay yields.

A similarity index calculation was used to compare plant communities of three different sites (Sorenson 1948; Bakır 1970; Okatan 1987; Koç 1995). The similarity index value was computed to compare two different sites at once. Equation 1 that suggested by Sorenson (1948) was employed to calculate similarity index.

$$SI = \left( \frac{2W}{a+b} \right) x100 \quad (1)$$

Where; *SI*, similarity index value; *W*, total value of the smallest basal area consisted of common plants in compared sites; *a* and *b*, the total value of the area covered by different plants within the compared sites.

## 3. Results and Discussion

A total of 101 plant species were identified within the study areas, of which four were endemic. Of the total species, 8 were of the family *Poaceae*, 7 were *Fabaceae*. Rests of the species belong to other families, of which 8 species were weeds that are toxic, thorny or otherwise harmful to both animal health and the quality of animal products.

The results indicated that average basal area was 15.77% for the whole rangeland. It was also found that the study area was exposed heavy grazing pressure. The average basal area was 10.71% around the lake in the first site (0-1000 m), while it was 14.46% and 22.16% within the second (1000-3000 m) and third (3000-5000 m) sites, respectively. It was realized that the lowest basal area was in the first site due to higher grazing pressure from animals visiting the lake for watering (Figure 4). As shown in Figure 5, the shores of the lake were severely grazed and the density of animal trails increased due to the animals continuously visiting the lake for watering, thereby leading to surface erosion in this area.

Analysis of variance showed a significant difference in basal area among the three sites (P<0.05) (Table 1). The basal area was increased with greater distance from the lake. Likewise, Todd (2006) reported that perennial plant cover increased with distance from water sources. Fusco et al (1995) indicated that long-term cattle grazing of areas near water sources was associated with a decline in perennial *Gramineae* species. Gemedo Dalle et al (2006) found a significant correlation between distance from water sources and *Gramineae* plants, with the number of *Gramineae* species increasing

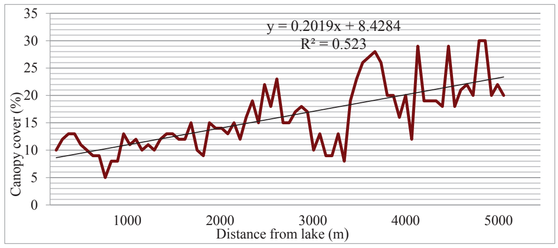


**Figure 4- Average basal area of study sites**

*Şekil 4- Deneme alanlarının ortalama bitki ile kaplı alan değerleri*

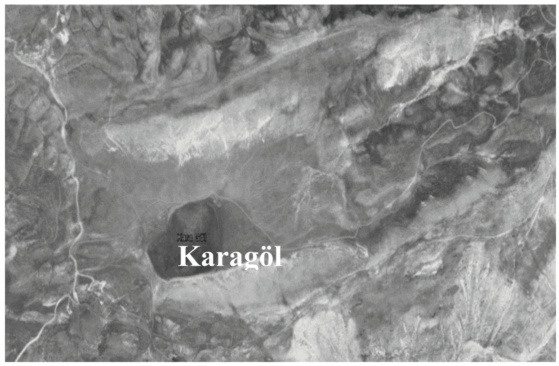


**Figure 5- The center of the study area; Karagol Lake and its circumference**

*Şekil 5- Çalışma alanının merkezi; Karagöl ve çevresi*

**Table 1- Variance analysis (ANOVA) of basal area of sample plots**

*Çizelge 1- Deneme alanlarının bitki ile kaplı alan değerlerine ait varyans analizi*

| *Sites* | *Number of samples* | *Average canopy cover (%)* | *Standard deviation* | *F value* | *Significance level* |
|---|---|---|---|---|---|
| First site (Plot I) | 42 | 10.71 | 2.10 a | 55.161 | 0.000* |
| Second site (Plot II-III) | 84 | 14.46 | 3.86 b | | 0.000* |
| Third site (Plot IV-V) | 84 | 22.16 | 4.74 c | | 0.000* |
| Total | 210 | 16.00 | 6.00 | | |

*, significant at the 5% of probability level (P<0.05)

with distance from the water source. Vallentine (1990) revealed that cattle heavily grazed on fodder plants around the water sources, thereby decreasing the basal area within this area. In conclusion, the values obtained for basal area indicate heavy grazing effect circularly around the water sources while grazing effect decreases moving away from water sources (Child et al 1971; Graetz & Ludwig 1978; Tolsma et al 1987; Perkins & Thomas 1993; Brits et al 2002).

Average oven-dry hay yield for the whole study area was 911.1 kg ha$^{-1}$. It was also determined that the average hay yields were 639.0 kg ha$^{-1}$, 1542.9 kg ha$^{-1}$, and 2146.3 kg ha$^{-1}$ for three sites, respectively (Figure 6). ANOVA results showed that hay yields differed significantly among the study sites (P<0.05) (Table 2). Hart et al (1989) found that 77% grazing in a 1000 ha range occur within 400 m of the water sources. Solomon et al (2007) found that heavy grazing pressure occurred circularly around water sources. They also stated that vegetation structure changed and hay yield decreased around the water source. Naveh & Whitaker (1979) found that cattle need to drink water regularly 2-3 times per day, and heavily grazed the circumferences of water sources and that changed the vegetation structure. Holechek et al (2004) found that animals spend much time around water sources, especially in dry seasons.

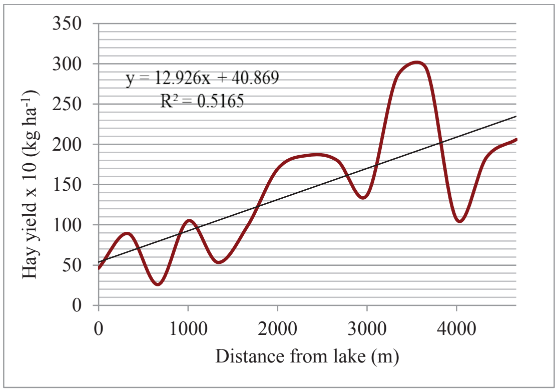


**Figure 6- Average hay yields in study sites**

*Şekil 6- Deneme alanlarına ait kuru ot verimi ortalamaları*

The similarity index of Sorenson (1948) was used to determine similarities in plant communities between the sites. The greatest similarity in vegetation was found between the second (1000-3000 m) and the third (3000-5000 m) sites (40.31%) (Table 3). The least similarity in vegetation was found when comparing the first site immediately around the lake (0-1000 m) with the third site (3000-5000 m). This finding indicated that the botanical composition of the vegetation differs according to distance from the water source.

**Table 2- Variance analysis (ANOVA) of hay yield of sample plots**

*Çizelge 2- Deneme alanlarının verim değerlerine ait varyans analizi*

| *Sites* | *Number of samples* | *Average hay yields (kg ha$^{-1}$)* | *Standard deviation* | *F value* | *Significance level* |
|---|---|---|---|---|---|
| First Site (Plot I) | 35 | 639.0 | 323.8 a | 10.45 | 0.002* |
| Second Site (Plot II-III) | 70 | 1542.9 | 362.4 b | | 0.009* |
| Third Site (Plot IV-V) | 70 | 2146.3 | 767.6 c | | 0.023* |
| Total | 175 | 14427 | 804.3 | | |

*, significant at the 5% of probability level (P<0.05)

**Table 3- Similarity indices in the study area (%)**

*Çizelge 3- Araştırma alanına ait benzerlik indeksi değerleri (%)*

| | *First site/second site* | *First site/third site* | *Second site/third site* |
|---|---|---|---|
| Similarity indices | 33.85 | 30.31 | 40.31 |

This study was carried out on the rangelands of Ahır Mountain in Kahramanmaras province, Turkey. The effect of distance from natural water sources directly affects uniform grazing, and therefore the hay yield and plant community structure. The findings indicated that basal area and hay yields decreased closer to water sources; and botanic composition changed due to the heavier grazing pressure around water sources. Therefore, survey sites with a greater difference in terms of their proximity to water sources showed less similarity between plant communities. The study also showed that the number of animal routes increased closer to water sources, with heavy grazing alongside these routes, because animals need to drink water frequently. One of the most basic issues of rangelands management is to identify the number and locations of water sources that might provide homogenous grazing within a rangeland area. It was concluded that there were insufficient or unevenly-distributed water sources within the study area to meet the needs of animals. The area therefore requires additional evenly distributed water sources and some other structures (salt-licks and scratching-posts, etc.) for animals. Besides, a new network of routes should be established to prevent animals wandering when accessing water sources.

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# Yield, Weed Infestation and Seed Quality of Soybean (*Glycine max* (L.) Merr.) under Different Tillage Systems

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**ABSTRACT**

Soybean is a very valuable crop plant and the soybean crop area is continually increasing in the world and in Poland. The effectiveness of soybean cultivation depends on soil and climatic conditions as well as on appropriate tillage. An alternative for plough tillage in the cultivation of soybean is to grow this crop using no-tillage, the popularity of which is constantly growing. The aim of this study was to compare the effect of conventional tillage (CT) and no-tillage (NT) on yield, weed infestation and qualitative seed composition of soybean grown under the conditions of the Lublin Upland. A field study was carried out over the period 2009-2012 at the Czesławice Experimental Farm (51° 18′ 23″ N, 22° 16′ 2″ E). The experiment was set up on loess-derived grey-brown podzolic soil as a split-block design in four replicates. The experimental factors were the following tillage systems: conventional tillage (CT) and no-tillage (NT). The soybean cultivar Nawiko was grown in the experiment. The present study showed that the soybean seed yield obtained under CT was higher by 24.3% than under NT. The main reason of the seeds yield decrease in the NT was less soybean plant density. The significant higher number and weight of weeds were recorded in NT, relative to CT. The oil content in seed harvested from the NT plots was found to be higher by 0.3%.

Keywords: *Glycine max*; Conventional system; No-tillage

# Farklı Toprak İşleme Sistemlerinin Soya Fasulyesinde (*Glycine max* (L.) Merr.) Verim, Tohum Kalitesi ve Yabancı Ot Oranına Etkisi

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Geliş Tarihi: 26 Kasım 2015, Düzeltmelerin Gelişi: 24 Aralık 2015, Kabul: 24 Aralık 2015

**ÖZET**

Soya fasulyesi önemli bir bitkidir ve dünyada ve Polonya'da ekiliş alanı artmaktadır. Soya fasulyesi yetiştiriciliğinin etkinliği toprak ve iklim faktörlerinin yanında uygun toprak işlemesine de bağlıdır. Soya fasulyesi yetiştiriciliğinde pullukla devirerek toprak işlemeye alternative bir yöntem de güncelliği giderek artan toprak işlemesiz soya fasulyesi yetiştiricilğidir. Bu çalışmanın amacı geleneksel toprak işleme (CT) ile toprak işlemesiz (NT) soya fasulyesi yetiştiriciliğinin Lublin, Polonya koşullarında verim, kalitatif tohum kalitesi ve yabancı ot oranına etkisini karşılaştırmaktır. Bu amaçla 2009-2012 yıllarında Czeslawice Araştırma Çiftliğinde (51° 18′ 23″ N, 22° 16′ 2″ E) bir tarla denemesi yürütülmüştür. Deneme, lös oluşumlu grikahverengi podzol toprak üzerinde 4 tekerrürlü olarak bölünmüş parseller deneme deseninde yürütülmüştür. Araştırmada; geleneksel toprak işleme (CT) ve toprak işlemesiz (NT) toprak işleme faktörleri olarak ele alınmıştır. Soya fasulyesinin Nawiko çeşidi kullanılmıştır. Çalışmadan elde edilen sonuçlar; soya fasulyesi tohum veriminin toprak işlemesiz (NT) yetiştiriciliğe göre geleneksel toprak işlemeli (CT) yöntemde % 24.3 daha fazla olduğunu göstermiştir. Toprak işlemesiz yöntemde bitki sıklığının az olması tohum veriminin az olmasında temel etken olmuştur. Geleneksel toprak işlemeye (CT) oranla, toprak işlemesiz (NT) yöntemde ağırlık ve sayı olarak yabancı ot önemli derecede yüksek olmuştur. Toprak işlemesiz yöntemde (CT) hasat edilen tohumların yağ içeriği % 0.3 daha yüksek olmuştur.

