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Relationships Between Some Agronomical Traits in Genotypes of Rusty Foxglove (*Digitalis ferrruginea* subsp. *ferruginea*)

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ABSTRACT

This research was conducted at experimental site (41°10.668′ N latitude, 40°54.018′E longitude), with 65 m elevation in Turkey. In the study, 8 different genotypes of *Digitalis ferrruginea* subsp. *ferruginea,* selected in the previous years with high performance, were used. These genotypes, grown in 2016-2017, were compared in terms of plant height, panicle length, number of capsules per panicle, capsule length, seeds yield per plant and 1000 seeds weight, and a modeling was developed to estimate seed yield per plant. The mean values obtained for the investigated traits were 95.21–130.43 cm for plant height, 46.29–72.57 cm for panicle length (PL), 9.63–11.14 mm for capsule length, 99.29–146.57 units for the number of capsules per panicle, 2.00–5.26 g/plant for seed yield per plant (SYP) and 0.34–0.49 g for 1000 seeds weight (TSW). However, in terms of the traits examined, each genotype showed a wide variation within itself. Multiple regression analysis was performed for the yield-prediction model relation to the seed yield per plant using the values obtained under the present conditions. As a result of the regression analysis, an equation of SYP=(-2.54)+ (0.11xPL)-(2.18xTSW) was obtained.

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Pas Renkli Yüksükotu (*Digitalis ferrruginea* subsp. *ferruginea*) Genotiplerinde Bazı Agronomik Özellikler Arasındaki İlişkiler

ÖZET

Bu araştırma, Türkiye'de 41°10.668′ N kuzey enlemi 40°54.018′E doğu boylamında ve deniz seviyesinden 65 m yüksekliğinde bulunan deneme arazisinde yürütülmüştür. Araştırmada önceki yıllarda seçilen *Digitalis ferrruginea* subsp. *ferruginea*'ya ait yüksek performans gösteren 8 farklı genotip kullanılmıştır. 2016-2017 yıllarında yetiştirilen bu genotipler, bitki boyu, salkım uzunluğu, salkımda kapsül sayısı, kapsül uzunluğu, bitki başına tohum verimi ve 1000 tohum ağırlığı bakımından karşılaştırılmış ve tohum verimini tahmin etmek için bir modelleme geliştirilmiştir. İncelenen özelliklere ait elde edilen ortalama değerler, genotipler arasında bitki boyu için 95.21–130.43 cm, salkım uzunluğu (SU) için 46.29–72.57 cm, kapsül uzunluğu için 9.63–11.14 mm, salkımda kapsül sayısı için 99.29–146.57 adet, tohum verimi için 2.00–5.26 g/bitki (BTV) ve 1000 tohum ağırlığı için (BTA) 0.34–0.49 g arasında değişim göstermiştir. Bununla birlikte, incelenen özellikler bakımından her bir genotip kendi içerisinde geniş bir varyasyon göstermiştir. Mevcut koşullar altında elde edilen değerler kullanılarak, bitkide tohum verimine ilişkin verim-tahmin modeli için çoklu regresyon analizi yapılmıştır. Regresyon analizi sonucunda, BTV=(-2.54)+(0.11xSU)-(2.18xBTA) şeklinde bir eşitlik elde edilmiştir.

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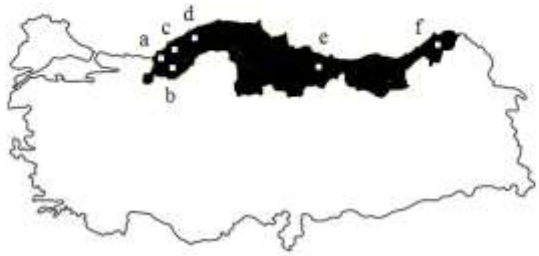
INTRODUCTION

Digitalis species are composed of biannual or perennial plants belonging to the family *Plantaginaceae (Scrophulariaceae)*, mainly from southwestern Europe to Asia. More than 20 *Digitalis* species spread around the world. The number of species identified in Turkey's flora is eight (Davis, 1978). *Digitalis* species, commonly known as "yüksük otu" in Turkey, are the main source of cardiac glycosides used in the treatment of some heart diseases (Baytop, 1999). Digoxin and Digitoxin from *Digitalis* species have been reported to be effective in cancer and partially in the treatment of prostate and breast cancer (Yeh et al., 2001; Lopez-Lazaro, 2007; Newman et al., 2008). These plants are diuretic in reducing edema (Perez-Bermudez et al., 1990), have heart strengthening effects (Gurel et al., 2017) and are also used in the treatment of various skin diseases (Chiej, 1988).

