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# The Effects of Plant Density and Shading on Some Agricultural Traits of Salep Orchid (*Serapias vomeracea* (Burm.f.) Briq.")

## Bitki Sıklığı ve Gölgelemenin Salep Orkidesinin (*Serapias vomeracea* (Burm.f.) Briq.") Bazı Tarımsal Özellikleri Üzerine Etkileri

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# THE EFFECTS OF PLANT DENSITY AND SHADING ON SOME AGRICULTURAL TRAITS OF SALEP ORCHID (*serapias vomeracea* (BURM.F.) BRIQ.")

## ABSTRACT

*Serapias vomeracea* is a valuable plant from the Orchidaceae family, especially in that its tubers are used to make hot drinks. In this study, the plants were grown in field conditions, and it was investigated in detail for the first time to determine the effect of plant density and shading on some agronomic traits of S. vomeracea. The five levels of plant density (20×10 cm, 20×5 cm, 10×10 cm, 10×6.6 and 10×5 cm) and three levels of shading (Control, 55% and 75%) were tested. The plants were harvested for new tubers in full flowering period. As a result of the study, the shading was effective on the dry matter ratio ($P<0.05$) and ash ratio ($P<0.01$) in the tubers while plant density was effective on plant height ($P<0.01$), panicle length ($P<0.01$), number of flowers per panicle ($P<0.05$), dry matter ratio ($P<0.01$), and ash ratio ($P<0.01$) in the tubers. It is possible to see the dominant effect of plant density on the investigated traits in the dendrogram created by cluster analysis. The results of the cluster analysis showed that the plant densities of 20×5 cm and 20×10 cm, the density of 10×10 cm and, the densities of 10×5 cm and 10×6.6 cm were distributed into three different clusters. Positive and significant correlations were found between tuber yield per plant and number of flowers per panicle (r=0.633*), number of roots per plant (r=0.728**), and number of leaves per plant (r=0.745**).

***Keywords:*** Agronomic Traits, Correlation, Leaf, Tuber.

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# BİTKİ SIKLIĞI VE GÖLGELEMENİN SALEP ORKİDESİNİN (*serapias vomeracea* (BURM.F.) BRİQ.") BAZI TARIMSAL ÖZELLİKLERİ ÜZERİNE ETKİLERİ

## ÖZ

*Serapias vomeracea*, Orchidaceae familyasından olup, özellikle yumruları sıcak içecek yapımında kullanılan değerli bir bitkidir. Rize'nin Pazar ilçesinde tarla koşullarında yetiştirilen bitkiler, bitki sıklığı ve gölgelemenin bazı agronomik özellikleri üzerine etkisini belirlemek amacıyla ilk kez detaylı olarak incelenmiştir. Beş bitki sıklığı seviyesi (20×10 cm, 20×5 cm, 10×10 cm, 10×6.6 ve 10×5 cm) ve üç gölgeleme seviyesi (Kontrol, %55 ve %75) ele alınmıştır. Bitkiler %50 çiçeklenme döneminde yumruları için hasat edilmiştir. Araştırma sonucunda, gölgeleme, incelenen özellikler içerisinde yumruda kuru madde oranı ($P<0.05$) ve yumruda kül

oranı (P<0.01) üzerinde etkili olurken; bitki sıklığı ise bitki boyu (P<0.01), salkım uzunluğu (P<0.01), salkımda çiçek sayısı (P<0.05), kuru madde oranı (P<0.01) ve kül oranı (P<0.01) üzerinde etkili olmuştur. Bitki sıklığının incelenen özellikler üzerindeki baskın etkisini kümeleme analizi ile oluşturulan dendrogramda da görmek mümkündür. Kümeleme analizi sonuçları, 20×5 cm ve 20×10 cm bitki sıklıklarının, 10×10 cm sıklığının ve 10×5 cm, 10×6,6 cm sıklıklarının üç farklı kümeye dağıldığını göstermiştir. Bitki başına yumru verimi ile salkım başına çiçek sayısı (r=0,633*), bitki başına kök sayısı (r=0,728**) ve bitki başına yaprak sayısı (r=0,745**) arasında pozitif ve önemli korelasyonlar bulunmuştur.

***Anahtar Kelimeler:*** Tarımsal Özellikler, Korelasyon, Yumru, Yaprak.

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## 1. INTRODUCTION

The orchids are members of the Orchidaceae family. Orchid species, of which tubers are used in hot beverages, are called salep in Turkey (Tamer et al., 2006). *S. vomeracea* is an orchid species widely cultivated in Turkey. Due to the collecting from the natural flora unconsciously in the past, orchid species are now endangered (Sezik, 2002; Sandal-Erzurumlu & Doran, 2011). The fact that the seeds of orchid germinate very difficult and the plants formed from the seeds take a long time to develop increases the destruction risk of these plants (Sandal, 2009). To prevent collecting of the salep from nature, various legal regulations have been made by the Ministry of Agriculture and Forestry. Action plans are implemented to encourage the cultivation of these species by the Ministry at the present time (Anonymous, 2014).

Most of the salep species prefer shade and semi-shade environments. In addition, coarse-textured soils create ideal conditions for tuberous plants if the requirements of their nutrient and moisture are met. The scarcity of soil moisture is an important factor limiting the spread of *Serapias* species (Parlak & Tutar, 2012). Therefore, it is important to provide suitable environmental conditions for salep cultivation and investigate the basic growing techniques that contribute to the salep farming (Çalışkan & Kurt, 2019). In addition, it is necessary to carry out breeding studies to ensure the continuity of the standard product (Ertaş et al., 2019).

Tutar et al. (2013) determined that the most suitable orchids were *S. vomeracea* (Burm. fil.) Briq. and Orchis sancta L. for salep cultivation in the Aegean region. In the study of Arabaci et al. (2014) on *S. vomeracea* regarding to different planting times, the plant height varied between 23.88 and 31.17 cm, number of tubers per plant varied between 1.53 and 1.74 units and tuber weight varied between 3.11 and 5.44 g.