Anahtar Kelimeler: *Glycine max*; Geleneksel toprak işleme; Toprak işlemesiz



## 1. Introduction

Soybean is a species that enjoys a growing popularity in the world. In the last ten years, soybean production has increased by 45%. The cultivation of this crop is concentrated mainly in North and South America. In 2013, these two regions accounted for as much as 87.1% of the production of this crop. The United States, Brazil, Argentina as well as China and India are the largest soybean producers. Over the last decades, Europe's soybean production has increased more than three times and in 2013, it made up 2.2% of the total global production. In Poland, the area of this crop has doubled since 2003, standing at 855 ha in 2012, while the soybean production increased more than five times in the same period (FAOSTAT 2015).

In soybean cropping, climatic conditions, primarily temperature and rainfall, are the factors that limit the yield potential of this crop plant. In areas with low levels of rainfall, it is very important to prepare the soil in a way that will ensure retention of the highest possible amount of rainwater. Agronomic practices involving the replacement of the plough with implements that do not turn the soil over or the complete abandonment of mechanical tillage (no-tillage) offer this possibility to agricultural producers. As a result of the use of no-tillage, there are changes in soil density and compactness, while the moisture and nutrient content in the soil upper layers increase (Majchrzak et al 2004; Martinez et al 2008; Çelik 2011). The effectiveness of no-tillage is dependent on the type of soil and its moisture conditions and using of appropriate seeder type (Altikat & Çelik 2012). Many authors stress that no-till should not be used in light soils (Munkholm et al 2003; De Vita et al 2007; Martinez et al 2008; Włodek et al 2012). No-tillage frequently results in excessive weed infestation of the crop and the weed structure changes as a result of long-term use of this tillage system (the proportion of perennial weeds increases) (Blecharczyk et al 2004). This problem can be solved, among others, by using non-selective systemic herbicides before sowing or by sowing soybean seeds in a cover crop (Oliveira et al 2013; Bernstein et al 2014). As a result of the use of no-tillage, reduced crop yields are recorded (Yalcin & Cakir 2006; Korzeniowska & Stanisławska-Glubiak 2009), but its soil protective effect and lower energy inputs on no-tillage operations, compared to conventional tillage, offer a huge opportunity to spread this tillage system (Dzienia et al 2006; Yalcin & Cakir 2006).

The aim of this study was to compare the effect of plough tillage and no-tillage on yield, qualitative seed composition and weed infestation of soybean grown under the conditions of the Lublin Upland.

## 2. Material and Methods

### *2.1. Materials and plant experiment*

A field study was carried out over the period 2009-2012 at the Czesławice Experimental Farm (51° 18′ 23″ N, 22° 16′ 2″ E), belonging to the University of Life Sciences in Lublin. In 2010, the soybean plantation was terminated due to adverse weather conditions and the resultant inhibited plant emergence. The area of each experimental plot was

96 $m^2$. The soybean cultivar Nawiko was grown in the experiment. The study factors were the following tillage systems.

Conventional tillage (CT)-skimming, double harrowing, autumn ploughing to a depth of 25 cm. In the spring, harrowing, cultivating, harrowing, sowing.

No-tillage (NT)-without mechanical tillage. In the spring, only Roundap Energy 450 SL (active ingredient (a.i.)-glyphosate) was applied at a rate of 3 L $ha^{-1}$.

Mineral fertilizer was applied to soybean crops before sowing at the following rates: N-50 kg $ha^{-1}$, P-35 kg $ha^{-1}$, K-83 kg $ha^{-1}$. Mineral fertilizer rates were determined based on the nutritional requirements of soybean and soil nutrient availability.

Each year, soybean was sown at the turn of April and May in a field after winter wheat. The row spacing was 20 cm, seeding depth 3 cm, and planned plant density 100 plants $m^{-2}$.

Before sowing, soybean seeds were inoculated with *Bradyrhizobium japonicum* bacteria and the seed dressing Vitavax 200 FS (a.i. carboxin, thiuram) was applied at a rate of 400 mL 100 $kg^{-1}$ seed. Immediately after sowing, a mixture of the herbicides Afalon Dyspersyjny 450 SC (a.i. linuron)+Dual Gold 960 EC (a.i. S-metolachlor) was applied at the rate of 1 L+1.8 L $ha^{-1}$. Each year, the soybean crop was harvested in the first 10-day period of September.

### *2.2. Soil conditions*

The soil was characterized by slightly acidic pH (in 1 M KCl= 6.2), high phosphorus and potassium availability as well as medium magnesium availability. The humus content was 1.2%.

### *2.3. Meteorological conditions*

During the first growing season of soybean (2009), the average air temperature in individual months was generally higher than the long-term mean (Figure 1). Lower temperatures were only recorded in May and June. The rainfall in 2009 exceeded the long-term mean only in May and June (Figure 2). The next growing season (in 2010) proved to be unfavorable for soybean, primarily due to a rather low temperature in the month of sowing (April) and heavy rainfall in May which much exceeded the long-term mean. On account of unsatisfactory emergence, the soybean plantation was terminated in the second year of the experiment. The year 2011 turned out to be favorable for soybean development in terms of thermal conditions. In particular months of the growing season, higher or similar (May, July) temperatures were generally recorded compared to the long-term mean. Lower than average rainfall was recorded during the initial period of soybean growth (April and May) as well as during maturation and harvest (August and September). The last year of the study (2012) was very warm and quite dry. A higher than average temperature was recorded in

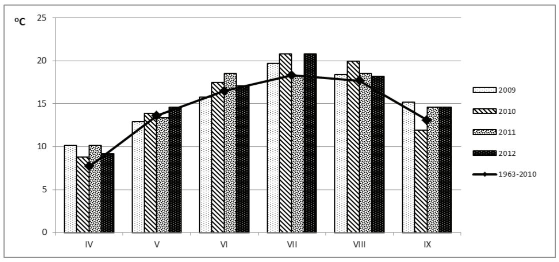


**Figure 1- Mean monthly in 2009 and 2012, and long term air temperature (°C) at the Czesławice Meteorological Station**

*Şekil 1- Czesławice Meteoroloji İstasyonu 2009-2012 yılları ve uzun dönem aylık ortalama hava sıcaklığı (°C) verileri*

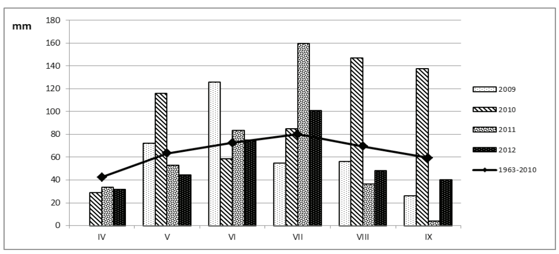


**Figure 2- Long term and monthly rainfall in 2009-2012 at the Czesławice Meteorological Station**

*Şekil 2- Czesławice Meteoroloji İstasyonu 2009-2012 yılları ve uzun dönem aylık ortalama yağış (mm) verileri* all the months. The total rainfall exceeded the long-term mean in June and July.

*2.4. Sampling and plant analysis*

Plant density after emergence and before harvest was estimated in two rows along a length of 2.5 m. The yield traits were determined based on a sample consisting of 30 randomly selected plants from each plot. The seed yield was weighed separately for each plot and the obtained results were expressed hectare basis. Weed infestation of the soybean crop was determined using the dry-weight-rank method at the pod and seed maturation stage (BBCH 81/82). The evaluation involved the determination of the botanical composition of weeds, their density and air-dry weight. The sampling area was delineated with a 1 m×0.5 m quadrat frame in two randomly selected places in each plot.

The content of protein, oil and fiber in soybean seed was determined using the phenomenon of light reflection within the range of near infrared of the analyzed substance, with the use of an Omega G computer transmission analyzer of the whole grain (Bruins Instruments, Germany) at the Department of Agricultural Ecology of the University of Life Sciences in Lublin.

*2.5. Experimental design and statistical analysis*

The experiment was set up on loess-derived grey-brown podzolic soil as a split-block design in four replicates. The results obtained in the years 2009, 2011, and 2012 were statistically analyzed using analysis of variance (ANOVA) using SAS programme (Statistical Analysis Software) and, the significance of differences was evaluated by Tukey's test at P≤0.05.

## 3. Results and Discussion

*3.1. Yielding and structure of yield of soybean*

On average for the three-year study, the soybean seed yield obtained in the CT treatment was higher by 24.3% compared to NT (Table 1). Most authors confirm that under NT conditions lower soybean

**Table 1- Yield and selected characteristic of soybean yield structure**

*Çizelge 1- Toprak işleme sistemlerine gore soya fasulyesi verim ve verim ögeleri*

| *Soil tillage (ST)* | *Years* | *Yield (t ha$^{-1}$)* | *Plant density after emergence (No m$^{-2}$)* | *Plant density before harvest (No m$^{-2}$)* | *Plant height (cm)* | *1000 seeds weight (g)* | *First pod height (cm)* |
|---|---|---|---|---|---|---|---|
| Conventional tillage (CT) | 2009 | 3.02 | 58.0 | 48.3 | 85.4 | 126.4 | 10.6 |
| | 2011 | 3.19 | 97.0 | 95.0 | 97.4 | 139.2 | 13.0 |
| | 2012 | 2.86 | 41.8 | 34.8 | 73.7 | 106.0 | 10.6 |
| | Mean | 3.02 | 58.0 | 59.4 | 85.5 | 123.9 | 11.0 |
| No tillage (NT) | 2009 | 1.70 | 39.5 | 35.0 | 71.9 | 124.1 | 7.4 |
| | 2011 | 2.93 | 78.8 | 75.8 | 93.8 | 141.1 | 12.2 |
| | 2012 | 2.65 | 30.0 | 25.8 | 69.4 | 105.8 | 7.7 |
| | Mean | 2.43 | 49.4 | 45.5 | 78.4 | 123.7 | 9.1 |
| Mean for years (Y) | 2009 | 2.36 | 48.8 | 41.6 | 78.6 | 125.2 | 9.0 |
| | 2011 | 3.06 | 87.9 | 85.4 | 95.6 | 140.2 | 12.6 |
| | 2012 | 2.76 | 35.9 | 30.3 | 71.6 | 105.9 | 8.5 |
| LSD (P= 0.05) | | | | | | | |
| ST | | 0.406 | 6.56 | 6.62 | 5.27 | ns | 1.61 |
| Y | | 0.604 | 9.76 | 9.86 | 7.84 | 6.68 | 2.40 |
| STxY | | ns | ns | ns | ns | ns | ns |

ns, not-significant

yields are obtained than under CT (Bujak et al 2001; Gawęda et al 2014; Monsefi et al 2014). Pikul et al (2001) showed that any modifications in tillage for sowing soybean negatively affect its yield potential and yields can be lower even by a dozen or so percent. Opposite results were obtained by Houx et al (2014) who proved a significant increase in soybean yield (by 4.8%) on loamy soil under NT compared to CT.