D. ferrruginea, especially spreading in the northern Mediterranean countries, has two subspecies including *ferruginea* and *schischkini* in Turkish flora (Davis, 1978; Clement et al., 2011). *D. ferruginea* subsp. *ferruginea* L. (rusty foxglove) is much more common than other *Digitalis* species in Turkey (Şavşatlı, 2017). This subspecies is distributed in the northern part of Turkey, especially in 6 provinces (Artvin, Ordu, Bolu, Duzce, Bartin and Zonguldak) of the Black Sea Region (Basaran and Adiguzel, 2001; Eminagaoglu and Ansin, 2005; Deveci et al., 2012; Kanoglu et al., 2016). This wide spread (Figure 1) indicates clearly that there are ecological conditions especially in the Black Sea Region of Turkey where the rusty foxglove is adapted, and proves that this plant, not yet cultivated, can be grown easily in the region.



The letters a, b, c, d, e and f on the map refer to the provinces of Düzce, Bolu, Zonguldak, Bartin, Ordu and Artvin of Black Sea Region respectively

Figure 1. Provinces where *D. ferruginea* subsp. *ferruginea* L. is adapted in the Black Sea Region of Turkey
Şekil 1. D. ferruginea subsp. ferruginea L'nin Türkiye'nin Doğu Karadeniz Bölgesi'nde adapte olduğu iller

However, the studies carried out on *D. ferrruginea* are mostly laboratory-oriented studies and no studies have been found on the agriculture of this plant species and there is not enough data on the agronomic characteristics of this plant. In addition, various studies in relation to yield prediction models in many plant species have been conducted, there have been no similar studies in foxglove up to now. Therefore, this study was carried out to determine the effect of yield components on the seed yield per plant and to derive some data that plant breeders could benefit from.

MATERIAL and METHODS

This research was carried out in trial plots belonging to Faculty of Agriculture and Natural Sciences of Recep Tayyip Erdogan University in Pazar district of Rize in 2016/2017. Rize, located in northern Black Sea Region, is the most rany province (1978 mm) in Turkey. The trial parcels where the research was conducted are located at 41°10.668′ N latitude, 40°54.018′E longitude and 65 m high above sea level.

8 genotypes were selected which were superior in terms of seed yield per plant among the plants (*D. ferruginea* subs. *ferruginea* L.) previously grown in 2014/2015. The seeds harvested from these genotypes were sown into vials in the greenhouse on February 21, 2016. 60 plants of each genotype were transplanted at a distance of 40x30 cm in 5-6 leaf period. The plants with rosette leave stage in the first year and flowered in the following year.

All measurements in the field were carried out during the ripening period on 7 plants randomly selected from each genotype. In this period, plant height (cm), panicle length (cm), capsule length (cm), number of capsule per panicle (unit), seed yield per plant (g/plant) and 1000 seeds weight were determined in these *Digitalis* genotypes.

In terms of traits, standard deviation values and standard deviation ratios (SdR) were calculated for each genotype. Standard deviation ratios were determined by proportioning the obtained values of agronomical tr aits to the standard deviation values. Statistical analysis, multiple regression analysis and basic Principal Component Analysis (PCA) were performed by using the average values obtained for the investigated traits. SPSS and excel package programs were used to evaluate the data.

RESULTS and DISCUSSION

In this study, which started in 2014/2015 and continued in 2016/2017, 8 genotypes with high seed yield per plant were grown in field conditions and the relationships between the agronomical traits of these genotypes were determined. The average values of plant height, panicle length, seed yield per plant, number of capsules per panicle, capsule length and 1000 seeds weight in rusty foxglove were shown in Table 1, 2 and Figure 2.

