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Research Article
(Araştırma Makalesi)

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A research on rejuvenation pruning of lavandin (*Lavandula x intermedia* Emeric ex Loisel.)

Lavanta (*Lavandula* x *intermedia* Emeric ex Loisel.)'da gençleştirme budaması üzerine bir araştırma

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ABSTRACT

Objective: The main purpose of the research was investigate whether to be renewed or not without the need for re-planting by rejuvenation pruning to the aged plantations of lavandin. In the study was also compare effects on fresh stem, dry stem flower and dried flower yield and essential oil content of the Super A lavandin cultivar of pruning methods (semi-pruning and full pruning) in three different seasons (March/Spring, August/Summer and December/Autumn).

Material and Methods: The experiment was arranged according to a randomized block design with factorial treatments with three replications using 10-year-old Super-A lavandin cultivar (*Lavandula x intermedia* var. Super A) between 2014 and 2017 in Isparta-a city in the south-western part of Turkey.

Results: Pruning season, pruning method and pruning season x pruning method interaction (except for the essential oil content of dried flower) were found to be significant according to the analysis of variance. The highest values in terms of fresh stem, dry stem and dried flower yield were obtained as semi pruning (8936 kg ha^{-1}, 4763 kg ha^{-1} and 1931 kg ha^{-1}, respectively) in March. The highest essential oil content (2.66%) fresh stem flower was determined to semi-pruning in August, while the highest volatile oil content (5.07%) was obtained in dried flower to full pruning in December. Generally, control (non-pruned) plants showed the lowest values in terms of the characteristics examined.

Conclusion: The results obtained from the research showed that the aging plantations can be renewed without re-planting by rejuvenation pruning in lavandin.

ÖZ

Amaç: Araştırmanın temel amacı lavantada gençleştirme budaması yapılarak yaşlanan plantasyonların yeniden dikime gerek kalmaksızın yenilenip yenilemeyeceğini araştırmaktır. Çalışmada, üç farklı mevsimde (Mart/İlkbahar, Ağustos/Yaz ve Aralık/Güz aylarında) iki farklı budama şeklinin (yarım ve tam budama) Super A lavandin çeşidinin taze saplı, kuru saplı, kuru çiçek verimi ve uçucu yağ oranına etkileri de karşılaştırılmıştır.

Materyal ve Yöntem: Deneme tesadüf blokları deneme desenine göre üç tekerrürlü olarak 10 yaşındaki Super-A lavandin çeşidi (*Lavandula* x *intermedia* var. Super A) kullanılarak Türkiye'nin güneybatısında yer alan Isparta'da 2014 ve 2017 yılları arasında yürütülmüştür.

Araştırma Bulguları: Varyans analiz sonucuna göre, budama mevsimi, budama şekli ve budama zamanı x budama şekli interaksiyonu önemli (kuru çiçeğin uçucu yağ oranı hariç) bulunmuştur. En yüksek yaş saplı çiçek, kuru saplı çiçek ve kuru çiçek verimi Mart ayında yapılan yarı budama metodunda (8936 kg ha^{-1}, 4763 kg ha^{-1} ve 1931 kg ha^{-1}) elde edilmiştir. En yüksek uçucu yağ oranı yaş saplı çiçekte Ağustos ayında yarı budama şeklinde (%2.66) ve kuru sapsız çiçekte Aralık ayında tam budama şeklinde (%5.07) tespit edilmiştir. Genel olarak incelenen özellikler bakımından kontrol (budama yapılmayan) bitkileri en düşük değerleri göstermiştir.

Sonuç: Araştırmadan elde edilen sonuçlar, lavantada gençleştirme budaması yapılarak yaşlanan plantasyonların yeniden dikime gerek kalmaksızın yenilenebileceğini göstermiştir.

INTRODUCTION

Lavandin (*Lavandula* sp.), a plant belonging to family Lamiaceae, a significant perfume, cosmetic and medicinal plant that is cultivated in the World due to its high essential oil content and quality. Lavandin essential oil has a wide usage area, especially as perfume, cosmetics, medicine and food aroma (Guenther, 1952). There are three important lavender species in the world with high agricultural and industrial value: 1. Lavender (*Lavandula angustifolia* Mill.), (2) Lavandin (*Lavandula* x *intermedia* Emeric ex Lois) and (3) Spike lavender (*Lavandula spica* L.). Lavandin (*L*. x *intermedia*), which is also known as crossbred or hybrid lavender, is a natural crossbred of *L. angustifolia* and *L. spica,* and it was firstly identified in 1828 (Tucker, 1985). Of these species, lavender (*L. angustifolia* Mill.) and lavandin (*L.x intermedia* Emeric ex Loisel) cultivars are the most cultivated in the World. Generally, lavandin varieties are more preferred according to lavender varieties for dry flower production. Because, marketing value of dried flower of Hidcote and Munstead lavender varieties with dark purple flower and sweetish fragrance have higher according to grayish purple and more pungent lavandin varieties such as Grosso and Super A (Baydar, 2019).