Soybean is a plant very sensitive to environmental stresses such as low and high temperature or drought. In cold climate countries, low temperatures are the factor that determines the production of this crop (Vollmann et al 2000; Ohnishi et al 2010). The critical periods in terms of water requirement and thermal conditions occur from sowing to full emergence as well as during flowering and seed maturation (Kołodziej & Pisulewska 2000; Thuzar et al 2010). Despite that the evaluated small-seeded soybean cultivar Nawiko is very sensitive to variable and adverse weather conditions (Kołodziej & Pisulewska 2000), its average yields obtained in this experiment were higher by 0.12 t $ha^{-1}$ compared to cv. Aldana and by 0.37 t $ha^{-1}$ in relation to cv. Augusta grown under the same agronomic, climatic and soil conditions (Gawęda et al 2014). In the present experiment, the highest soybean yield was harvested in the year 2011 which proved to be most favorable for the growth of this crop (Table 1). Moderate rainfall and the temperature in May and June at a level of the long-term mean guaranteed even emergence; this was translated into a high plant density, in particular under conventional tillage. Regardless of tillage system, soybean produced the worst yield in the first year of the study in which April was a rainless month, in May and June the rainfall much exceeded the long-term mean, whereas July, August and September were dry months. The air temperature slightly exceeded the long-term average. Rainfall was the yield-limiting factor in this growing season. Excessive rainfall at the initial growth stages disturbed the water and air relations and caused soil crusting and uneven emergence. The adverse weather conditions in 2009 had a particularly negative effect on the yield of soybean grown under NT. Relative to CT, the crop productivity was lower by 43.7%. Włodek et al (2012) proved that in the case where NT is used both an excess and deficiency of rainfall cause large changes in yields. In the present study, in 2009 an almost half lower yield was obtained under NT conditions compared to CT, which could have been caused by a high amount of rainfall during the initial growth stages of soybean; in grey-brown podzolic soil this resulted in excessive soil moisture. This problem was not observed when mechanical tillage was used. Lower yields were also obtained under NT, compared to CT, in the next two years of the study, but the differences between these tillage systems were smaller as 8.2% in 2011 and 7.3% in 2012.

As far as the soybean crop and yield components are concerned, the tillage systems used significantly modified only the plant density after emergence and before harvest, plant height, and first pod height (Table 1). Under CT, the plant density was found to be higher by 32.8% after emergence and by 30.5% before harvest compared to that found under NT. The plant height and first pod height were also higher in the CT treatment, respectively by 9.1 and 20.9%. The values for the above-mentioned crop and yield components were most favorable in the year 2011 in which the highest seed yield was obtained. Tillage system did not have a major effect on 1000 seed weight, number of seeds per pod, number of pods per plant as well as number and weight of seeds per plant (Tables 1 and 2). The number of pods per plant differed significantly depending on the interaction between factor of experience and years of research. In both soil tillage systems, the highest number of pods per plant were obtained in 2012. In their research, Gawęda et al (2014) also demonstrated similar trends in the changes in the soybean yield structure. Monsefi et al (2014) showed tillage system to have a significant effect on plant height only during the initial period of plant growth, whereas the soybean plant height before harvest was similar under CT and NT. On the other hand, Bujak et al (2001) proved that due to high weed infestation of the crop NT resulted in the lengthening of soybean plants and thus the higher first pod height compared to CT. In the present experiment, the 1000 seed weight and the number of seeds per pod were comparable under CT and NT. Monsefi et al (2014) proved however that the above-mentioned traits were significantly lower under NT compared to CT.

*3.2. Weed infestation*

On average for the three-year study period, the tillage systems used significantly modified the number and air-dry weight of weeds in the soybean crop (Table 2). In the NT treatment, compared to CT, the number of weeds was higher by 24.3 plant $m^{-2}$, whereas their dry weight by 40.1 g $m^{-2}$. The dry weight of weeds differed significantly depending on the tillage system throughout the study years. The highest weight of weeds was recorded in no tillage plots (NT) in the years 2012 and 2009, which were characterized by low rainfall. In conventional tillage (CT) weed growth was inhibited by a shortage of rainfall.

The tillage systems used significantly modified the floristic composition of weeds (Figure 3). Under NT, the perennial species *Elymus repens* was dominant. *Galinsoga ciliata* was also found in great numbers. The use of CT substantially reduced the numbers of most weeds occurring in the soybean crop, in particular *E. repens* and *G. ciliata*. Under CT, *Chenopodium album* was the most numerous, while among the perennial species it was *Equisetum arvense*. The increased numbers of perennial weeds in NT treatments are also confirmed by the studies of Halford et al (2001) and Bujak et al (2004). Gibson et al (2005) report that in soybean and maize crops weeds are a greater problem than diseases, nematodes and insects. Norsworthy (2003) and Vollmann et al (2010) also found that weed competition significantly reduced soybean yields.

**Table 2- Some of characteristic of soybean yield structure and number and weight of weeds in soybean canopy**

*Çizelge 2- Toprak işleme yöntemlerine gore soya fasulyesi verim ögeleri ile yabancı ot sayı ve ağırlıkları*

| *Soil tillage (ST)* | *Years* | *Number of pods per plant (No)* | *Number of seeds per pod (No m⁻²)* | *Number of seeds per plant (No m⁻²)* | *Weight of seeds per plant (g)* | *Number of weeds (No m⁻²)* | *Weight of weeds (g m⁻²)* |
|---|---|---|---|---|---|---|---|
| Conventional tillage (CT) | 2009 | 29.1 | 1.8 | 53.4 | 6.8 | 4.0 | 8.5 |
| | 2011 | 16.9 | 1.9 | 32.2 | 4.5 | 9.0 | 53.3 |
| | 2012 | 33.4 | 2.0 | 68.2 | 7.3 | 4.3 | 29.0 |
| | Mean | 26.5 | 1.9 | 51.3 | 6.2 | 5.8 | 30.3 |
| No tillage (NT) | 2009 | 24.9 | 2.0 | 48.6 | 6.0 | 20.2 | 86.2 |
| | 2011 | 18.3 | 1.8 | 33.5 | 4.8 | 33.2 | 33.0 |
| | 2012 | 39.6 | 2.0 | 78.9 | 8.6 | 36.8 | 92.0 |
| | Mean | 27.6 | 1.9 | 53.7 | 6.5 | 30.1 | 70.4 |
| Mean for years (Y) | 2009 | 27.0 | 1.9 | 51.0 | 6.4 | 12.1 | 47.4 |
| | 2011 | 17.6 | 1.8 | 32.8 | 4.6 | 21.1 | 43.2 |
| | 2012 | 36.5 | 2.0 | 73.6 | 8.0 | 20.6 | 60.5 |
| LSD (P= 0.05) | | | | | | | |
| ST | | ns | ns | ns | ns | 13.02 | 16.13 |
| Y | | 4.48 | ns | 10.46 | 1.38 | ns | ns |
| STxY | | 7.88 | ns | ns | ns | ns | 12.24 |

ns, not-significant

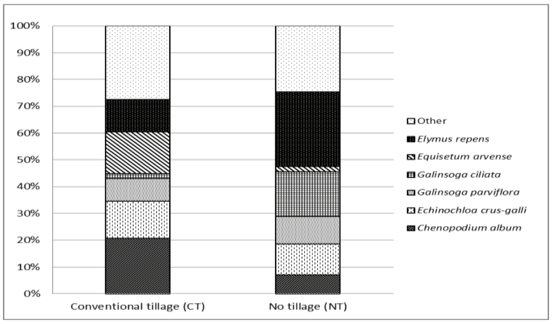


**Figure 3- Percentage of dominant weeds species in soybean canopy (mean from 2009-2012)**

*Şekil 3- Soya fasulyesi deneme alanında 2009-2012 ortalaması olarak yaygın yabancı ot türleri*

*3.3. Qualitative seed composition*

In the present study, tillage system did not have a significant effect on the seed protein and fiber content, but the oil content in seed harvested from the NT treatment was higher by 0.3% relative to CT (Table 3). In both tillage systems the highest fat content was recorded in 2012, characterized by a small but well-distributed rainfall during the growing season.

**Table 3- Selected quality properties in seeds of soybean**

*Çizelge 3- Soya fasulyesi tohumlarının kimi kalite özellikleri*

| *Soil tillage (ST)* | *Years* | *Protein* | *Fat* | *Fibre* |
|---|---|---|---|---|
| | | | *(%)* | |
| Conventional tillage (CT) | 2009 | 35.3 | 17.1 | 5.0 |
| | 2011 | 35.0 | 17.1 | 5.0 |
| | 2012 | 29.5 | 18.6 | 5.5 |
| | Mean | 33.3 | 17.6 | 5.2 |
| No tillage (NT) | 2009 | 35.0 | 17.2 | 5.0 |
| | 2011 | 33.8 | 17.9 | 5.0 |
| | 2012 | 29.6 | 18.6 | 5.4 |
| | Mean | 32.8 | 17.9 | 5.1 |
| Mean for years (Y) | 2009 | 35.2 | 17.2 | 5.0 |
| | 2011 | 34.4 | 17.5 | 5.0 |
| | 2012 | 29.6 | 18.6 | 5.5 |
| LSD (P= 0.05) | | | | |
| ST | | ns | 0.20 | ns |
| Y | | 1.02 | 0.29 | 0.09 |
| STxY | | ns | 0.52 | ns |

ns, not-significant

Also, the results of other authors' research do not show that tillage system determines the content of major constituents of soybean seed. In the studies of Houx et al (2014), the use of NT did not modify significantly the seed protein and fiber content. In the research of Gao et al (2009), however, NT contributed to an increase in oil yield per hectare.

## 4. Conclusions

The soybean seed yield obtained under CT was higher by 24.3% relative to NT. The main reason of the seeds yield decrease in the NT was less soybean plant density, which contributed indirectly to increased weed infestation. A 5-fold higher number of weeds and an over 2-fold higher weed weight were recorded in the NT treatment compared to CT. A richer floristic composition of weeds in the soybean crop and an increase in the numbers of the dominant species, in particular *E. repens* and *G. ciliata*, were found under NT. In seed harvested from the NT plots the oil content was found to be higher by 0.3%.