In the research, minimum and maximum values belongigng to genotypes were 95.21–130.43 cm for plant height; 46.29–72.57 cm for panicle length; 2.00–5.26 g for seed yield per plant; 99.29–146.57 for capsule number per panicle; 9.63–11.14 mm for capsule length and 0.34–0.49 g for 1000 seeds weight.

In a study conducted by Savsatli et al. (2016), the changes between genotypes were 68.5–148.5 cm in plant height; 28.0–95.5 cm in panicle length; 0.3–9.4 g in seed yield per plant; 0.31 to 0.69 g in 1000 seeds weight. The values obtained in terms of these traits are similar to the results in the present study.

Each genotype showed a wide variation in terms of all the traits except capsule length. This wide variability is probably due to the cross pollination tendency of plants. The standard deviation values and high SdR ratios calculated for each genotype indicate the size of this variation and also genetic expansion (Table 1, 2).

Table 1. Mean values, standard deviation values (Sd) and standard deviation rates (SdR) of some agronomic traits in rusty foxglove

Çizelge 1. Pas Renkli Yüksükotunda bazı agronomik özelliklere ait ortalama değerler, standart sapma değerleri ve standart sapma oranları

Genotype No *Genotip No*	Plant height (cm) *Bitki Boyu (cm)*	Sd *Standart sapma*	SdR (%) *Standart sapma oranı (%)*	Panicle length (cm) *Salkım uzunluğu (cm)*	Sd *Standart sapma*	SdR (%) *Standart sapma oranı (%)*	Capsule length (mm) *Kapsül Uzunuğu (mm)*	Sd *Standart sapma*	SdR (%) *Standart sapma oranı (%)*
G1	118.29	24.09	20.37	64.57	19.68	30.48	10.70	1.12	10.47
G2	112.14	25.24	22.51	62.43	22.09	35.38	9.83	0.83	8.44
G3	116.71	15.06	12.90	57.43	18.83	32.79	11.14	0.88	7.90
G4	130.43	19.34	14.83	72.57	18.82	25.93	10.91	0.65	5.96
G5	95.21	22.56	23.69	54.43	23.34	42.88	9.63	0.99	10.28
G6	97.29	18.31	18.82	46.29	11.60	25.06	10.39	0.66	6.35
G7	107.86	28.91	26.80	56.64	20.81	36.74	10.31	1.05	10.18
G8	96.57	17.15	17.76	46.50	17.74	38.15	10.99	0.97	8.83
General Mean (*Genel Ortalama*)			19.71			33.43			8.55

Table 2. Mean values, standard deviation values (Sd) and standard deviation rates (SdR) of some agronomic traits in rusty foxglove

Çizelge 2. Pas Renkli Yüksükotunda bazı agronomik özelliklere ait ortalama değerler, standart sapma değerleri ve standart sapma oranları

Genotype No *Genotip No*	Number of capsules per panicle (unit) *Salkımdaki kapsül sayısı (adet)*	Sd *Standart sapma*	SdR (%) *Standart sapma oranı (%)*	Seed yield per plant (g plant^{-1}) *Bitkide tohum verimi (g/bitki)*	Sd *Standart sapma*	SdR (%) *Standart sapma oranı (%)*	1000 seeds weight (g) 1000 tohum ağırlığı (g)	Sd *Standart sapma*	SdR (%) *Standart sapma oranı (%)*
G1	127.71	58.39	45.72	3.31	1.81	54.68	0.49	0.11	22.45
G2	135.57	49.36	36.41	3.14	2.38	75.80	0.39	0.06	15.38
G3	129.71	38.96	30.04	2.98	1.70	57.05	0.43	0.07	16.28
G4	146.57	46.79	31.92	5.26	2.41	45.82	0.42	0.08	19.05
G5	108.00	58.53	54.19	2.56	1.42	55.47	0.36	0.08	22.22
G6	99.29	38.62	38.90	2.05	1.65	80.49	0.34	0.11	32.35
G7	112.14	65.54	58.44	3.11	1.63	52.41	0.44	0.11	25.00
G8	100.43	28.98	28.86	2.00	1.07	53.50	0.42	0.09	21.43
General Mean (*Genel Ortalama*)			40.56			59.40			21.77