In recent years, lavender/lavandin cultivation has shown great improvement in Isparta-a city in the south-western part of Turkey, which is called “The Lavender Valley of Turkey” (Kara and Baydar, 2013). Lavandin cultivation began on 0.3 hectare area in Kuyucak village of Keciborlu district of Isparta in the early 1970s. In later years, lavandin has been spread to the surrounding villages such as Kuscular, Aydogmus, Cukuroren and Ardicli, and it cultivated in an area of 362.3 hectares, with an annual production of 535 tons in 2018 year. In addition to Isparta, lavandin cultivation began in Afyonkarahisar (196.0 ha), Burdur (132.0 ha), Denizli (93.8 ha), Konya (17.8 ha), Tekirdag (11.7 ha), Mugla (15.1 ha), Nigde (17.0 ha), Kutahya (9.8 ha), Eskisehir (5.3 ha), Bursa (2.7 ha), Antalya (1.2 ha), Kayseri (1.1 ha), Edirne (1.0 ha), Adana (0.9 ha) and Kocaeli (0.7 ha) provinces. In Turkey, lavender is cultivated in an area of 868.4 hectares, with an annual production of 1040 tons (Anonymous, 2019a). Lavandin (Super A) variety is mostly cultivated in Isparta and these provinces, and in addition to, Bulgarian lavender (Sevtopolis, Hebar, Hemus and Raya) varieties are little cultivated (Baydar, 2019).

Lavender/lavandin plants begins to bud in June and bloom in July in Isparta climatic conditions. Harvest time, agronomic practices and age of plant in lavender/lavandin very effectives on essential oil yield and quality. For example, the highest essential oil content in lavandin Super cultivar in Isparta conditions was reached at the beginning of flowering (Erbas and Baydar, 2009). Since lavender is a perennial plant with long-lasting, it can be utilized economically for many years from the same lavender plantation. For example, some lavandin plantations in Isparta in the early 1970s were established, and production still continues in these fields. Economically, flower production in lavender begins the third year after planting, and flower yield continues to increase in the following years. However, the plant stem becomes woody on 10-15 years of age, and the plant has increasingly fallen from the yield due to aging, and flower yield was decreased. In this case, the lavender plants is removed, and it is replanted. Another alternative way is to rejuvenate. Pruning affects the health of the plants, the longevity of a field and the ease of harvest. But, wrong pruning can be very damaging to the plants. Heavy pruning can result in substantial winter damage, poor flower yield or plant death (Anonymous, 2019b). A study on rejuvenation pruning in the lavender has not been demonstrated in Turkey and the world. Therefore, the aim of the research was to compare effects on fresh stem/dry flower yield and essential oil content of the Super A cultivar of pruning methods in different seasons.

MATERIALS and METHODS

In the research, Super A lavandin variety for teen years were used. The experiment was conducted as three replications in a randomized block design with factorial treatments between 2014 and 2017 years in the experiment field of the Isparta University of Applied Sciences, Turkey. The distance of rows space 2 m and rows was 1 m, and each plot was 12 m in length, had 4 rows and 12 plants. Plants were not watered during pruning and in the following years, and were carried out depending on natural rainfall.

Nitrogen and phosphorus fertilizers were applied at March of each year at a rate of 80 kg ha^{-1} and 40 kg ha^{-1} in the form of ammonium sulfate and triple super phosphate, respectively. Rotary hoeing was used for weed control, and chemical control wasn't done due to disease and pests could not be detected. All the necessary agricultural practices were applied identically to the plots. Any observations from the experiment until the year 2016 were not conducted; however, the growing shoots were harvested. The yield and plant characteristic observations in both the propagation methods were measured in 2017.

The soil at a depth of 90 cm was low in organic matter (1.35%), in alkaline (pH 8.3) and limey (23.45% $CaCO_3$), low salt (EC: 0.16 ds/m) and sandy-loamy.

Some climatic data belong to experiment area and years are presented in Table 1.