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# Farklı Kullanım Geçmişine Sahip Doğal Meralarda Yem Kalitesinin Büyüme Mevsimindeki Değişimi

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**ÖZET**

Bu araştırma, Tekirdağ Karahisarlı köyünün otlanan, korunan ve sürülüp terkedilen meralarında iki yıl süreyle (2010 ve 2011) yürütülmüştür. Meraların her birinde 30x20 m (600 $m^2$) 4'er örneklik alan içerisinde belirlenen 4 hat üzerinde 4 farklı noktadan 30 Mart-15 Temmuz arasında 15'er günlük aralıklar ile ot örnekleri alınmıştır. Mera otlarının iki yıllık ortalamalarına göre sırasıyla ham protein (HP), ham yağ (HY), ham kül (HK) oranları korunan merada % 10.93, % 1.78 ve % 7.71, otlanan merada % 9.46, % 2.03 ve % 7.86 ve sürülüp terkedilen merada % 8.55, % 1.69 ve % 8.55 olarak bulunmuştur. Mart-Temmuz arası 15 günlük aralıklarla alınan örneklerde en yüksek ham protein otlanan merada 30 Nisan'da (% 10.86), korunan merada 15 Mayıs'ta (% 12.17) ve sürülüp terkedilen merada 15 Nisan'da (% 14.92) belirlenmiştir. Otun, ADF ve NDF oranları sırasıyla korunan merada % 38.38 ve % 49.68, otlanan merada % 36.92 ve % 51.77 ve sürülüp terkedilen merada % 35.84 ve % 50.93 olarak bulunmuştur.

Anahtar Kelimeler: Mera; Besin maddesi içerikleri; Ham protein; ADF ve NDF

# The Changes of Chemical Content of Natural Pastures with Different Using History during Growing Season

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**ABSTRACT**

This research was carried out on enclosured, grazed and abandoned pastures in Karahisarlı village in the province of Tekirdağ for two years (2010 and 2011). The measurements were taken on four line in each of four designated sampling areas on the pastures. The forage samples were taken between 30 March and 15 July for 15-days intervals. According to average of the two year, the ratio of crude protein, crude fat, crude ash content were found as 10.93%, 1.78% and 7.71% on enclosured pastures, 9.46%, 2.03% and 7.86% on grazed pastures and 8.55%, 1.69% and 8.55% on abandoned pastures, respectively. Between March and July, samples collected for 15-days intervals indicated that the highest ratio of crude protein was determined on 30 April on grazed pastures (10.86%), on 15 May on enclosured pastures (17.12%) and on 15 April on abandoned pastures (14.92%). ADF and NDF ratios which shows digestibility of feed were found in enclosured range as 38.28% and 49.68%, in the grazed range as 36.92% and 51.77%, on abandoned range as 35.84% and 50.93%, respectively.

Keywords: Pasture; Nutrient contents; Crude protein; ADF and NDF



## 1. Giriş

Türkiye, 14.8 milyon BBHB'ne eşdeğer hayvan ile dünyada ön sıralarda yer alırken, hayvan başına üretilen et ve süt veriminde ise gerilerde yer almaktadır. Bu durum daha çok hayvan ırkları ile hayvanların yetersiz beslenmesi ve hayvan refahının düşünülmemesi gibi nedenlerden kaynaklanmaktadır. Ancak, 2008-2012 yılları arasında hayvancılık desteklerinin artırılması ile kültür ve melez ırklar % 42, küçükbaş hayvanlar % 17.4 oranında artmış, buna karşılık süt üretimi ise yaklaşık % 30 oranında (Anonim 2013) artmıştır.

Ülkemizde büyük ve küçükbaş hayvanların beslenmesinde en önemli kaba yem kaynağı olan çayır ve meraların uygunsuz ve amaç dışı kullanılmaları sonucunda, üretim güçlerinin ve biyoçeşitliliklerinin azalması ile topraklarının erozyona maruz kalması gibi büyük değişikliler ortaya çıkmıştır. Mera bitki örtülerinde lezzetli besin değeri yüksek türler üretim güçlerini kaybetmiş ya da ortamdan kaybolmuş, daha az tercih edilen yabancı otlar hakim olmuşlardır. Ancak son yıllarda mera ıslah ve amenajman çalışmaları ile bu durum tersine dönmeye başlanmıştır.

Mera bitki örtüleri çok sayıda buğdaygiller ve baklagiller ile diğer familyalara ait farklı türlerden oluşan bir karışımdır. Bu karışımlarda buğdaygillerin karbonhidrat, baklagillerin protein ve diğer familyaların da mineral elementler bakımından daha zengin (Andiç 1981; Bakoğlu 1995; Vallentine 2000) oldukları ifade edilmiştir. Bu nedenle çayır ve meraların besin değerleri mono kültür yem bitkilerinden farklıdır (Vázquez de Aldana et al 2000).

Yem üretiminin kalitesi ve miktarı meralarda otlayan hayvanların üretim seviyesinin belirlenmesinde temel faktördür (Heitschmidt et al 1995). Hayvancılıkta bol süt verimi, yüksek üreme gücü ve yeterli kâr edinimi hayvanların yeterli derecede beslenmesine bağlıdır. Yemlerdeki besin eksiklikleri, hayvanların yeterli beslenememesine, düşük verime, salgın hastalıklara ve parazitlere karşı korumasız olmasının yanında üreme problemlerine neden olmaktadır (Sultan et al 2008).

Mera otlarının besin değerlerinin bilinmesi hayvan besleme açısından önem arz eder. Türkiye'de hayvanların yıllık ham protein ihtiyacı 2.1 milyon tondur. Bu ihtiyacın ne kadarının meralarımızdan karşılanabileceğinin bilinmesi önemlidir. Karslı et al (2003), otlatma sezonunda HP, ADF ve NDF oranlarının sırasıyla, korunan merada % 6.33-15.18, % 33.57-43.14 ve % 55.23-70.73, otlanan merada % 7.04-15.74, % 32.44-44.51 ve % 55.63-73.83 arasında değiştiğini belirtmişlerdir. NRC (2001) süt ineklerinin erken laktasyon döneminde günlük protein ihtiyacının kuru maddede % 16.5-17.5 arasında olması gerektiğini ön görmüştür. Besi hayvanları için ham protein oranı % 6.25 in altına düşmeyen kaba yemler için ek yemleme yapılmaz (Caton et al 1988). ABD'de bulunan Dairyland Laboratuvarında 2001'de yapılan kaba yem tahlili sonucunda, mera otlarında ADF ve NDF arasında % 20'lik farkın ideal olduğu belirtilmiştir (Anonim 2014). Redfearn et al (2004), yemlerin nispi besleme değerinin 100 olabilmesi için ADF'nin % 41 ve NDF'nin % 53 olması gerektiğini ve nispi besleme değerinin 100'den büyük olması durumunda yem kalitesinin arttığını, altına düşmesi durumunda ise azaldığını bildirmişler ve nispi besleme değerini, ADF'nin % 20 ve NDF'nin % 30 olduğu durumda 227 ve ADF'nin % 49 ve NDF'nin % 56 olduğu durumda ise 84 olarak bulmuşlardır.

Çayır ve mera otlarının yem üretimi ve kalitesinin çeşitli ekolojik ve çevre faktörlerine göre değiştiği bilinmektedir. Yem üretimi ve kalitesi bitki florası, büyüme şartları, vejetasyon dönemi, botanik bileşim, iklim faktörleri, toprağın yapısı, denizden yükseklik, sulama ve gübrelemeye bağlı olarak değişmenin yanında (Holmes 1994; Ergün et al 2002) otun örnekleme zamanı (Avcı et al 2006; Çetiner et al 2012) ile meralardan faydalanma biçimi ve şiddetine (George et al 2001) göre de değişmektedir.

Bu çalışmanın amacı, korunan, otlanan ve sürülüp terkedilen meralarda bitki büyüme döneminde ve farklı örnekleme tarihlerinde otun ham protein, ham kül, ham yağ, ADF ve NDF oranlarının belirlenmesi ve hayvan besleme yönünden yeterlilik durumunun ortaya konmasıdır.

## 2. Materyal ve Yöntem

Araştırma, Tekirdağ ili Merkez Karahisarlı Köyü'nde iki yıl süreyle (2010, 2011) otlanan, korunan ve sürülüp terk edilen doğal meralarda yürütülmüştür.

Yıllık ortalama sıcaklık 2010 yılında 14.9 °C, 2011 yılında 15.8 °C ve bu yılların ortalaması 15.4 °C olmuştur. Uzun yıllar (1975-2011) ortalama sıcaklık ise 14.3 °C'dir. Toplam yağış 2010 yılında 803.9 mm, 2011 yılında 729.6 mm ve bu yılların ortalama yağışı 766.8 mm olarak gerçekleşirken uzun yılların toplam ortalama yağışı 589.8 mm olmuştur (Anonim 2013). Araştırma yıllarında bütün ayların sıcaklık ortalaması uzun yıllar ortalamalarından yüksek olmuştur. Trakya Yöresinin bitki örtüsü Akdeniz, Orta Avrupa, kolşik ve Anadolu step bitki örtüsü özellikleri taşır (Dönmez 1990). Trakya yöresinde *Trifolium campestre*, *Medicago minima*, *Lotus corniculatus*, *Dactylis glomerata*, *Lolium perenne*, *Chrysopogon gryllus*, *Koleria cristata*, *Vulpia ciliata*, *Eryngium campestre*, *Plantago lanceolata* ve *Sanguisorba minor* baskın türler olarak belirlenmiştir (Tuna 2000; Altın et al 2007; Gür 2008).

Araştırma sahalarının toprak özelliklerinden organik madde, pH, P ve K miktarları sırasıyla otlanan merada % 2.66, 6.45, 8.50 mg $kg^{-1}$, 165.64 mg $kg^{-1}$, korunan merada % 1.19, 7.72, 3.54 mg $kg^{-1}$, 52.56 mg $kg^{-1}$ ve sürülüp terk edilen merada % 0.96, 7.74, 4.76 mg $kg^{-1}$, 75.51 mg $kg^{-1}$ olarak tespit edilmiştir. Araştırma alanında toprak reaksiyonu ve bünye sınıfları, korunan merada hafif alkali ve tınlı, otlanan merada hafif asit ve killi, sürülüp terk edilen merada ise hafif alkali ve tınlı olarak belirlenmiştir.