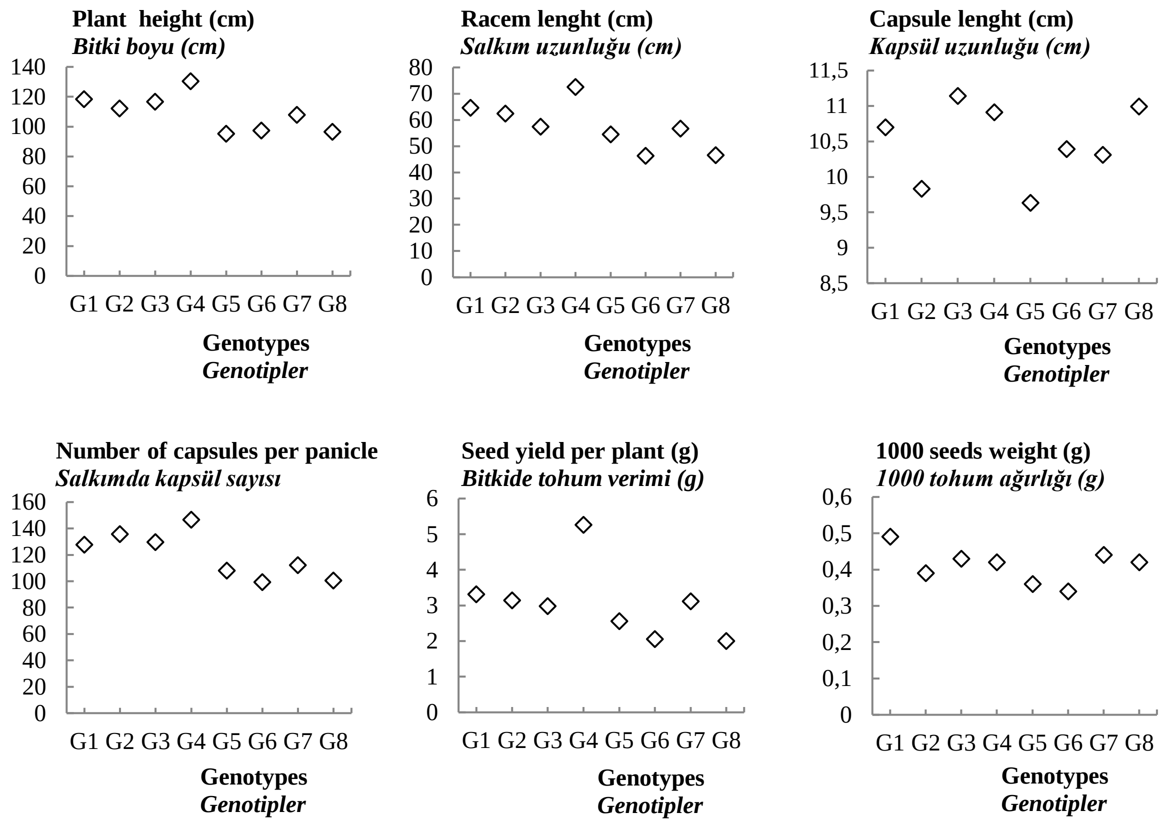


Figure 2. Variation of some agronomic traits according to genotypes
Şekil 2. Genotiplere göre bazı agronomik özelliklerdeki değişim

When the standard deviation rates of the genotypes regarding the investigated traits were taken into consideration, the highest average SdR value was obtained in the seed yield per plant with 59.40%, followed by the number of capsules per panicle, the panicle length and others. The lowest mean SdR ratio was calculated as 8.55% in capsule length. This case indicate that the variation in capsule length is very limited and stable between both among genotypes and in itself.

Considering seed yield per plant (SYP), the most important parameter, 1000 seeds weight (TSW) and panicle length (PL) were found to be important factors affecting yield. As a result of multiple regression analysis, a mathematical equation was obtained with SYP = (-2.54) + (0,11xPL) - (2.18xTSW) and R^2 of 0.922. The R^2 value indicates that the equation can predict the SYP with a accuracy of 92% (Figure 3).