Table 1. Some climatic data of experiment area*

Çizelge 1. *Deneme alanının bazı iklim verileri*

Climatic factors	Years	Months												Total or Average
		Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
Average temperature (^{0}C)	2014	3.7	5.2	7.3	11.7	15.1	20.0	24.5	24.9	18.4	12.9	6.8	6.0	13.04
	2015	1.9	3.3	6.7	9.0	18.3	20.4	24.2	23.8	21.8	14.5	8.7	2.4	12.91
	2016	1.3	7.3	7.6	14.0	14.6	21.6	25.0	24.4	18.9	14.8	7.2	0.3	13.08
	2017	-0.8	3.0	7.3	10.6	14.9	20.1	25.1	24.0	17.8	13.2	0.3	2.1	11.46
	Long years	1.7	2.6	5.9	10.5	15.5	20.1	23.4	25.8	18.3	12.8	6.9	3.0	12.20
Precipitation (mm)	2014	61.3	23.4	78.6	44.8	57.0	42.8	0.8	10.2	9.2	57.1	37.0	108.6	630.8
	2015	125.9	57.7	111.6	26.1	67.5	92.2	3.0	43.4	8.2	23.1	17.5	6.4	582.6
	2016	101.6	33.3	59.9	47.8	87.6	12.4	25.7	45.4	31.6	21.6	48.8	33.5	549.2
	2017	87.8	3.6	74.4	25.6	149.5	30.9	13.1	20.4	28.5	1.6	45.9	82.1	563.4
	Long years	64.2	54.9	52.8	58.8	46.0	27.8	12.8	0.3	15.4	38.0	51.5	70.9	493.4

*Data were taken from Isparta Meteorology Station.

The rejuvenation pruning was applied as two different pruning methods (semi-pruning, full pruning and control-no pruning) in three different seasons Spring (March), Summer (August) and Autumn (December) periods in 2014 year. Pruning treatment was made by wood cutting engine, and applications are as follows. 1. Semi-pruning: Above ground all branches of the plant was cut from 30 cm above the soil level. 2. Full pruning: Above ground all branches of the plant was cut 5-10 cm above of the soil level, and 3. Control: Pruning treatment wasn't applied.

In the research, data were measured in the third year after pruning treatment. When plants reached blooming stage, 2 rows in the center of each plot were harvested manually in July, and fresh stem flower (kg ha^{-1}), dry stem flower (kg ha^{-1}) and dried flower (kg ha^{-1}) were determined as describe by Kara and Baydar (2013). The fresh stem samples were dried on the wire rack in shade at room temperature, and dried flower were obtained by separating with hand from dried stem flower. In order to determine essential oil content of lavandin samples, 100 g samples in 1 L water were extracted by hydro-distillation for three hours using Clevenger apparatus (v/w %).

All the data were analyzed according to the analysis of variance (ANOVA) using SAS Statistical Package Program; the significant differences between the means were separated using the LSD test (Steel and Torrie, 1980).

RESULTS and DISCUSSION

Variance analysis results belong to effects on yield (fresh stem flower, dry stem flower and dried flower) and essential oil content of lavandin of pruning methods in different seasons are presented in Table 2. According to the results of variance analysis of data, pruning methods, pruning seasons and their (pruning methods x pruning seasons) interaction (except for the essential oil content of dried flower) were statistically significant for all examined characteristics (Table 2).

Table 2. Variance analysis results belong to examined characteristics
***Çizelge 2.** İncelenen özelliklere ait varyans analiz sonuçları*

Sources of variation	df	Mean square				
		Flower yield			Essential oil content	
		Fresh stem flower	Dry stem flower	Dried flower	Fresh stem flower	Dried flower
Pruning seasons (PS)	2	33028.8*	11737.2*	2054.4**	0.94**	0.25**
Pruning methods (PM)	2	140336.0**	48013.5**	9861.3*	1.46**	0.52*
PS x PM interaction	4	43510.5**	16060.1**	1648.5**	0.27*	0.08
Error	16	8255.5	2484.2	296.3	0.05	0.032
Corrected total	26					
*P<0.05, **P<0.01						

In the first year of experiment, shoot development quite lowed in both pruning methods in every season, however, since from the second year accelerated to growth and development of shoots. In other words, healthy plants were formed in subsequent years. Effect on flowering time of pruning methods weren't statistically significant.