In the study conducted by Ertaş et al. (2019) on *Serapias* species in Şanlıurfa conditions, it was reported that the flowering period lasted 30 days and also average values belonging to various traits were determined, ie, 4.37±1.44 units plant-1 for the number of flowers per panicle, 3.50±0.70 units plant-1 for the number of leaves per plant, 1.13±0.34 units plant for the number of tubers per plant, 9.34±1.10 cm for the leaf length, 1.78±0.14 for the leaf width and 5.30±0.25 g plant-1 for tuber yield per plant. In the same study, the average plant height was 24.33±5.70 cm. On the other hand, plant height could reach 45-50 cm in salep (Karık et al., 2020).

Another study conducted in field conditions is on weed control realized by Parlak (2016). As it is known, weeds cause serious problems in salep cultivation. If weeds cannot be controlled, growth of salep tubers is limited. Parlak (2016) pointed out the importance of using chemical pesticides instead of manual weed control which caused to an increase in cost.

On the other hand, in the studies conducted on the flora of Turkey, large variations were determined in the agronomic traits of *S. vomeracea*. The values varied between 10-50 cm for plant height, 3-20 units for the number of flowers, and 2-4 units for the number of tubers (Renz and Taubenheim, 1984). Güler (2005) stated the variations in the Kaz Mountains were 16.0-46.0 cm for plant height, 2-3 units for the number of tubers, 2-10 units for the number of flowers in the panicle. The authors also determined the number of leaves per plant as 4-9 units. Sandal (2009) reported that the most effective environmental factor in the distribution of orchid species was altitude. The researcher determined that the plant height of *S. vomeracea* varied between 10-30 cm while the number of leaves were 4-6, the number of flowers were 3-6, and the flowering period took place between March and May.

The results of the literature show that the investigations on salep mostly consist of studies conducted in natural flora, and the studies carried out in field conditions are limited to a few studies. For this reason, this study is very important in terms of contributing to salep cultivation. In this study, the effects of plant density and shading on the agricultural traits of salep orchid (*S. vomeracea*) grown in Rize conditions were determined.

## 2. MATERIAL AND METHOD

This study was carried out in the Pazar district of Rize province in split-plot design with randomized blocks as three replications. The seedlings of *S. vomeracea* purchased from a producer company were used as trial material (Figure 1). In the study, seedlings with similar main tuber sizes were used. Shading was placed on the main plots, and plant density was placed on the sub plots. Three levels of shading ratio (Control, 50 % and 75 %) and five levels of plant density (20×10 cm, 20×5 cm,

10×10 cm, 10×6.6 and 10×5 cm) were applied. No shading treatment was applied in the control.

The seedlings were transplanted into the cover soil (15 cm deep) formed by mixing 1/3 field soil, 1/3 stream sand and 1/3 tea fiber on December 29, 2021. Thirty-eight seedlings were planted per plot. The values obtained in 10 plants were averaged. Statistical analyzes were made using the averages.

The shading cover was covered on the plots 60 cm above the soil level on April 8, 2022, during the spring season when the air temperature started to increase. In this study, agricultural traits discussed in the study were plant height, number of leaves per plant, leaf length, leaf width, panicle length, number of flowers per panicle, number of roots per plant, stem diameter, and new tuber traits (tuber yield per plant, number of tuber per plant, first tuber weight, first tuber length, first tuber width, first tuber depth, second tuber weight, second tuber length, second tuber width, second tuber depth, dry matter ratio in tuber, and ash ratio in tuber).

**Figure 1.** The plants of *S. vomeracea*

In determining of the leaf length and leaf width in the plant, the average of the values obtained in the best developed three leaves in the same plant was taken. Leaf width was determined by measuring the widest part of the leaf, while stem diameter was determined by measuring the diameter of the plant stem at soil level with a caliper. The date on which 50 % of the plants flowered was recorded as flowering date. The number of days between the date when the first flowers began to appear and the date when the last flower bloomed was determined as the flowering period. The dry matter ratio and the ash ratio in tuber were determined by using fresh tubers. The amount of dry matter in the harvested fresh tuber was determined by keeping the tubers in an oven set at 70 °C until they were completely dry, and the

dry matter ratio was calculated by proportioning the obtained dry weight value to the fresh tuber weight. After the dried tubers were turned into powder, they were kept in the crematorium at 525 ºC until they completely turned into ash. The ash ratio was calculated by proportioning the amount of ash obtained to the initial fresh weight.

All statistical analyses were performed using the JMP software program (JMP, 2006). TUKEY Multiple Comparison Test was applied to compare the averages. Hierarchical cluster analysis (Ward method with Squared Euclidean distances) was performed by using the SPSS 20.0 software (SPSS, 2011).

## 3. RESULTS

### 3.1. Phenological Observations

The flowering period was determined as 28 days for the control plots, 29 days for the plots with 55 % shading, and 30 days for the plots with 75 % shading. The flowering date of the plants was on 10th of May 2022 in the control plots. In contrast, flowering dates were determined as on 13rd of May 2022 with a delay of three days for 55 % shading and on 15th of May 2022 with a delay of five days for 75 % shading. In the plots where different plant densities were applied, no difference was observed in terms of flowering.

### 3.2. The Effect of Shading on the Investigated Traits

Considering the data obtained in shading applications, only the differences in leaf width ($P<0.05$), dry matter ratio in tuber ($P<0.05$), and ash ratio in tuber ($P<0.01$) were found to be statistically significant (Table 1, 2). The highest leaf width was obtained in 55 % and 75 % shading ratios. The highest dry matter ratio occurred in the control plots and was followed by the shading ratios of 55 % and 75 % within the same statistical group. The highest ash ratios were obtained in control and 55 % shading groups.

### 3.3. The Effect of Plant Density on the Investigated Traits

The effects of plant density on plant height, panicle length, dry matter ratio in tuber, ash ratio in tuber, and leaf width were very significant ($P<0.01$), while the effect on the number of flowers per panicle was significant ($P<0.05$). More much plant density generally caused increases in plant height, panicle length and number of flowers per panicle, and caused decreases in dry matter ratio in tuber, ash ratio in tuber, and leaf width.