Various yield estimation models have been developed in many plants such as Barley (Agomoh et al., 2018), paddy (Confalonieri et al., 2009), wheat (Müjdeci et al., 2005), soybean (Duarte et al., 2018), potato (Griffin et al., 1993) tomato (Jones et al., 1991) and cucumber (Kurtar and Odabaş, 2010). These models are formed by Regression analysis which shows the effect of the factors affecting the targets (Sen and Srivastava, 1990). Before real values are obtained, these values are predicted by modeling based on closely related criteria. Such a modeling also helps to identify priorities in various researches and plant breeding programs (Penning De Vries, 1983; Kalaji et al., 2004).

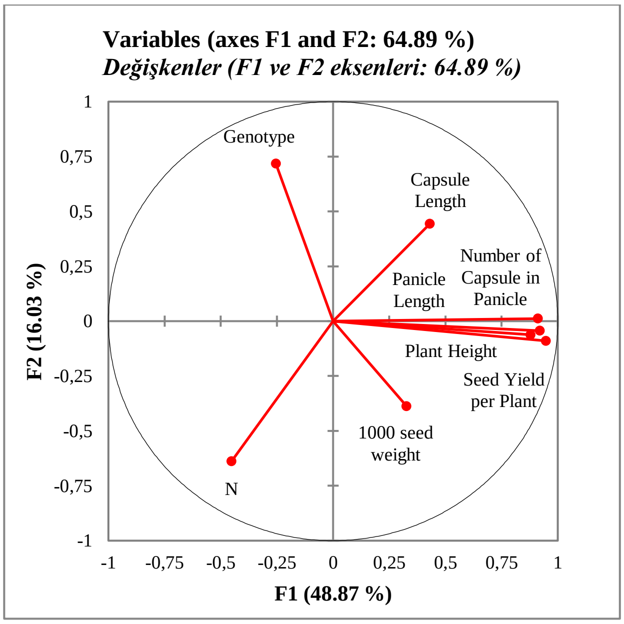


Figure 3. Results of PCA analysis of the investigated traits
Şekil 3. İncelenen özelliklerin PCA analiz sonuçları

Principal component analysis is the most used technique in multivariate data analysis, revealing the decisive dimensions in the data. Principal component analysis (PCA) is a technique used to reduce the dimensionality of data sets, increase their interpretability and at the same time minimize the loss of information (Jolliffe and Cadima, 2016).

In the principal component analysis, the eigen values are used to find the number of components in the data and the highest eigen value represents the most important component. As shown in Table 3, the first basic component explains the relationship between yield components by 48.9%, while the second main component explains 16.0%. These two basic components explain the relationship between yield components cumulatively 64.9%.

When examine the Principal Component Analysis graph shown in Figure 4, three different clusters are noticed. Plant height, capsule length, seed yield per plant and number of capsules per panicle formed a group. Similarly, capsule length and 1000 seeds weight were divided into 2 groups.

Plant height, panicle length and number of capsules per panicle were found to be related to seed yield per plant in the first degree but capsule length and 1000 seeds weight were found to be related to same trait in the second degree. Savsatli, et al. (2016) reported that there is a positive ($P<0.05$) relationship between the seed yield per plant and panicle length and between the panicle length and the plant height. These results support the results obtained in the current research.

Table 3. Eigen values, variability values (%) and cumulative values (%) obtained as a result of Principal Component Analysis
Çizelge 3. Temel Bileşen Analizi sonucu olarak elde edilen Eigen değerleri, varyabilite değerleri (%) ve kümülatif değerler (%)

	F1	F2	F3	F4	F5	F6	F7	F8
Eigen value- *Eigen değerleri*	3.910	1.282	1.114	0.711	0.557	0.227	0.145	0.055
Variability (%)- *Varyabilite (%)*	48.869	16.025	13.920	8.886	6.958	2.842	1.814	0.686
Cumulative (%)-*Kümülatif (%)*	48.869	64.894	78.814	87.700	94.658	97.500	99.314	100.000

Contribution of the variables (%) (*Değişkenlerin katkısı (%)*)