Fresh stem flower, dry stem flower and dried flower yield (kg ha^{-1})

The highest fresh stem flower yield was obtained from semi-pruning in the March and August seasons (8936 kg ha^{-1} and 7896 kg ha^{-1}, respectively), while the lowest yield was determined in full-pruning in the August season (3718 kg ha^{-1}) (Table 3). Fresh stem flower obtained from control parcel was higher than full-pruning treatment. Considering the overall averages, the most proper pruning time was determined as semi-pruning in March season for fresh stem flower yield.

Table 3. Fresh/dry stem and dried flower yields of lavandin according to pruning methods and seasons
***Çizelge 3.** Budama metotları ve mevsimlere göre lavandinin taze/kuru saplı ve kuru çiçek verimleri*

Pruning seasons (PS)	Fresh stem flower yield (kg ha^{-1})			Mean
	Rejuvenation Pruning (RP)			
	Full-pruning	Semi-pruning	Control	
March	5803 b	8936 a	5861 b	6866 A
August	3718 c	7896 a		5825 B
December	5779 b	5781 b		5809 B
Average	5100 B	7541 A	5861 B	6166
LSD_{PS*PM} = 1573; $LSD_{PS\ and\ PM}$ = 908				

Pruning seasons (PS)	Dry stem flower yield (kg ha^{-1})			Mean
	Rejuvenation Pruning (RP)			
	Full-pruning	Semi-pruning	Control	
March	2789 d	4763 a	3422 c	3658 A
August	1545 f	3940 ab		2969 B
December	3016 e	2939 d		3126 B
Average	2450 B	3881 A	3422 A	3251
LSD_{PS*PM} = 863; $LSD_{PS\ and\ PM}$ = 498				

Pruning seasons (PS)	Dried flower yield (kg ha^{-1})			Mean
	Rejuvenation Pruning (RP)			
	Full-pruning	Semi-pruning	Control	
March	1021 c	1931 a	1209 c	1387 A
August	659 d	1522 b		1130 B
December	969 c	1183 c		1121 B
Average	883 C	1545 A	1209 B	1213
LSD_{PS*PM} = 298; $LSD_{PS\ and\ PM}$ = 172				

The highest dry stem flower yield was obtained from semi-pruning in the March season (4763 kg ha^{-1}), while the lowest yield was determined in full-pruning in the August season (1545 kg ha^{-1}) (Table 3). According to averages, dry stem flower obtained from control was higher than full-pruning treatment. On average, 52.7 kg dried stem flower were obtained from 100 kg fresh stem flower. This proportion varied according to the moisture amount of plant at the harvest date. It is expected to be lower at the beginning of flowering, and higher at the end of flowering.

As in fresh and dry stem flower yields, the highest dried flower yield was determined in semi-pruning in the March season (1931 kg ha^{-1}), while the lowest yield was determined in full-pruning in the August season (659 kg ha^{-1}) (Table 3). Shoot formation and yield were affected from pruning times, this may be due to the physiological structure of rootstock plants (Nicola et al., 2003). In addition too, shoot growing and development were affected by nutrient content according to the seasons, and shoot formation may be higher when there is high sugar and low starch (Gill and Boix, 1978). Rana (1996) reported that there were positive correlation between total C/N ratio, carbohydrate and phenol compounds with rooting and development. The fresh and dry stem flower yields in semi-pruning were higher than in full- pruning. The reason for this can be explained with the shoot formation and growth was better due to the shoot eyes were further and upwards in half pruning. Arabaci and Bayram (2005) found that the dry flower yield of the lavender varied between 700.0 0 kg ha^{-1} and 5780.0 kg ha^{-1}. Baydar and Erbas (2007) determined the mean fresh stem flower and dry flower yield of the variety Super A as 2500.0 kg ha^{-1} and 500.0 kg ha^{-1}, respectively, in the Isparta ecological conditions. Kara and Baydar (2013) informed that the fresh stem, dry stem and dried flower yield of lavandin were 5878 kg ha^{-1}, 3260 kg ha^{-1} and 1273 kg ha^{-1}, respectively. Karik et al. (2017) determined that the fresh stem, dry stem and dried flower yield of Super A variety were 7813.7 kg ha^{-1}, 3617.5 kg ha^{-1} and 1842.5 kg ha^{-1}, respectively. Sonmez and Okkaoglu (2019) stated that the fresh herb, dry herb and dried flower yield were 10442.7 kg ha^{-1}, 3706.1 kg ha^{-1} and 2245.6 kg ha^{-1}, respectively. Our findings showed differently with results of the above-mentioned researchers. The most significant characteristic affected to yield of lavandin is age of plant because of its perennial a plant, besides, genotype, harvest times, climatic and agronomic conditions (Pinto et al., 2007; Kara and Baydar, 2013; Sonmez and Okkaoglu, 2019).