**Table 1.** The average values belonging to some agronomic traits of *S. vomeracea*

| Shading | Plant Density | Plant Height | | Panicle Length | | Number of Flowers Per Panicle | | Number of Roots Per Plant | | Stem Diameter | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (cm) | ±Sx | (cm) | ±Sx | (Unit) | ±Sx | (Unit) | ±Sx | (mm) | ±Sx |
| Control | **20×10** | 14.44 | 0.45 | 5.91 | 0.37 | 6.43 | 0.46 | 9.17 | 0.14 | 5.84 | 0.21 |
| | **20×5** | 13.42 | 0.58 | 5.49 | 0.24 | 6.53 | 0.18 | 9.40 | 0.10 | 6.18 | 0.32 |
| | **10×10** | 13.53 | 0.85 | 5.29 | 0.55 | 6.50 | 0.81 | 9.63 | 0.43 | 6.93 | 0.59 |
| | **10×6,6** | 16.46 | 0.95 | 6.62 | 0.40 | 7.00 | 0.25 | 9.50 | 0.25 | 6.27 | 0.18 |
| | **10×5** | 15.98 | 1.22 | 6.02 | 0.23 | 6.90 | 0.31 | 9.47 | 0.29 | 6.07 | 0.18 |
| | **Average** | **14.77** | | **5.87** | | **6.67** | | **9.43** | | **6.26** | |
| 55 % | **20×10** | 14.34 | 1.18 | 6.34 | 0.36 | 6.43 | 0.62 | 9.68 | 0.21 | 6.28 | 0.42 |
| | **20×5** | 14.21 | 1.95 | 6.04 | 0.20 | 6.25 | 0.32 | 8.97 | 0.35 | 6.29 | 0.32 |
| | **10×10** | 14.22 | 2.07 | 5.45 | 0.37 | 5.69 | 0.51 | 9.27 | 0.54 | 6.35 | 0.61 |
| | **10×6,6** | 16.18 | 2.11 | 6.61 | 0.78 | 7.07 | 0.49 | 9.23 | 0.14 | 9.36 | 2.70 |
| | **10×5** | 17.86 | 2.59 | 6.74 | 0.68 | 6.73 | 0.20 | 9.33 | 0.09 | 6.69 | 0.35 |
| | **Average** | **15.36** | | **6.24** | | **6.43** | | **9.30** | | **6.99** | |
| 75 % | **20×10** | 16.44 | 0.68 | 7.63 | 0.70 | 7.52 | 0.55 | 8.67 | 0.72 | 6.46 | 0.25 |
| | **20×5** | 14.41 | 2.53 | 5.92 | 0.50 | 5.23 | 0.54 | 8.50 | 0.41 | 5.79 | 0.31 |
| | **10×10** | 12.47 | 2.53 | 5.54 | 0.46 | 5.05 | 0.85 | 7.78 | 0.64 | 4.82 | 0.31 |
| | **10×6,6** | 16.64 | 7.89 | 6.56 | 0.33 | 5.90 | 0.31 | 8.13 | 0.20 | 5.05 | 0.04 |
| | **10×5** | 16.94 | 1.08 | 6.35 | 0.39 | 6.57 | 0.14 | 9.53 | 0.32 | 6.05 | 0.35 |
| | **Average** | **15.38** | | **6.40** | | **6.05** | | **8.52** | | **5.63** | |
| | **CV%** | **9.98** | | **9.99** | | **11.72** | | **6.43** | | **20.04** | |

Sx: Standard errors. CV: Coefficient of variation. There is no significant difference between the means with the same letter at the *P<0.05 and **P<0.01

**Table 1.** The average values belonging to some agronomic traits of *S. vomeracea (Continued)*

| Shading | Plant Density | Number of Tubers Per Plant | | Tuber Yield Per Plant | | Number of Leaves Per Plant | | Leaf Length | | Leaf Width | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (Unit) | ±Sx | (g) | ±Sx | (Unit) | ±Sx | (cm)** | ±Sx | (cm) | ±Sx |
| Control | **20×10** | 1.60 | 0.10 | 3.18 | 0.28 | 4.60 | 0.31 | $7.39^{a-d}$ | 0.50 | $1.37^{bc**}$ | 0.05 |
| | **20×5** | 1.57 | 0.07 | 3.89 | 0.17 | 4.80 | 0.36 | $7.70^{a-d}$ | 0.58 | $1.35^{bc}$ | 0.05 |
| | **10×10** | 1.57 | 0.13 | 3.69 | 0.93 | 5.47 | 0.26 | $7.92^{abc}$ | 0.48 | $1.39^{abc}$ | 0.09 |
| | **10×6,6** | 1.63 | 0.03 | 4.46 | 1.17 | 5.30 | 0.51 | $7.87^{abc}$ | 0.73 | $1.37^{bc}$ | 0.07 |
| | **10×5** | 1.40 | 0.06 | 3.56 | 0.44 | 5.03 | 0.13 | $7.86^{abc}$ | 0.58 | $1.40^{abc}$ | 0.06 |
| | **Average** | **1.55** | | **3.76** | | **5.04** | | **7.75** | | **$1.37^{b*}$** | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 55 % | **20×10** | 1.35 | 0.25 | 3.19 | 0.24 | 3.22 | 0.42 | 6.85$^{cd}$ | 0.47 | 1.50$^{ab}$ | 0.05 |
| | **20×5** | 1.60 | 0.10 | 3.71 | 0.15 | 4.40 | 0.61 | 7.40$^{a-d}$ | 0.48 | 1.37$^{bc}$ | 0.08 |
| | **10×10** | 1.53 | 0.09 | 3.27 | 0.51 | 4.57 | 1.04 | 7.27$^{a-d}$ | 0.31 | 1.43$^{abc}$ | 0.07 |
| | **10×6,6** | 1.62 | 0.11 | 3.75 | 0.62 | 4.20 | 0.78 | 8.38$^{a}$ | 1.25 | 1.41$^{abc}$ | 0.04 |
| | **10×5** | 1.40 | 0.10 | 3.47 | 0.59 | 4.90 | 0.79 | 7.75$^{-cd}$ | 0.65 | 1.49$^{abc}$ | 0.06 |
| | **Average** | **1.50** | | **3.48** | | **4.26** | | **7.53** | | **1.44$^{a*}$** | |
| 75 % | **20×10** | 1.65 | 0.15 | 2.96 | 0.76 | 4.30 | 0.46 | 8.24$^{abc}$ | 0.45 | 1.55$^{a}$ | 0.05 |
| | **20×5** | 1.55 | 0.20 | 2.49 | 0.54 | 2.91 | 1.10 | 8.30$^{ab}$ | 0.51 | 1.51$^{b}$ | 0.06 |
| | **10×10** | 1.31 | 0.08 | 2.35 | 0.21 | 3.56 | 0.28 | 6.42$^{d}$ | 0.48 | 1.33$^{c}$ | 0.08 |
| | **10×6,6** | 1.33 | 0.09 | 2.81 | 0.15 | 3.86 | 0.17 | 6.90$^{bcd}$ | 0.77 | 1.34$^{bc}$ | 0.06 |
| | **10×5** | 1.37 | 0.17 | 3.13 | 0.20 | 4.63 | 0.50 | 7.18$^{a-d}$ | 0.60 | 1.49$^{abc}$ | 0.07 |
| | **Average** | **1.44** | | **2.75** | | **3.85** | | **7.41** | | **1.45$^{a*}$** | |
| | **CV%** | **14.54** | | **26.75** | | **19.28** | | **6.15** | | **3.91** | |