	F1	F2	F3	F4	F5	F6	F7	F8
Genotype *(Genotip)*	1.658	40.147	3.277	53.386	0.332	1.087	0.109	0.004
N	5.220	31.775	1.945	21.773	37.715	0.004	1.445	0.122
Panicle length *(Salkım uzunluğu)*	21.278	0.010	7.962	1.921	1.099	5.927	13.456	48.345
1000 seeds weight *(1000 tohum ağırlığı)*	2.738	11.700	54.873	0.939	21.490	0.279	0.657	7.325
Number of capsules per panicle *(Salkımda kapsül sayısı)*	19.776	0.300	0.933	7.016	0.561	69.607	0.430	1.378
Capsule length *(Kapsül uzunluğu)*	4.732	15.289	30.321	13.433	32.054	1.753	2.346	0.071
Plant height *(Bitki boyu)*	21.676	0.149	0.521	0.746	5.967	4.204	66.628	0.108
Seed yield per plant *(Bitkide tohum verimi)*	22.921	0.629	0.167	0.786	0.781	17.139	14.930	42.647

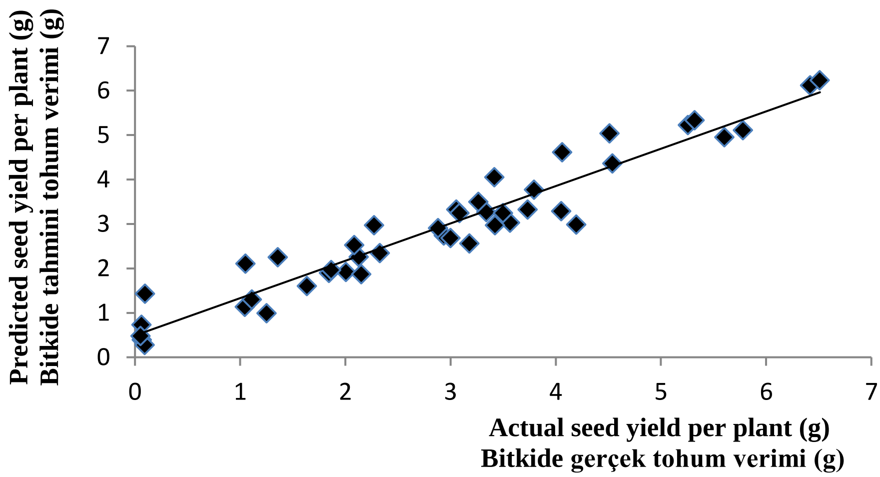


Figure 4. Modelling with multiple regression values of actual yield per plant and their estimated values
Şekil 4. Bitki başına gerçek verim ve tahmini değerlerinin çoklu regresyon değerleri ile modellemesi

CONCLUSION

In this study, it was determined that plant height, panicle length, number of capsules in panicle were the most important yield factors affecting the seed yield per plant. Considering these important traits in the breeding activities could provide a significant contribution to obtaining high seed yield per plant. In addition, the yield model generated from the data is the first model obtained in the plant.

Statement of Conflict of Interest

Authors have declared no conflict of interest.

Author's Contributions

The contribution of the authors is equal.

REFERENCES

Agomoh I, Zvomuya F, Hao X, Benke M 2018. Modeling Barley Yield in A Dark Brown Chernozem after Discontinuation of Long-term Manure Application. Soil Science Society of America Journal, 82: 392-402.

Başaran MS, Adıgüzel N 2001. Flora of Hazelnut Plantation in Bolu, Bartın and Zonguldak Provinces. Plant Protection Bulletin, 41(1-2): 39-66.

Baytop T 1999. Therapy with Medicinal Plants in Turkey. Nobel Medicine Publication, Istanbul, p 480.

Chiej R 1988. The Macdonald Encyclopedia of Medicinal Plants. Macdonald & Co. Ltd. Shoe Lane, London, p 66-73.

Clemente ES, Müller-Uri F, Nebauer SG, Segura J, Kreis W, Arrillaga I 2011. *Digitalis*. (Wild Crop Relatives. (Genomic and Breeding Resources: Plantation and Ornamental Crops. Springer-Verlag, Heidelberg: Ed. Chittaranjan K) 73-112.

Davis PH 1978. *Digitalis* L. in "Flora of Turkey and the East Aegean Islands, University Press, Edinburgh, p 680.

Deveci M, Bayrak Özbucak T, Demirkol G 2012. Determination of Ordu University Campus Flora. Akademic Journal of Agriculture, 1(2): 107-116.