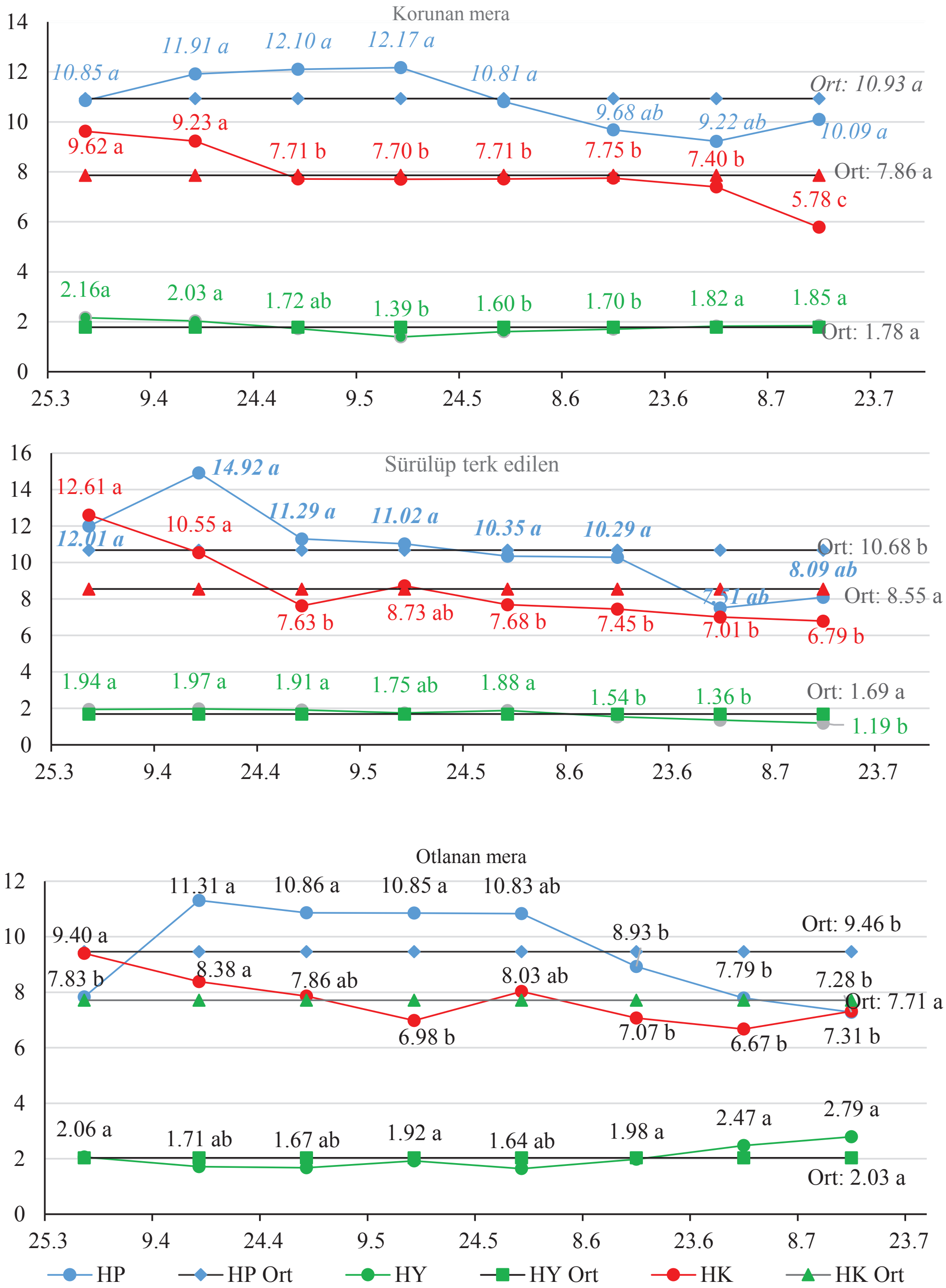
Araştırmaya konu meraların her birinde 600'er $m^2$'lik (30x20 m) 4'er adet örneklik alanlar oluşturulmuştur. Bu alanlarda, 4 hat üzerinde, 4 er adet işaret kazıkları ile ölçüm noktaları belirlenmiştir. Büyüme mevsiminde (Mart-Temmuz) otun besin maddesindeki değişimi belirlemek için 15'er günlük (Karslı et al 2003) aralıklarla 8 farklı örnekleme tarihinde işaretli noktalardan 0.25 $m^2$'lik (0.5x0.5 m) alanda toprak seviyesinden 3-5 cm yükseklikten biçilerek ot örnekleri alınmıştır. Biçilen otlar ağırlıkları sabitleşinceye kadar gölgede kurumaya bırakılmış, daha sonra 70 ºC'de 24 saat kurutulan (Tuna et al 2010) mera otlarının HP, HY, HK, ADF ve NDF oranları AOAC (1990)'nın belirttiği esaslara göre yapılmıştır.

Araştırma sonuçları tesadüf parselleri deneme planına uygun olarak SPSS 15.0 paket programında varyans analizine tabi tutulmuştur. Ortalamalar arasındaki farkların tespiti Duncan çoklu karşılaştırma testi ile yapılmıştır.

## 3. Bulgular ve Tartışma

Meraların bitki örtüsünün farklı gelişme dönemlerinde alınan ot örneklerine ait HP, HY ve HK oranları Şekil 1'de, ADF ve NDF oranları ise Şekil 2'de verilmiştir.

Meraların HP ve HY oranları arasındaki farklar önemli ($P<0.05$) bulunurken, HK oranındaki farklar önemsiz bulunmuştur. HP oranları otlanan ve sürülüp terk edilen merada aynı grupta, korunan merada farklı grupta, HY ve HK oranları aynı grupta yer almıştır. Meraların ADF ve NDF oranları arasındaki fark istatistiki açıdan önemsiz bulunmuştur. Meraların bitki örtüsünün gelişiminin hızlı olduğu 15 Nisan-15 Mayıs tarihleri arasında HP oranları aynı grupta yer almıştır.




**Şekil 1- Meraların ham protein, ham kül ve ham yağ oranları (%)**

*Figure 1- The ratios of crude protein, crude fat and ash at different times of pastures (%)*

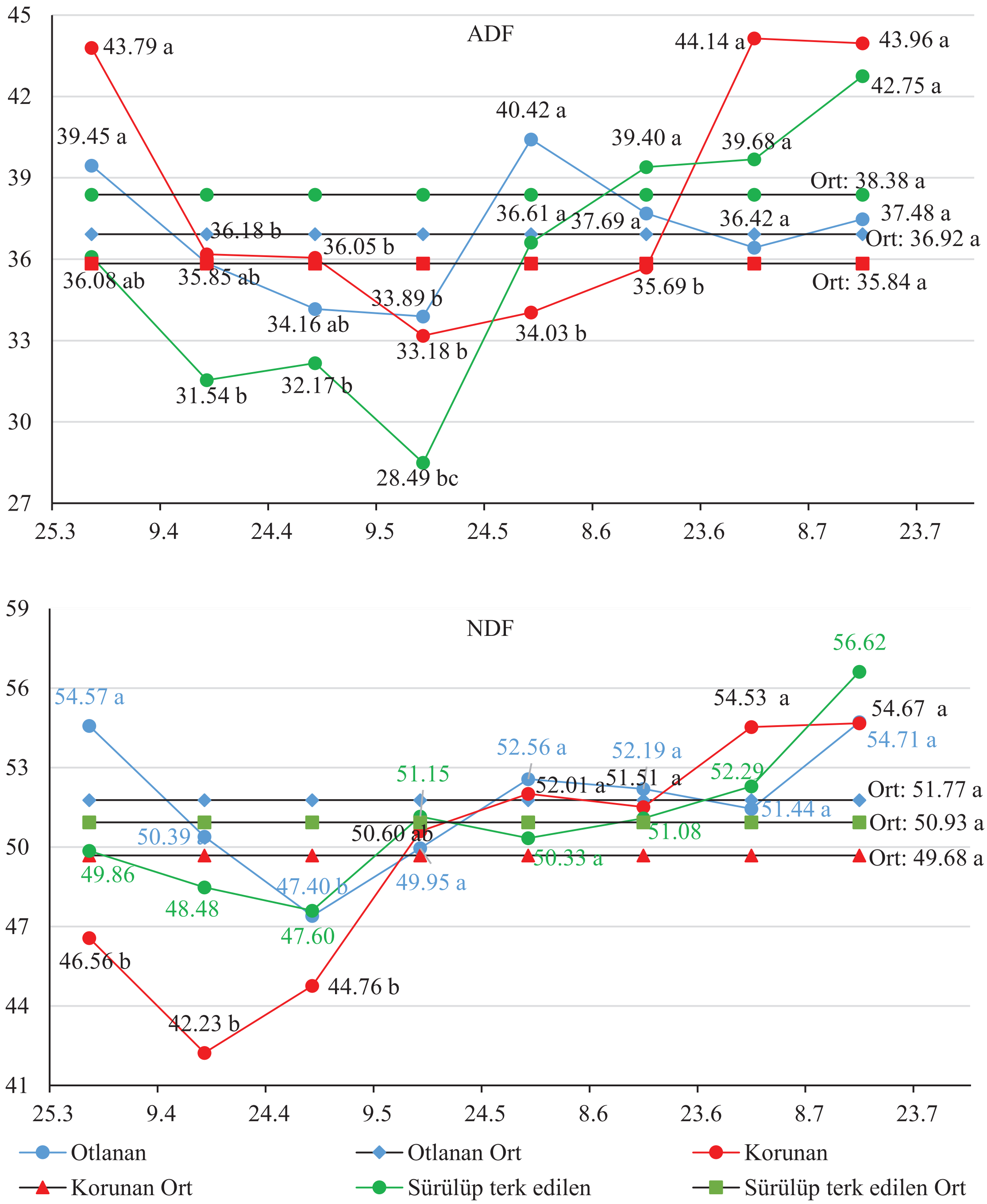
Meraların iki yıllık ortalamalarına göre; HP değeri korunan, otlanan ve sürülüp terkedilen meralarda sırasıyla % 10.93, % 9.46 ve % 10.68 olarak bulunmuştur. HP oranı en yüksek korunan, en düşük ise otlanan merada olmuştur. Bu durumun meralarda familyaların botanik kompozisyona katılım oranlarındaki farklılıklardan kaynaklandığı düşünülmüştür. Nitekim buğdaygiller karbonhidrat yönünden, baklagiller protein yönünden ve diğer familyalar da mineral maddeler yönünden daha zengindir (Andiç 1981; Vallentine 2000). Familyalardaki oran miktarındaki değişimler otun toplam oranını etkilemektedir. Ayrıca otlanan meralarda otlatma yolu ile kütle kaybı olması da ham protein oranının azalmasına neden olmuştur. Meralarda en yüksek ve düşük HP oranları sırasıyla otlanan merada 15 Nisan (% 11.31) ve 15 Temmuz (% 7.28), korunan merada 15 Mayıs (% 12.17) ve 30 Haziran (% 9.22) ile sürülüp terk edilen merada 15 Nisan (% 14.92) ve 30 Haziran (% 7.51) tarihlerinde gerçekleşmiştir. Otlanan ve korunan merada Nisan ve Mayıs aylarında HP oranları en yüksek olurken Haziran ve Temmuz aylarında en düşük olmuştur. Nisan ortalarından Mayıs sonlarına kadar HP oranları hemen hemen sabit kalmıştır. Bu zaman aralığındaki örnekleme zamanları aynı gruplarda yer almıştır. Sürülüp terkedilen merada vejetasyona hakim olan tek yıllık bitkilerin erken gelişmesi nedeniyle HP oranının 15 Nisan'da en yüksek olduğu görülmüştür. Meraların, Mart-Temmuz ayları arasında HP oranları hayvanların yaşam payı için yeterli ancak süt sığırları için yetersiz (Strange 1980) olmuştur. Ancak tüm meralarda 15 Nisan-30 Haziran tarihleri arasında ham protein oranları yeterli (NRC 2001) düzeydedir. Koç & Gökkuş (1996) otlatma sezonu başlangıcında HP oranının % 17 civarında olduğunu, yaz sonlarına doğru ise % 4 civarına düştüğünü bildirmişlerdir. Meraların HP oranları, tür çeşitliliği ve türlerin ait olduğu familyalar, toprak yapısı, gübreleme ve bitki gelişmesine bağlı olarak değişmektedir (McDonald et al 1995; Işık & Kaya 2011). Bu çalışmada elde edilen sonuçlar, benzer konuda yapılmış olan araştırma sonuçlarıyla uyumludur (Bakoğlu & Koç 2002; Erkovan et al 2009; Arslan & Tufan 2011; Bayraktar 2012).