**Table 2.** The average values belonging to some agronomic traits of *S. vomeracea*

| Shading | Plant Density | First Tuber Weight | | Second Tuber Weight | | First Tuber-Length | | First Tuber Width | | First Tuber Depth | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (g) | ±Sx | (g) | ±Sx | (mm) | ±Sx | (mm) | ±Sx | (mm) | ±Sx |
| Control | **20×10** | 3.20 | 0.05 | 0.43 | 0.08 | 22.19 | 1.59 | 15.24 | 0.36 | 13.69 | 0.31 |
| | **20×5** | 3.60 | 0.13 | 0.57 | 0.05 | 22.93 | 1.43 | 15.97 | 0.47 | 13.81 | 0.38 |
| | **10×10** | 3.25 | 0.32 | 0.85 | 0.18 | 24.92 | 3.28 | 15.66 | 1.65 | 14.16 | 1.37 |
| | **10×6,6** | 3.48 | 0.48 | 0.52 | 0.06 | 20.54 | 0.93 | 16.22 | 0.33 | 14.92 | 0.26 |
| | **10×5** | 3.32 | 0.37 | 0.65 | 0.10 | 22.21 | 0.15 | 16.22 | 0.58 | 14.21 | 0.61 |
| | **Average** | **3.37** | | **0.60** | | **22.56** | | **15.86** | | **14.16** | |
| 55 % | **20×10** | 3.55 | 0.59 | 0.36 | 0.14 | 24.18 | 1.14 | 16.69 | 1.30 | 15.61 | 1.18 |
| | **20×5** | 3.22 | 0.20 | 0.76 | 0.08 | 24.04 | 1.22 | 16.40 | 0.12 | 14.82 | 0.44 |
| | **10×10** | 2.96 | 0.43 | 0.65 | 0.27 | 20.74 | 2.74 | 16.14 | 0.87 | 15.14 | 1.02 |
| | **10×6,6** | 3.25 | 0.47 | 0.78 | 0.13 | 22.31 | 1.73 | 16.30 | 0.57 | 14.77 | 0.64 |
| | **10×5** | 3.22 | 0.61 | 0.75 | 0.16 | 21.22 | 2.05 | 16.07 | 1.14 | 14.53 | 1.14 |
| | **Average** | **3.24** | | **0.66** | | **22.50** | | **16.32** | | **14.97** | |
| 75 % | **20×10** | 3.44 | 0.21 | 0.94 | 0.21 | 21.88 | 0.98 | 16.13 | 1.15 | 14.26 | 0.96 |
| | **20×5** | 3.46 | 0.63 | 0.62 | 0.13 | 22.35 | 1.68 | 17.28 | 1.21 | 15.84 | 1.04 |
| | **10×10** | 2.87 | 0.16 | 0.47 | 0.17 | 17.82 | 1.26 | 13.93 | 1.96 | 12.96 | 1.71 |
| | **10×6,6** | 2.62 | 0.11 | 0.62 | 0.08 | 22.36 | 0.73 | 14.57 | 0.50 | 13.73 | 0.25 |
| | **10×5** | 2.91 | 0.23 | 0.69 | 0.08 | 23.93 | 0.73 | 16.55 | 0.52 | 14.70 | 0.18 |
| | **Average** | **3.06** | | **0.67** | | **21.67** | | **15.69** | | **14.30** | |
| | **CV%** | **20.77** | | **36.26** | | **12.22** | | **9.97** | | **10.49** | |

Sx: Standard errors. CV: Coefficient of variation. There is no significant difference between the means with the same letter at the *P<0.05 and **P<0.01