Eminağaoğlu Ö, Anşin R 2005. The Flora of Cerattepe, Meydanlar, Demirci, Gavur Creek and Near Environment in Artvin. Journal of the Faculty of Forestry Istanbul University, 55(2): 31-46.

Confalonieri R, Rosenmund AS, Baruth B 2009. An Improved Model to Simulate Rice Yield. Agronomy for Sustainable Development, 29(3): 463-474.

Duarte GV, Braga A, Miquelluti DL, Ozaki VA 2018. Modeling of Soybean Yield Using Symmetric, Asymmetric and Bimodal Distributions: Implications for Crop Insurance. Journal of Applied Statistics, 45(11): 1920-1937.

Griffin TS, Johnson BS, Ritchie JT 1993. A Simulation Model for Potato Growth and Development. SUBSTOR-Potato Version 2.0. IBSNAT Research Report Series 02. Dept. of Agronomy and Soil Science. College of Tropical Agriculture and Human Resources, p 29.

Gurel E, Karvar S, Yucesan B, Eker I, Sameeullah M 2117. An Overview of Cardenolides in *Digitalis* - more than A Cardiotonic Compound. Current Pharmaceutical Design, 23(34): 5104-5114.

Jolliffe IT, Cadima J 2016. Principal Component Analysis. A Review and Recent Developments. Philosophical Transactions of the Royal Society, A 374:20150202, p 1-16.

Jones JW, Dayan E, Allen LH, Keulen HV, Challa H 1991. A Dynamic Tomato Growth and Yield Model (TOMGRO). American Society of Agricultural Engineers, 34(2): 663-672.

Kalaji MH, Pietkiewicz S 2004. Review: Some Physiological Indices to be Exploited as A Crucial Tool in Plant Breeding. Plant Breeding and Seed Science, 49: 19-39.

Kanoğlu SS, Aksoy N, Kaya A 2016. The Flora of Sülüklü Göl Around (Bolu-Adapazarı/Turkey). Journal of Vineyard-Garden Science, 3(2): 20-42.

Kurtar ES, Odabaş S 2010. Modelling of the Yield of Cucumber (*Cucumis sativus* L.) Using Light Intensity, Temperature and Spad Value. Advances in Food Sciences, 32(3): 170-173.

Lopez-Lazaro M 2007. Digitoxin as an Anticancer agent with Selectivity for Cancer Cells: Possible Mechanisms Involved. Expert Opin Ther Targets, 11(8): 1043-53.

Müjdeci M, Sarıyev A, Polat, V 2005. Mathematical Modelling of Wheat Yield (*Triticum aestivum* L.). Journal of Agricultural Sciences, 11(4): 349-353.

Newman RA, Yang P, Pawlus AD, Block KI 2008. Cardiac Glycosides as Novel Cancer Therapeutic Agents. Molecular Interventions, 8(1): 36-49.

Penning De Vries FWT 1983. Modeling of Growth and Production. (Physiological Plant Ecology IV. Encyclopedia of Plant Physiology (New Series), Berlin, Heidelberg: Ed. Lange OL, Nobel PS, Osmond CB, Ziegler H) 117-150.

Perez-Bermudez P, Cornejo MJ, Segura J 1990. *Digitalis* spp.: In vitro Production of Haploids. (Biotechnology in Agriculture and Forestry, Haploids in Crop Improvement I. Berlin: Ed. Bajaj YPS) 277-288.

Savsatli Y 2017. Digitalis Species in Flora of Turkey and Possibilities of Utilization from These Species. 4. National Agriculture Congress, 19-22 October, Afyon.

Savsatli Y, Catal MI, Seyis F 2016. Variation in *Digitalis ferruginea* L. Multiplicated with Seed under the Province Rize Conditions in Turkey. VII International Scientific Agriculture Symposium "Agrosym 2016", 06-09 October, Jahorina.

Sen A, Srivastava M 1990. Regression Analysis-Theory Methods and Applications. Springer-Verlag, New York inc, p 365.

Yeh JY, Huang WJ, Kan SF, Wang PS 2001. Inhibitory Effects of *Digitalis* on the Proliferation of Androgen Dependent and Independent Prostate Cancer Cells. Journal of Urology, 166(5): 1937-1942.