Meraların iki yıllık ortalamalarına göre; HY oranları sırasıyla korunan, otlanan ve sürülüp terkedilen merada % 1.78, % 2.03 ve % 1.69 olmuştur. Meraların HY oranları yetersiz düzeyde (NRC 2001) kalmıştır. HY oranları, otlanan merada % 2.79-1.67, korunan merada % 2.16-1.39 ve sürülüp terkedilen merada % 1.91-1.19 arasında değişmiştir. Bitki örtüsünün geliştiği dönemlerde (Nisan-Mayıs) ham yağ oranları azalırken olgunlaşmanın ilerlemesi ile (Haziran-Temmuz) artmıştır. Avcı et al (2006), vejetasyonun ilerlemesine bağlı olarak ham yağ içeriğinde rakamsal olarak yavaş bir azalma, Arslan & Tufan (2011) ise artış olduğunu belirlemiştir. Bu araştırma sonuçları, Işık & Kaya (2011)'in belirttiği oranlardan (% 2.68) düşük bulunmuştur.

Meraların iki yıllık ortalamalarına göre; HK oranları korunan, otlanan ve sürülüp terkedilen merada sırasıyla % 7.71, % 7.86 ve % 8.55 olarak bulunmuştur. NRC (2001)'e göre mera otunun HK oranı olması gerekenden (% 9.80) daha az düzeydedir.

Meraların ADF oranları korunan, otlanan ve sürülüp terkedilen merada sırasıyla % 38.38, % 36.92 ve % 35.84 olarak bulunmuştur. Mart-Temmuz ayları arasında, ADF değişimi otlanan merada % 33.89-39.45, korunan merada % 33.18-44.14 ve sürülüp terkedilen merada % 28.49-42.75 arasında gerçekleşmiştir. Bu sonuçların, Karslı et al (2003)'ın sonuçları ile uyumlu, Avcı et al (2006) ve Bayraktar (2012)'ın sonuçlarından ise yüksek olduğu bulunmuştur. Araştırmalar arasındaki bu farklılıklar meraların bulunduğu yöre ve ekolojik faktörler ile vejetasyonu oluşturan bitki türlerinin farklılığından kaynaklanmıştır.

Meraların NDF oranları sırasıyla korunan, otlanan ve sürülüp terkedilen merada % 49.68, % 51.77 ve % 50.93 olarak belirlenmiştir. Mart-Temmuz ayları arasında NDF değişimi otlanan merada % 47.40-54.71, korunan merada % 42.23-54.67 ve sürülüp terkedilen merada % 47.60-56.62 arasında olmuştur. Bu sonuçlar Mulkey et al (2008), Erkovan et al (2009), Arslan & Tufan (2011), Alatürk (2012), Bayraktar (2012)'nin bulduğu sonuçlar ile uyumludur.




**Şekil 2- Meraların ADF ve NDF oranları (%)**

*Figure 2- The ratios of ADF and NDF at different times of pastures (%)*

Şekil 2'de görüldüğü gibi meralarda bitki örtüsünün gelişmesine bağlı olarak ADF ve NDF oranları Mart ayından Nisan ayı sonlarına kadar azalmış, bu tarihten sonra tekrar artmıştır. Ancak otlanan meralarda 30 Mayıs'tan sonra bu oranlar kısmen azalmıştır. Bu durum bitki örtüsünde diğer türlere göre daha yüksek oranda bulunan ve Haziran-Temmuz aylarında gelişme göstererek bütün yaz yeşil kalan *Chrysopogon gryllus* L.'den kaynaklanmıştır. ADF ve NDF oranlarının bazı dönemlerde azalırken bazı dönemlerde artması, mera bitki örtülerinde önce buğdaygillerin daha sonra baklagillerin (Çetiner et al 2012) ve tekrar sıcak iklim özelliği gösteren buğdaygillerin gelişme göstermesinden kaynaklandığı düşünülmüştür. Bölgede yapılan çalışmalarda (Gür 2008; Bayraktar 2012; Tuna et al 2013), Trakya'da çok sayıda buğdaygiller türünün Mart ayından Mayıs ayının ilk haftalarına kadar vejetatif gelişmesini tamamladığı özellikle 15 Mayıs'tan sonra ise başaklanmaya başladığı gözlemlenmiştir. Baklagiller ise 15 Nisan'dan sonra hızla gelişmeye başlamakta ve 15 Mayıs'tan sonra çiçeklenme dönemine girmektedir. Buğdaygiller baklagillere göre daha hızlı gelişmekte, daha çok ve daha sert saplara sahip olmaktadır. Ancak baklagillerde olgunlaşma daha yavaş olmaktadır (Nelson & Moser 1994). Bitkilerde gelişmenin ilerlemesine bağlı olarak özellikle saplarda depolanan karbonhidratların oranının artması ve kurumanın sonucunda yaprak oranının azalması ham selüloz oranının artmasına etki etmektedir (Bokhari et al 1989). Bu aynı zamanda gelişme ile birlikte ADF ve NDF içeriğinin de artması anlamına gelmektedir. Bitkiler olgunlaştıkça hücrelerinin protoplazma içerikleri hızla azalmakta (Alatürk 2012) hatta olgun hücrelerde protoplazma miktarı genç hücrelerin % 10'una kadar düşmektedir (Taiz & Zieger 2008). Bu yüzden olgunlaşma ile birlikte bitkilerde hücre çeperlerinin oranının artmasına bağlı olarak yapısal bileşiklerin oranı artmaktadır.

## 4. Sonuçlar

Tekirdağ ili Karahisarlı köyü farklı kullanım geçmişine sahip otlanan, korunan ve sürülüp terk edilen meralarında iki yıl süre ile yürütülen bu çalışmada bitki büyüme döneminde sekiz farklı örnekleme zamanında mera otlarının besin maddeleri içerikleri belirlenmiştir.

Araştırma sonuçlarına göre; meralarda ve farklı örnekleme tarihlerinde otların besin içerikleri farklı olmuştur. Bu değişimin, meraların botanik kompozisyonu ve türlerin gelişim dönemleri farklılığından kaynaklandığı düşünülmüştür. Bu bölge için meraların besin değerleri göz önüne alınarak 30 Nisan-30 Mayıs tarihleri arası en ideal otlatma dönemi olarak önerilmiştir. Ancak ilerleyen mevsimde de hayvanlara kaliteli ve besleyici bir yem periyodu için, otlanan meralarda; bitki kompozisyonunda ham proteince zengin baklagiller oranının artırılması amacıyla fosforlu gübrelemenin yapılması ve meranın belli zamanlarda korunması gibi ıslah ve yönetim ilkeleri uygulanmalıdır. Tek yıllık ve istilacı türlerin daha çok hakim olduğu sürülüp terk edilen merada ise; otlatma daha erken dönemde yapılarak türlerin başaklanmasının ve yayılmasının önüne geçilmelidir. Korunan meralarda da; botanik kompozisyonun iyileştirilmesi ve sürdürülebilirliğinin devamı amacıyla mera yönetim ilkelerinin yerine getirilmesi tavsiye edilebilir.

## Teşekkür

Araştırmamıza ekonomik destek veren Namık Kemal Üniversitesi Bilimsel Araştırma Komisyonu'na teşekkür ederiz (Proje No: 2007/88).

| **Kısaltmalar ve Semboller** | |
|---|---|
| *BBHB* | Büyükbaş hayvan birimi |
| *HP* | Ham protein |
| *HK* | Ham kül |
| *HY* | Ham yağ |
| *ADF* | Asit deterjan lif |
| *NDF* | Nötral deterjan lif |

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## TARIM BİLİMLERİ DERGİSİ-JOURNAL OF AGRICULTURAL SCIENCES
## YAZIM KURALLARI

### Genel

Tarım Bilimleri Dergisi, tarım bilimleri alanında ve yazım dili İngilizce olan özgün araştırma makaleleri yayınlar. Sonuçları önceden bilinen ve yenilik getirmeyen araştırma makaleleri, taksonomi ile sadece durum tespitine dayanan ve yöresel çalışmalar ile veri ve anket analizine dayanan çalışmalar derginin kapsamı dışındadır. Basılacak makalelerin daha önce hiçbir yerde yayınlanmamış olması ve yayın haklarının verilmemiş olması gerekir. Dergide yayımlanacak makalelerin her türlü sorumluluğu yazarına/yazarlarına aittir.

Yayımlanması için gönderilen eser, yayın ilkeleri doğrultusunda Başeditör tarafından ön incelemeye alınır. Başeditör, dergide yayınlanabilecek nitelikte bulmadığı makaleleri editörlere/hakemlere göndermeden yazara/yazarlara iade kararı verme hakkına sahiptir. Ayrıca yazım kurallarına uymayan veya anlatım dili yetersiz olan makaleler, düzeltilmek üzere yazara/yazarlara iade edilir. Değerlendirmeye alınan makaleler, incelenmek üzere en az 2 hakeme gönderilir. Hakem değerlendirmesinden geçen makalelere ait düzeltmeler, düzeltmeler listesiyle birlikte en fazla 30 gün içerisinde sisteme yüklenerek gönderilmelidir. Bu süreden sonraki gönderimler kabul edilmez. Yazarlara makaleleri hakkındaki editör ve hakem görüşleri ve önerileri 8 hafta içerisinde bildirilir. Başeditör, hakem raporlarını ve/veya istenilen düzeltmelerin yeterli olup olmamasını dikkate alarak makalenin yayımlanıp yayımlanmamasına yönelik nihai karar vericidir.

Makalede isimleri yer alan tüm yazarlar, yayım haklarını Tarım Bilimleri Dergisine verdiklerine dair **Makale Gönderme ve Telif Hakkı Devir Sözleşmesini** imzalamalıdır. Makalenin yayımlanması kabul edildikten sonra makale metninde, yazarlarında ve yazarların sıralamasında değişiklik yapılamaz. Makale yayıma kabul edildiğinde, sorumlu yazar Ankara Üniversitesi adına açılmış banka hesabına 400 TL yatırmalıdır. Makaleden sorumlu yazara banka hesap numarası, makalenin basıma kabul edilmesinden sonra bildirilir.

### Makale Yükleme

Hazırlanan makaleler; sadece makaleden sorumlu yazar (makalenin yayım başlangıcından basım sonrasındaki her türlü yazışmalarda sorumluluğu bulunan) tarafından Tarım Bilimleri Dergisi web sayfasındaki çevrimiçi **Makale Gönderme ve Değerlendirme Sistemi** kullanılarak elektronik ortama yüklenmelidir. Makale yükleme bölümünün **"Başvuruyu Yükle"** bölümünde pdf formatındaki makale dosyasına ilave olarak "**Ek Dosyalar**" bölümüne aşağıdaki dosyaların da yüklenmesi gerekir.