**Table 2.** The average values belonging to some agronomic traits of *S. vomeracea (Continued)*

| Shading | Plant Density | Second Tuber Length | | Second Tuber Width | | Second Tuber Depth | | Dry Matter Ratio in Tuber | | Ash Ratio in Tuber | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (mm) | ±Sx | (mm) | ±Sx | (mm) | ±Sx | (%) | ±Sx | (%) | ±Sx |
| Control | **20×10** | 11.03 | 0.79 | 8.03 | 0.52 | 7.03 | 0.40 | 21.47 | 0.16 | $0.55^{a*}$ | 0.01 |
| | **20×5** | 11.36 | 0.39 | 8.90 | 1.37 | 8.61 | 1.14 | 21.20 | 0.51 | $0.51^{a*}$ | 0.01 |
| | **10×10** | 15.74 | 3.09 | 10.88 | 1.70 | 9.37 | 1.35 | 18.96 | 0.37 | $0.43^{bc*}$ | 0.03 |
| | **10×6,6** | 10.21 | 0.48 | 8.31 | 0.24 | 7.38 | 0.38 | 18.98 | 0.50 | $0.39^{cd*}$ | 0.01 |
| | **10×5** | 12.18 | 0.73 | 8.44 | 0.52 | 7.74 | 0.60 | 18.01 | 0.47 | $0.39^{bcd}$ | 0.01 |
| | **Average** | **12.10** | | **8.91** | | **8.03** | | **19.72$^{a}$** | | **0.454$^{a**}$** | |
| 55 % | **20×10** | 10.62 | 0.62 | 7.90 | 1.41 | 7.06 | 1.24 | 20.87 | 0.40 | $0.54^{a*}$ | 0.01 |
| | **20×5** | 11.72 | 0.35 | 9.47 | 0.16 | 8.84 | 0.13 | 20.73 | 0.70 | $0.53^{a*}$ | 0.02 |
| | **10×10** | 10.37 | 1.76 | 9.42 | 1.53 | 8.54 | 1.50 | 18.64 | 0.61 | $0.45^{b*}$ | 0.02 |
| | **10×6,6** | 13.00 | 0.76 | 9.45 | 0.40 | 8.72 | 0.51 | 17.93 | 0.23 | $0.41^{bc*}$ | 0.01 |
| | **10×5** | 12.37 | 0.97 | 9.75 | 1.27 | 8.30 | 0.91 | 17.63 | 0.31 | $0.40^{bcd*}$ | 0.01 |
| | **Average** | **11.62** | | **9.20** | | **8.29** | | **19.16$^{b}$** | | **0.465$^{a**}$** | |
| 75 % | **20×10** | 14.71 | 1.11 | 10.71 | 1.14 | 9.41 | 1.35 | 20.62 | 0.70 | $0.38^{cd*}$ | 0.01 |
| | **20×5** | 12.04 | 1.02 | 9.47 | 0.56 | 8.41 | 0.24 | 20.62 | 0.46 | $0.35^{de*}$ | 0.02 |
| | **10×10** | 13.46 | 0.00 | 9.86 | 0.00 | 8.04 | 0.00 | 18.02 | 0.31 | $0.33^{ef*}$ | 0.02 |
| | **10×6,6** | 11.13 | 0.83 | 9.36 | 0.73 | 8.18 | 0.42 | 17.89 | 0.23 | $0.29^{f*}$ | 0.01 |
| | **10×5** | 12.31 | 0.73 | 9.23 | 0.30 | 8.83 | 0.36 | 17.76 | 0.24 | $0.31^{ef*}$ | 0.02 |
| | **Average** | **12.73** | | **9.73** | | **8.57** | | **18.98$^{b}$** | | **0.329$^{b**}$** | |
| | **CV%** | **18.29** | | **20,21** | | **19,68** | | **3.99** | | **4.32** | |

Sx: Standard errors. CV: Coefficient of variation. There is no significant difference between the means with the same letter at the *P<0.05 and **P<0.01

### 3.4. Combinations of Shading and Plant Density

Combination of shading and plant density had a significant effect on leaf length (P<0.01), leaf width (P<0.01), and ash ratio (P<0.05) in tuber (Table 3, 4). The highest values of leaf length were obtained in all planting densities without shading. On the other hand, high values were determined in the shaded plots for some agronomic traits depending on the plant densities. The highest values in terms of leaf width were generally determined in combinations of planting density levels with 55 % shading. The highest ash ratio in tuber was determined in the control group, and combinations of 55 % shading with 20×10 cm and 20×5 cm density.

### 3.5. Relationships Between the Agronomic Traits

Relationships and significance levels between the traits are given in Table 5. Positive and significant correlations were found between tuber yield per plant and number of flowers per panicle (r=0.633*), number of roots per plant (r=0.728**), and number of leaves per plant (r=0.745**) (Figure 2). It will be useful to examine the traits which showed significant correlations with tuber yield per plant.

Number of flowers per panicle was correlated with plant height (r=0.583*), panicle length (r=0.618*), root number per plant (r=0.584*), stem diameter (r=0.563*), number of leaves per plant (r=0.569*), and leaf length (r=0.535*). Significant (P<0.05) relationships were also determined between the number of roots per plant and the number of leaves per plant (r=0.580*), the length of the first tuber (r=0.562*), and the width of the first tuber (r=0.581*). There were no significant correlations between the number of leaves per plant and the number of roots per plant, the number of flowers per panicle, and the tuber yield per plant (Figure 3, 4, 5).

**Table 3.** General average values belonging to plant density in terms of some agronomic traits in *S. vomeracea*

| Plant Density | Plant Height ** | | Panicle Length ** | | Number of Flowers Per Panicle * | | Number of Roots Per Plant | | Stem Diameter | |
|---|---|---|---|---|---|---|---|---|---|---|
| | (cm) | ±Sx | (cm) | ±Sx | (Unit) | ±Sx | (Unit) | ±Sx | (mm) | ±Sx |
| **20×10** | 15.07$^{ab}$ | 0.68 | 6.63$^{a}$ | 0.52 | 6.79$^{a}$ | 0.36 | 9.17 | 0.29 | 6.19 | 0.18 |
| **20×5** | 14.01$^{b}$ | 0.30 | 5.82$^{ab}$ | 0.17 | 6.00$^{ab}$ | 0.39 | 8.96 | 0.26 | 6.09 | 0.15 |
| **10×10** | 13.41$^{b}$ | 0.51 | 5.43$^{b}$ | 0.08 | 5.75$^{b}$ | 0.42 | 8.89 | 0.57 | 6.03 | 0.63 |
| **10×6,6** | 16.43$^{a}$ | 0.39 | 6.60$^{a}$ | 0.15 | 6.66$^{ab}$ | 0.25 | 8.95 | 0.31 | 6.89 | 0.84 |
| **10×5** | 16.93a | 0.54 | 6.37$^{a}$ | 0.21 | 6.73$^{ab}$ | 0.10 | 9.44 | 0.06 | 6.27 | 0.21 |
| **Average** | **15.17** | | **6.17** | | **6.39** | | **9.08** | | **6.30** | |

Sx: Standard errors. There is no significant difference between the means with the same letter at the *P<0.05 and **P<0.01

**Table 3.** General average values belonging to plant density in terms of some agronomic traits in S. vomeracea (Continued)

| Plant Density | Number of Tubers Per Plant | | Tuber Yield Per Plant | | Number of Leaves Per Plant | | Leaf Length | | Leaf Width ** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | (Unit) | ±Sx | (g) | ±Sx | (adet) | ±Sx | (cm) | ±Sx | (cm) | ±Sx |
| **20×10** | 1.53 | 0.09 | 3.11 | 0.08 | 4.04 | 0.42 | 7.49 | 0.40 | 1.48$^{a}$ | 0.05 |
| **20×5** | 1.57 | 0.02 | 3.36 | 0.44 | 4.04 | 0.58 | 7.80 | 0.27 | 1.41$^{abc}$ | 0.05 |
| **10×10** | 1.47 | 0.08 | 3.10 | 0.40 | 4.53 | 0.55 | 7.20 | 0.43 | 1.38$^{bc}$ | 0.03 |
| **10×6,6** | 1.53 | 0.08 | 3.67 | 0.33 | 4.45 | 0.43 | 7.71 | 0.43 | 1.37$^{c}$ | 0.02 |
| **10×5** | 1.39 | 0.01 | 3.39 | 0.13 | 4.85 | 0.12 | 7.60 | 0.21 | 1.46$^{ab}$ | 0.03 |
| **Average** | **1.50** | | **3.33** | | **4.38** | | **7.56** | | **1.42** | |

Sx: Standard errors. There is no significant difference between the means with the same letter at the **P<0.01

**Table 4.** General average values belonging to plant density in terms of some tuber traits in *S. vomeracea*

| Plant Density | First Tuber Weight | | Second Tuber Weight | | First Tuber Length | | First Tuber Width | | First Tuber Depth | |
|---|---|---|---|---|---|---|---|---|---|---|
| | (g) | ±Sx | (g) | ±Sx | (mm) | ±Sx | (mm) | ±Sx | (mm) | ±Sx |
| **20×10** | 3.40 | 0.10 | 0.58 | 0.18 | 22.75 | 0.72 | 16.02 | 0.42 | 14.52 | 0.57 |
| **20×5** | 3.43 | 0.11 | 0.65 | 0.06 | 23.11 | 0.50 | 16.55 | 0.39 | 14.82 | 0.59 |
| **10×10** | 3.03 | 0.12 | 0.66 | 0.11 | 21.16 | 2.06 | 15.24 | 0.67 | 14.09 | 0.63 |
| **10×6,6** | 3.12 | 0.26 | 0.64 | 0.08 | 21.74 | 0.60 | 15.70 | 0.57 | 14.47 | 0.38 |
| **10×5** | 3.15 | 0.12 | 0.70 | 0.03 | 22.45 | 0.79 | 16.28 | 0.14 | 14.48 | 0.14 |
| **Average** | **3.25** | | **0.65** | | **22.24** | | **15.96** | | **14.48** | |

Sx: Standard errors. There is no significant difference between the means with the same letter at the **P<0.01

**Table 4.** General average values belonging to plant density in terms of some tuber traits in *S. vomeracea (Continued)*

| Plant Density | Second Tuber Length | | Second Tuber Width | | Second Tuber Depth | | Dry Matter Ratio in Tuber ** | | Ash Ratio in Tuber ** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | (mm) | ±Sx | (mm) | ±Sx | (mm) | ±Sx | (%) | ±Sx | (%) | ±Sx |
| **20×10** | 12.12 | 1.30 | 8.88 | 0.92 | 7.83 | 0.79 | 20.99$^{a}$ | 0.25 | 0.49$^{a}$ | 0.06 |
| **20×5** | 11.71 | 0.20 | 9.28 | 0.19 | 8.62 | 0.13 | 20.85$^{a}$ | 0.18 | 0.46$^{b}$ | 0.06 |
| **10×10** | 13.19 | 1.56 | 10.05 | 0.43 | 8.65 | 0.39 | 18.54$^{b}$ | 0.28 | 0.40$^{c}$ | 0.03 |
| **10×6,6** | 11.45 | 0.82 | 9.04 | 0.36 | 8.09 | 0.39 | 18.27$^{b}$ | 0.28 | 0.36$^{d}$ | 0.03 |
| **10×5** | 12.29 | 0.06 | 9.14 | 0.38 | 8.29 | 0.32 | 17.80$^{b}$ | 0.11 | 0.37$^{d}$ | 0.03 |
| **Average** | **12.15** | | **9.28** | | **8.30** | | **19.29** | | **0.42** | |

Sx: Standard errors. There is no significant difference between the means with the same letter at the **P<0.01