- ✓ Makalenin pdf ve Word (2003 veya daha üst versiyonları) formatındaki dosyası. Sisteme yüklenen makalenin hem pdf formatında ve hem de Word formatında iletişim, ad-soyad, kurum gibi yazarları tanıtıcı bilgiler bulunmamalıdır.
- ✓ Tüm yazarlar tarafından imzalanmış ve pdf formatında taranmış olan "Makale Gönderme ve Telif Hakkı Devir Sözleşmesi". Yayıma kabul edilmesi durumunda bu formların aslı da posta ile editöre gönderilmelidir.
- ✓ Yazar Makale Kontrol Listesi (pdf formatında),
- ✓ Yazarların ad-soyad, kurum ve iletişim bilgilerini içeren Word dosyası,
- ✓ Gerekiyorsa Etik Kurul Raporu eklenmelidir.

### Derginin Kapsamı

Tarım Bilimleri Dergisi, tarım bilimleri alanında yapılan özgün araştırmaları ve yeni bulguları içeren makaleleri yayımlar. Sonuçları önceden bilinen ve yenilik getirmeyen araştırma makaleleri, taksonomi ile sadece durum tespitine dayanan ve yöresel çalışmalar ile veri ve anket analizine dayana çalışmalar derginin kapsamı dışındadır. Derleme makaleler, yayın komisyonunun çağrısı üzerine hazırlanmışsa normal inceleme ve değerlendirme sürecinden geçirilerek yayınlanır.

### Makale Hazırlama

Makaleler, A4 boyutundaki kâğıdın tek yüzüne 12 punto Times New Roman yazı tipinde ve çift satır aralıklı yazılmalıdır. Sayfanın sağında, solunda, altında ve üstünde 3'er cm boşluk bırakılmalıdır. Makalenin her sayfası ve satırları numaralandırılmalıdır. Yazar ad(lar)ı açık olarak yazılmalı ve herhangi bir akademik unvan belirtilmemelidir. Editörler kurulu, anlatım dili yeterli olmayan makaleleri değerlendirme dışı tutabilir. Yazar(lar)ın makale göndermeden önce eseri dil yönünden bir dil bilimciye incelettirmesi tavsiye olunur. Sıralama olarak, İngilizce özet ve peşinden Türkçe özet verilir. Bu durum şekil ve çizelge başlıkları için de geçerlidir.

Makale; Türkçe Başlık, Türkçe Özet, Anahtar Kelimeler, İngilizce Başlık, İngilizce Özet, Keywords, 1.Giriş, 2.Materyal ve Yöntem, 3.Bulgular ve Tartışma, 4.Sonuçlar, Teşekkür (varsa), Kısaltmalar ve/veya Semboller (varsa), Kaynaklar bölümleri ile Şekil ve Çizelgelerden oluşmalıdır. Bölüm adları koyu yazılmalıdır.

Makale, "Kaynaklar" bölümü dâhil 16 sayfayı geçmemelidir. Yazar(lar), bu kısımların oluşturulmasında derginin web sayfasındaki **Makale Hazırlama Şablonunu** kullanmalıdır.

**Başlık**: Kısa ve açıklayıcı olmalı, 14 punto ve koyu, kelimelerin ilk harfi büyük olmalı, ortalanarak yazılmalı ve 15 kelimeyi geçmemelidir. İngilizce başlık Türkçe başlığı tam olarak karşılamalı, 13 punto ve koyu yazılmalıdır.

**Özet ve Anahtar Kelimeler**: Türkçe ve İngilizce özetlerin her biri 300 kelimeyi geçmemelidir. Türkçe ve İngilizce özetlerde sırasıyla "Özet" ve "Abstract" kelimeleri kullanılmalıdır. Özet, çalışmanın amacını, nasıl yapıldığını, sonuçları ve sonuçlar üzerine yazar(lar)ın yaptığı değerlendirmeleri içermelidir. Özetlerin 1 satır altına, her anahtar kelimenin ilk harfi büyük diğerleri küçük harflerle, mümkünse başlıkta kullanılmayan, çalışmayı en iyi biçimde tanımlayacak ve aralarında noktalı virgül (;) olacak şekilde en fazla 6 anahtar kelime yazılmalıdır.

**1. Giriş**: Bu bölümde; çalışma konusu, gerekçesi, konu ile doğrudan ilgili önceki çalışmalar ve çalışmanın amacı verilir.

**2. Materyal ve Yöntem**: Kullanılan materyal ve yöntem aynı başlıkta verilmelidir. Alt başlık verilecekse bölüm numarası ile birlikte numaralandırılmalı (2.1. gibi) ve italik yazılmalıdır. Yeni veya değiştirilmiş yöntemler, aynı konuda çalışanlara araştırmayı tekrarlama olanağı verecek nitelikte açıklanmalıdır.

**3. Bulgular ve Tartışma**: Elde edilen bulgular verilmeli, gerekirse çizelge, şekil ve grafiklerle desteklenerek bulgular açıklanmalıdır. Elde edilen bulgular tekrardan kaçınılması amacıyla ya çizelge ya da grafik olarak verilmelidir. İstatistikî olarak önemli bulunan faktörler, uygulanan istatistik analiz tekniğine uygun karşılaştırma yöntemi ile yorumlanarak ilgili istatistikler üzerinde harflendirme yapılmalıdır. İstatistiki analiz yönteminin doğru seçilmediği ve/ya analizin gereği gibi yapılmadığı durumlarda Başeditör makaleyi değerlendirme dışında tutabilir. Bulgular tartışılmalı ancak gereksiz tekrarlardan kaçınılmalıdır. Bulguların başka araştırmalarla benzerlik ve farklılıkları verilmeli, nedenleri açıklanmalıdır.

**4. Sonuçlar**: Elde edilen sonuçlar, bilime ve uygulamaya katkısıyla birlikte kısa ve öz olarak verilmelidir. Giriş ile Bulgular ve Tartışma bölümünde verilen ifadeler bu kısımda aynı şekilde tekrar edilmemelidir.

**Teşekkür**: Gerekli ise mümkün olduğunca kısa olmalı ve yapılan katkı ifade edilerek verilmelidir.

**Kısaltmalar ve/veya Semboller**: Makalede kısaltmalardan mümkün olduğunca kaçınılmalıdır. Semboller Makale Hazırlama Şablonunda belirtildiği gibi verilmelidir. Kısaltma ve semboller metin içinde ilk kez kullanıldığı yerde açıklanmalıdır. Uluslararası geçerliliği olan ve yerleşik kısaltmalar tercih edilmelidir. Kısaltmalar makalenin başlığında kullanılmamalıdır. Semboller SI sistemine göre verilmelidir.

**Kaynaklar**: Eserde yararlanılan kaynaklara ilişkin atıf metin içinde "(Yazarın soyadı yıl)" yöntemine göre yapılmalıdır. Örnek: (Doymaz 2003), (Basunia & Abe 2001). Yazara atıf yapılırsa sadece yayının yılı parantez içine alınmalıdır. Örnek: Doymaz (2003)'e göre ya da Basunia & Abe (2001). Üç ya da daha fazla yazar için makale içindeki atıfta "et al" kullanılmalıdır. Örnek: (Lawrence et al 2001) veya Lawrence et al (2001)'e göre. Aynı yazarın aynı yıl içinde 1'den fazla yayını varsa, yıldan sonra küçük harfler verilmelidir. Örnek: (Akpınar et al 2003a). Aynı yazarın birden fazla yayınına atıf yapılacaksa yıldan sonra noktalı virgül (;) işareti ile ayırt edilmelidir. Örnek: (Akpınar 2007; 2009; 2013). Birden fazla atıf yapılırsa atıflar arasında noktalı virgül (;) kullanılmalı ve eskiden yeniye doğru yıl sırasına göre verilmelidir. Örnek: (Perl et al 1987; Bailly et al 1996; Copeland & McDonald 2001; Goel & Sheoran 2003). Eğer bilginin, kaynağın belirli bir sayfasından ya da sayfalarından alındığı belirtilmek istenirse (Hardeman & Jochemsen 2012, s 657-674; Naess 1991, s 34) biçiminde gösterilmelidir. Kaynaklarda Anonim ya da Anonymous şeklinde gösterim yapılmamalıdır.

Kaynaklar bölümünde metin içinde atıfı yapılan tüm kaynaklar alfabetik olarak (yazarların soyadlarına göre) ve orijinal dilinde verilir. Aynı yazara birden çok atıf yapılıyorsa önce tek isim, sonra iki isim ve sonra da üç ve daha fazla yazarlı kaynak sırasına göre hepsi kendi içinde eskiden yeniye yıl sırasına göre verilmelidir. İki veya daha fazla yazarlı eserlerin bildiriminde son yazardan önce "&" kullanılmalıdır. Örnek: Lawrence K C, Funk D B & Windham W R (2001). Dergi isimleri kısaltma yapılmadan tam adı ile ve italik yazılmalıdır. Kongre kitaplarında Türkçe ya da yabancı dilde özeti yayınlanmış çalışmalara atıf yapılamaz. Makaledeki yanlış atıf ve kaynak gösterimlerine ait sorumluluk yazar(lar)a aittir. Kaynaklar bölümündeki her bir kaynağın sonuna nokta (.) konmamalıdır.

**Dergi:**

Doymaz I (2003). Drying kinetics of white mulberry. *Journal of Food Engineering* **61**(3): 341-346

Basunia M A & Abe T (2001). Thin-layer solar drying characteristics of rough rice under natural convection. *Journal of Food Engineering* **47**(4): 295-301

Lawrence K C, Funk D B & Windham W R (2001). Dielectric moisture sensor for cereal grains and soybeans. *Transactions of the ASAE* **44**(6): 1691-1696

Akpinar E, Midilli A & Bicer Y (2003a). Single layer drying behaviour of potato slices in a convective cyclone dryer and mathematical modelling. *Energy Conversion and Management* **44**(10): 1689-1705

**Kitap:**

Yıldırım O (1996). Bahçe Bitkileri Sulama Tekniği. Ankara Üniversitesi Ziraat Fakültesi Yayınları: 1438, Ders Kitabı: 420, Ankara

Mohsenin N N (1970). Physical Properties of Plant and Animal Materials. Gordon and Breach Science Publishers, New York

**Kitapta Bölüm:**

Fıratlı Ç (1993). Arı yetiştirme. (Ed: M Ertuğrul), *Hayvan Yetiştirme*, Baran Ofset, Ankara, s. 30-34

Rizvi S S H (1986). Thermodynamic properties of foods in dehydration. In: M A Rao & S S H Rizvi (Eds), *Engineering Properties of Foods*, Marcel Dekker, New York, pp. 190-193

**Yazarı Belirtilmeyen Kurum Yayınları:**

TUİK (2012). Tarım İstatistikleri Özeti. Türkiye İstatistik Kurumu, Yayın No: 3877, Ankara

ASAE (2002). Standards S352.2, 2002, Moisture measurement-unground grain and seeds. ASAE, St. Joseph, MI

**İnternetten Alınan Bilgi:**

FAO (2013). Classifications and standards. http://www.fao.org/economic/ess/ess-standards/en/ (Erişim tarihi:10.02.2013)

**Tez:**

Koyuncu T (1992). Tarım arabalarında kullanılan çarpma etkili frenlerin araştırılması. Yüksek lisans tezi, Ankara Üniversitesi Fen Bilimleri Enstitüsü (Basılmamış), Ankara