**Table 5.** The correlations between the investigated traits in *S. vomeracea* (r)

| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Plant height | 1 | | | | | | | | | | | | | | | | | | | |
| 2 | Panicle length | 0.779** | 1 | | | | | | | | | | | | | | | | | | |
| 3 | Number of flowers per panicle | 0.583* | 0.618* | 1 | | | | | | | | | | | | | | | | | |
| 4 | Number of roots per plant | 0.194 | -0.067 | 0.584* | 1 | | | | | | | | | | | | | | | | |
| 5 | Stem diameter | 0.259 | 0.223 | 0.563* | 0.490 | 1 | | | | | | | | | | | | | | | |
| 6 | Number of tubers per plant | -0.069 | 0.103 | 0.413 | 0.248 | 0.498 | 1 | | | | | | | | | | | | | | |
| 7 | Tuber yield per plant | 0.206 | 0.020 | 0.633* | 0.728** | 0.511 | 0.495 | 1 | | | | | | | | | | | | | |
| 8 | Dry matter ratio in tuber | -0.455 | -0.074 | 0.027 | 0.088 | -0.121 | 0.503 | 0.019 | 1 | | | | | | | | | | | | |
| 9 | Number of leaves per plant | 0.244 | -0.078 | 0.569* | 0.580* | 0.249 | 0.330 | 0.745** | -0.230 | 1 | | | | | | | | | | | |
| 10 | Ash ratio in tuber | -0.420 | -0.273 | 0.176 | 0.493 | 0.215 | 0.401 | 0.403 | 0.703** | 0.128 | 1 | | | | | | | | | | |
| 11 | Leaf length | 0.322 | 0.303 | 0.535* | 0.310 | 0.635* | 0.719** | 0.394 | 0.133 | 0.281 | 0.005 | 1 | | | | | | | | | |
| 12 | Leaf width | 0.405 | 0.525* | 0.268 | 0.210 | 0.206 | 0.035 | -0.251 | 0.116 | -0.281 | -0.104 | 0.361 | 1 | | | | | | | | |
| 13 | First tuber weight | -0.110 | 0.112 | 0.438 | 0.493 | 0.326 | 0.523* | 0.446 | 0.618* | 0.072 | 0.523* | 0.576* | 0.327 | 1 | | | | | | | |
| 14 | Second tuber weight | 0.358 | 0.338 | 0.426 | 0.038 | 0.461 | 0.386 | 0.135 | -0.231 | 0.354 | -0.268 | 0.594* | 0.322 | -0.032 | 1 | | | | | | |
| 15 | First tuber length | 0.057 | -0.024 | 0.332 | 0.562* | 0.290 | 0.171 | 0.278 | 0.327 | 0.134 | 0.360 | 0.236 | 0.234 | 0.267 | 0.257 | 1 | | | | | |
| 16 | First tuber width | 0.256 | 0.197 | 0.316 | 0.581* | 0.430 | 0.363 | 0.308 | 0.281 | -0.035 | 0.228 | 0.587* | 0.659** | 0.620* | 0.212 | 0.510 | 1 | | | | |
| 17 | First tuber depth | 0.194 | 0.159 | 0.046 | 0.415 | 0.334 | 0.207 | 0.152 | 0.184 | -0.264 | 0.157 | 0.357 | 0.618* | 0.417 | 0.034 | 0.371 | 0.884** | 1 | | | |
| 18 | Second tuber length | -0.081 | 0.069 | 0.186 | -0.149 | 0.240 | 0.120 | -0.187 | -0.164 | 0.150 | -0.282 | 0.317 | 0.185 | -0.008 | 0.675** | 0.120 | -0.161 | -0.316 | 1 | | |
| 19 | Second tuber width | -0.030 | 0.072 | -0.034 | -0.335 | 0.144 | 0.153 | -0.243 | -0.241 | 0.089 | -0.398 | 0.250 | 0.187 | -0.227 | 0.798** | -0.018 | -0.164 | -0.195 | 0.822** | 1 | |
| 20 | Second tuber depth | 0.030 | 0.060 | 0.126 | -0.094 | 0.307 | 0.295 | -0.030 | -0.142 | 0.182 | -0.276 | 0.383 | 0.223 | -0.107 | 0.880** | .252 | 0.123 | -0.029 | 0.682** | 0.876** | 1 |

*P<0.05 ve **P<0.01

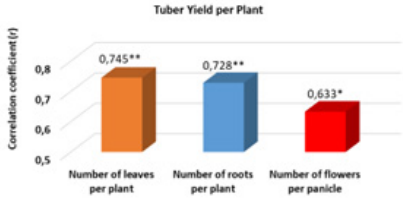


**Figure 2.** The agronomic traits correlated with the tuber yield per plant in S. vomeracea

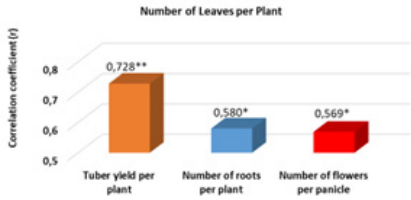


**Figure 3.** The agronomic traits correlated with the number of leaves per plant in S. vomeracea

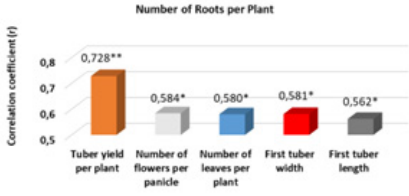


**Figure 4.** The agronomic traits correlated with the number of roots per plant in S. vomeracea

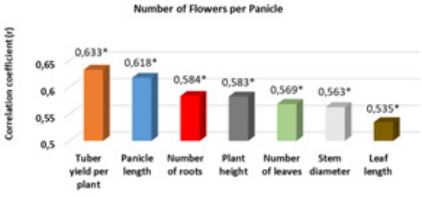


**Figure 5.** The agronomic traits correlated with the number of flowers per panicle in S. vomeracea

The effect of the first tuber (r=0.446) on the tuber yield per plant was higher than that of the second tuber (r=0.135). First tuber weight was correlated significantly with number of tubers per plant (r=0.523*), ash ratio in tuber (r=0.523*), leaf length (r=0.576*), first tuber width (r=0.620*), and dry matter ratio in tuber (r=0.618*).

### 3.6. Clustering Analysis

The clustering analysis related to combinations of shading and plant density depending on the investigated traits in *S. vomeracea* was determined by using the hierarchical clustering method called Ward's Method. As a result of the dendogram obtained by twenty agronomic traits, a total of 4 clusters A, B, C and D formed (Figure 6). At first, two groups were formed. Both groups were separated into two subgroups within itself. One of these subgroups (A) consisted of K 20×5, G1 20×5, K 20×10, G1 20×10 and G2 20×5. The other subgroup (B) consisted of K 10×10, G1 10×10 and G2 10×10. The subgroup (C) consisted of K 10×6.6, K 10×5, G1 10×5, G2 10×5 and G2 10×6.6 while the last one (D) consisted of G1 10×6.6 ve G2 20×10.

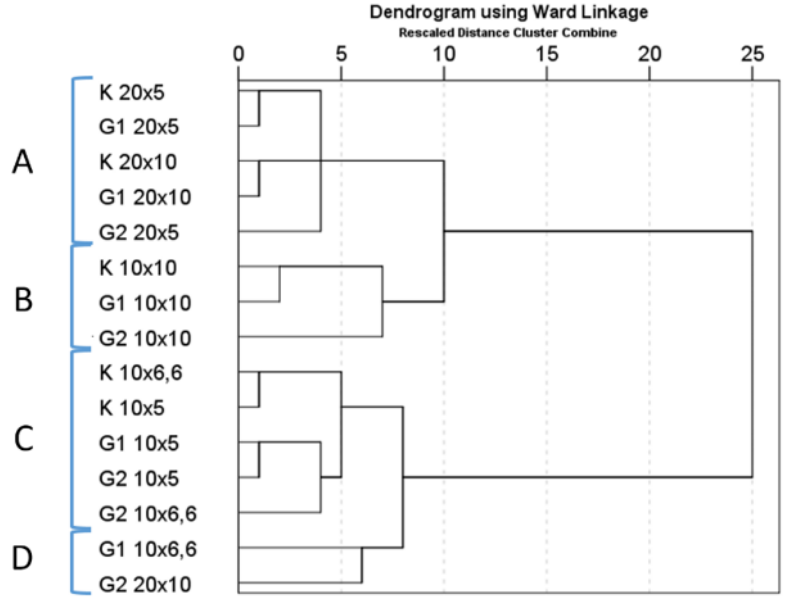


**Figure 6.** Clustering analysis related to the combinations of shading and plant density depending on the investigated traits in S. vomeracea
K: Control, G1: 55 % Shading, G2: 75 % Shading

## 4. DISCUSSION

The effects of shading and plant density on *S. vomeracea* were determined in detail. As the results of the study, shading had an effect only on a few agronomic traits, flowering period and date, dry matter ratio and ash ratio in tuber. When the shading ratio increased, the flowering period increased, and flowering date delayed. It is stated that it is suitable to shade the plants 2 months before the harvest. Exposure to direct sun light of plants causes sunburns and growth retardation (Çalışkan, 2020). However, this negative effect of the sun may vary depending on ecological conditions. As a matter of fact, the results of the research showed that there was no yield loss due to sunny weather in Rize province.

Plant density was effective on plant height, panicle length, number of flowers per panicle, dry matter ratio and ash ratio in tuber. These investigated traits were affected by the plant density at significant level statistically. In contrast, plant density had no effect on tuber yield per plant. Çalışkan (2020) recommends planting as many plants as possible per unit area. Sparse planting makes weed control difficult and limits tuber growth (Parlak, 2016).

Except for the combination of G2 and 20×10 cm, all combinations of K, G1 and G2 with 20×10 cm and 20×5 cm took place in the cluster (A). The cluster (B) was composed of only combinations of shading and 10×10 cm planting density, while the remaining combinations with 10×5 cm and 10×6.6 cm of plant density were distributed in the clusters (C) and (D). Cluster analysis results show that plant density has a dominant effect on the studied traits. Variance analysis results also confirm these results.

The average plant height obtained in the study was between the values recorded in the previous studies conducted by Renz and Taubenheim (1984) and Sandal (2009). Sevgi et al. (2012) reported that the variations for tuber width and tuber length were 5-19 mm (average, 11.28±0.23 mm) and 8-30 mm (16.41±0.35 mm), respectively. These values are consistent with the values obtained in the study. Arabaci et al. (2014) determined that the tuber diameter varied from 13.93 to 17.10 mm While it ranged from 15.69 to 16.32 mm in their study. Similarly, the average tuber yield per plant obtained in the study was close to the values reported by Arabaci et al. (2014) (between 2.49 and 5.71 g plant-1). The values recorded by the same researcher in terms of the number of tubers per plant (between 1.37 and 1.96 tubers plant-1) are also consistent with the findings of the present study. On the other hand, in the current study, the average number of tubers per plant was higher than the average value (1.13±0.34 units plant-1) obtained by Ertaş et al. (2019).

The values we obtained in terms of the number of leaves per plant are similar to the findings of the researchers. The current average values are consistent with the

findings reported by Çalışkan et al. (2020) (3.00-9.83 units plant-1), Güler (2005) (4-9 units plant-1), and Sandal (2009) (4-6 units plant-1).

It was reported that the values of *S. vomeracea* varied from 3.78 to 13.52 mm for leaf width and 45.82 to 86.93 mm for leaf length (Çalışkan et al., 2020). The measurements of the current study in terms of leaf length and leaf width are consistent with the findings determined by Çalışkan et al. (2020).

## CONCLUSION

The shading applications have no effect on the new tuber yield per plant, number of tubers per plant, and tuber weight. Therefore, *S. vomeracea* can be grown without shading in Rize conditions. The fact that the statistical insignificant differences between the plant densities in terms of the studied yield elements show that higher tuber yield can be obtained by growing more plants (in density of 10×5 cm) in unit area. On the other hand, since transplanting more seedlings in a unit area requires more labor, it would be beneficial to consider the income-expenditure balance when deciding on planting frequency. Number of flowers per panicle, number of roots per plant, and number of leaves per plant were positively correlated with tuber yield per plant. These positive interactions are important data for orchid breeding.

### Conflict of Interest

The authors declare that there is no conflict of interest.

### Ethics

This study does not require ethics committee approval.

### Author Contribution Rates

Design of Study: YŞ (%50), MA (%50)

Data Acquisition: YŞ (%50), MA (%50)

Data Analysis: YŞ (%90), MA (%10)

Writing up: YŞ (%100), MA (%0)

Submission and Revision: YŞ (%100), MA (%0)

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