Berbert P A (1995). On-line density-independent moisture content measurement of hard winter wheat using the capacitance method. PhD Thesis, Crandfield University (Unpublished), UK

**Tam Metin Kongre/Sempozyum Kitabı:**

Yağcıoğlu A, Değirmencioğlu A & Cağatay F (1999). Drying characteristics of laurel leaves under different drying conditions. In: *Proceedings of the 7th International Congress on Agricultural Mechanization and Energy*, 26–27 May, Adana, Turkey, pp. 565–569

Kara Z & Beyoğlu N (1995). Konya ili Beyşehir yöresinde yetiştirilen üzüm çeşitlerinin göz verimliliklerinin belirlenmesi üzerine bir araştırma. *Türkiye II. Ulusal Bahçe Bitkileri Kongresi. Bildiriler (II)*: 3-6 Ekim, Adana, s. 524-528

**Şekiller ve Çizelgeler**: Şekil, grafik, fotoğraf ve benzerleri "Şekil", sayısal değerler ise "Çizelge" olarak belirtilmelidir. Tüm şekil ve çizelgeler makalenin sonuna yerleştirilmelidir. Şekil ve çizelgelerin boyu tek sayfa düzeninde en fazla 16x20 cm ve çift sütun düzeninde ise genişliği en fazla 8 cm olmalıdır. Şekil ve çizelgelerin boyutu baskıda çıkabilecek çözünürlükte olmalıdır. Araştırma sonuçlarını destekleyici nitelikteki resimler 600 dpi çözünürlüğünde "jpg" formatında olmalıdır. Renkli resimler yerine gri ya da siyah tonlu resimler tercih edilmelidir. Çizelgelerde düşey çizgi kullanılmamalı ve makale hazırlama şablonunda belirtildiği gibi hazırlanmalıdır. Her çizelge ve şekle metin içerisinde atıf yapılmalıdır. Tüm çizelge ve şekiller makale boyunca sırayla numaralandırılmalıdır (Çizelge 1 ve Şekil 1). Çizelge ve şekil başlıkları ve açıklamaları kısa ve öz olmalıdır. Çizelge ve şekillerin İngilizce başlıkları, Türkçe başlığın hemen altına italik olarak yazılmalı, ilk yazılan Türkçe başlık yazısı koyu olmalıdır. Şekil ve çizelge başlık yazıları 9.5 punto, şekil ve çizelgelerin içindeki yazılar 9 punto, çizelge altı yazılar 8 punto Times New Roman yazı karakterinde olmalıdır. Şekillerde yatay ve düşey kılavuz çizgiler ve rakamlar bulunmamalıdır. Ancak istatistiksel karşılaştırmalar yapılıyorsa küçük harfler bulunabilir. Çizelge ve şekillerde kısaltmalar kullanılmış ise hemen altına bu kısaltmalar açıklanmalıdır. Şekil ve çizelge başlıkları ile çizelge altı yazılarının sonuna nokta (.) konmamalıdır.

**Birimler**: Tüm makalelerde SI (Systeme International d'Units) ölçüm birimleri kullanılmalıdır. Ondalık kesir olarak nokta kullanılmalıdır ( 1,25 yerine 1.25 gibi). Birimlerde "/" kullanılmamalı ve birimler arasında bir boşluk verilmelidir (m/s yerine $m\ s^{-1}$, J/s yerine $J\ s^{-1}$, kg m/$s^2$ yerine $kg\ m\ s^{-2}$ gibi). Sayı ile sembol arasında bir boşluk bırakılmalıdır ( 4 kg N $ha^{-1}$, 3 kg $m^{-1}\ s^{-2}$, 20 N m, 1000 $s^{-1}$, 100 kPa, 22 °C ve % 29 gibi). Bu kuralın istisnaları düzlemsel açılar için kullanılan derece, dakika ve saniye sembolleridir (°, ′ ve ″). Bunlar sayıdan hemen sonra konmalıdır (10°, 45', 60" gibi). Litrenin kısaltması "l" değil "L" olarak belirtilmelidir. Cümle sonunda değillerse sembollerin sonuna nokta konulmamalıdır (kg. değil kg).

**Formüller ve Eşitlikler**: Formüller numaralandırılmalı ve formül numarası formülün yanına sağa dayalı olarak parantez içinde gösterilmelidir. Formüllerin yazılmasında Word programı matematik işlemcisi kullanılmalı, ana karakterler 12 punto, değişkenler italik, rakamlar ve matematiksel ifadeler düz olarak verilmelidir. Metin içerisinde atıf yapılacaksa "Eşitlik 1" biçiminde verilmelidir (…ilişkin model, Eşitlik 1' de verilmiştir).

**JOURNAL OF AGRICULTURAL SCIENCES**

## Guide for Authors

***Journal of Agricultural Sciences* is abstracted and/or indexed in:** Science Citation Index – Expanded, TUBITAK-ULAKBİM, CAB Abstracts, CAB International, FAO AGRIS/CARIS, and Directory of Open Access Journals (DOAJ).

*Journal of Agricultural Sciences (JAS)* is an international, double-blind peer-reviewed, open-access journal, published by the Faculty of Agriculture, Ankara University. The journal invites original research papers containing new insight into any aspect of Agricultural Sciences that are not published or not being considered for publication elsewhere. Preliminary, confirmatory or inconclusive research, review articles, case and local studies and works presenting taxonomy will not be published.

Before preparing papers for journal, authors should read through **Guide for Authors** and consult a current issue to make themselves familiar with general format.

The journal uses double-blind system for peer-review; both reviewers and authors' identities remain anonymous. The paper will be peer-reviewed by two reviewers from outside and one editor from the journal typically involve in reviewing a submission. Authors will normally receive reviewers' comments within 8 weeks of submission. Please note that authors are required to pay $ 150 for each manuscript published.

## Manuscript Submission

Manuscripts should be submitted to journal's online submission system by the corresponding author. All submissions should include following documents:

- ✓ **Title page** with author names, titles, addresses and contact information (in Word format).
- ✓ **Manuscript** (in PDF and Word format version 2003 or above). All author names, titles and affiliations should be excluded.
- ✓ **Transfer of Copyright Form**. This form should be filled and signed by all authors and sent electronically as a scanned copy. Authors of the accepted papers should send the original version of this form.
- ✓ **Submission Check List** (in PDF format).
- ✓ **Ethics Committee Approval** (if needed).

Papers should be written with fluent English without any grammatical and typographical errors. Manuscripts with any of those errors will be rejected and sent to the authors for corrections before submission and review.

Manuscripts should be typed using Times New Roman font 12 pt. with numbered lines, in the left-hand margin and double spacing throughout, i.e. also for abstracts, footnotes and references. The pages of the manuscript, including the title page, abstract, references, tables, etc. should be numbered consecutively. Make the width at 3 cm for all margins. Place tables and figures with captions after the text. Each figure and table should be referred to in the text. Avoid excessive use of italics to emphasize part of the text.

Manuscripts should include the following sections; **Title** (short, specific and informative), **Keywords** (indexing terms, up to 6 items), **1. Introduction**, **2. Material and Methods**, **3. Results and Discussion**, **4. Conclusions**, **Acknowledgements** (if needed), **Abbreviations and Symbols** (if needed), **References**, **Figures and Tables** with captions not exceeding 16 pages (with references). All headings and titles should be written in bold.

## Acknowledgements

Acknowledgements should be a brief statement at the end of the text and may include source of financial support. The contract number should be provided.

## References

Cite references in the text as author's family name should be followed by the year of the publication in parentheses (Peter 2010; Basunia & Abe 2001). Use et al after the first author's family name for citations with three or more authors (Lawrence et al 2001). For citations of the same authors published on the same year, use letters after the year (Dawson 2009a).

References cited in the text should be arranged chronologically. The references should be listed alphabetically on author's surnames, and chronological per author. Names of journals should be in full titles rather than the abbreviations. Avoid using citations of abstract proceedings. The following examples are for guidance.

### Journal Articles

Doymaz I (2003). Drying kinetics of white mulberry. *Journal of Food Engineering* **61**(3): 341-346

Basunia M A & Abe T (2001). Thin-layer solar drying characteristics of rough rice under natural convection. *Journal of Food Engineering* **47**(4): 295-301

Lawrence K C, Funk D B & Windham W R (2001). Dielectric moisture sensor for cereal grains and soybeans. *Transactions of the ASAE* **44**(6): 1691-1696

Akpinar E, Midilli A & Biçer Y (2003a). Single layer drying behavior of potato slices in a convective cyclone dryer and mathematical modeling. *Energy Conversion and Management* **44**(10): 1689-1705

**Books**

Mohsenin N N (1970). Physical Properties of Plant and Animal Materials. Gordon and Breach Science Publishers, New York

**Book Chapter**

Rizvi S S H (1986). Thermodynamic properties of foods in dehydration. In: M A Rao & S S H Rizvi (Eds.), *Engineering Properties of Foods*, Marcel Dekker, New York, pp. 190-193

**Publications of Institutions / Standard Books**

ASAE (2002). Standards S352.2, 2002, Moisture measurement - unground grain and seeds. ASAE, St. Joseph, MI

**Internet Sources**

FAO (2013). Classifications and standards. Retrieved in April, 12, 2011 from http://www.fao.org/economic/ess/ess-standards/en/

**Thesis and Dissertations**

Berbert P A (1995). On-line density-independent moisture content measurement of hard winter wheat using the capacitance method. PhD Thesis, Crandfield University (Unpublished), UK

**Conference Proceedings (Full papers)**

Yağcıoğlu A, Değirmencioğlu A & Cağatay F (1999). Drying characteristics of laurel leaves under different drying conditions. In: *Proceedings of the 7th International Congress on Agricultural Mechanization and Energy*, 26–27 May, Adana, pp. 565–569

**Tables and Figures**

Tables and Figures should be numbered consecutively and accompanied by a title at the top. All tables and figures should not exceed 16x20 cm size. Figures should have high resolution, minimum 600dpi in jpg format. For publication purposes use grayscale images. Avoid using vertical lines in tables.

**Illustrations**

Do not use figures that duplicate matter in tables. Figures can be supplied in digital format, or photographs and drawings, which can be suitable for reproduction. Label each figure with figure number consecutively.

**Units**

Units of measurement should all be in SI units. Use a period in decimal fractions (1.24 rather than 1,24). Avoid using "/". Include a space between the units (m $s^{-1}$ rather than m/s,J $s^{-1}$ rather than J/s, kg m $s^{-2}$ rather thankg m/$s^2$). Units should have a single space between the number and the unit (4 kg N $ha^{-1}$, 3 kg $m^{-1}$ $s^{-2}$, 20 N m, 1000 $s^{-1}$, 100 kPa, 22 °C). The only exceptions are for angular definitions, minutes, seconds and percentage; do not include a space (10°, 45›, 60», 29%). The abbreviation of liter is "L".

**Formulas and Equations**

Number each formula with the reference number placed in parentheses at the end. Use Word mathematical processor for formulas with 12pt., variances in Italics, numbers and mathematical definitions in plain text. If needed, refer as "Equation 1" in the text (….the model, as given in Equation 1).

***Note: Title and Abstract, Tables and Figures Captions are translated into Turkish by editor for authors whose native language is not Turkish.***