Fresh stem flower and dried flower essential oil content (%)

Essential oil contents of fresh stem and dried flower of lavandin were presented in Table 4. Essential oil content of fresh stem flower varied between 1.43% (control)-2.66% (semi-pruning in the August season) (Table 4). Essential oil contents of fresh stem flower in both full-pruning and semi-pruning were higher than control.

When the pruning methods were compared, the essential oil content in full-pruning (2.18%) increased according to semi-pruning (2.01%), but, there was no statistically significant difference between their (Table 4).

Of the seasons, the highest essential oil content of fresh stem flower was determined in August month (2.23%), while the lowest essential oil content (1.58%) was obtained from March month (Table 4). These differences can be explained with higher seconder metabolite produce due to high temperature in August. The essential oil content of dried flower varied between 4.10%-5.07%, differences between pruning methods and seasons were significant, while pruning method x season interaction wasn't significant (Table 2). When the pruning methods were compared, the essential oil content in full-pruning increased according to semi-pruning.

The highest essential oil content of dried flower was obtained from December(4.78%) and March month (4.60%), while the lowest essential oil content (4.44%) was obtained in August month (Table 4). The essential oil content was affected from many biotic and abiotic factors such as harvest time, agronomic, climatic and environmental conditions, drying and distillation method (Arabacı and Bayram, 2005; Baydar and Erbaş, 2007; Kara and Baydar, 2013). Generally, it was found that the content of essential oil in dried flower was about 2.5 times higher than fresh stem flower (Table 4). Baydar (2019) reported that the essential oil content in fresh stem and dried flower of *L.x intermedia* Super A varied

between 1.0-1.5% and 5.0-6.0%, respectively, while Kara and Baydar (2011) determined its varied between 2.24-2.35% and 7.50-8.60%, respectively, in the Isparta ecological conditions. In another study carried out under the same ecological conditions, Kara and Baydar (2013) reported that the essential oil content in fresh stem and dried flower of Super A cultivar varied between 1.48-1.49% and 7.12-8.37%, respectively. Karik et al. (2017) determined that the essential oil content of variety Super A were 6.82%. Sonmez and Okkaoglu (2019) stated that essential oil content of lavender varied between 2.65-4.45%. Factors such as harvest time, genetic, biotic and abiotic, light density, agronomic and geographical conditions may influence the essential oil content (Ceylan et al., 1990; Gupta and Ganjewala, 2015; Lima et al., 2017).

Table 4. Essential oil contents of fresh stem and dried flower of lavandin according to pruning methods and seasons

Çizelge 4. *Budama metotları ve mevsimlere göre lavandinin taze saplı ve kuru çiçek uçucu yağ oranları*

Pruning seasons (PS)	Essential oil content of fresh stem flower (%)			Mean
	Rejuvenation Pruning (RP)			
	Full-pruning	Semi-pruning	Control	
March	1.83 bc	1.50 cd		1.58 C
August	2.60 a	2.66 a	1.43 d	2.23 A
December	2.10 b	2.07 b		1.87 B
Average	2.18 A	2.01 A	1.43 B	1.89
LSD_{PS*PM} = 0.387; $LSD_{PS\ and\ PM}$ = 0.25				

Pruning seasons (PS)	Essential oil content of dried flower (%)			Mean
	Rejuvenation Pruning (RP)			
	Full-pruning	Semi-pruning	Control	
March	4.87	4.40		4.60 AB
August	4.70	4.10	4.53	4.44 B
December	5.07	4.73		4.78 A
Average	4.87 A	4.41 B	4.53 B	4,61
$LSD_{PS\ and\ PM}$ = 0.18				

CONCLUSION

In conclusion, the highest fresh stem and dried flower yield (8936 kg ha^{-1} and 1931 kg ha^{-1}) were determined from semi-pruning method in March season. Dried flower yield obtained from semi-pruning method in lavandin plants that have fallen from yield was 27.8% higher than those without rejuvenation pruning. If semi-pruning takes place in March, this rate rises to 37.4%. On the other hand, fresh stem flower and dried flower yield were decreased in full-pruning method due to its negative effect on growth and development of plants.

The highest essential oil content in fresh stem flower (2.66%) was semi-pruning method in August season, while the highest essential oil content in dried flower (5.07%) was full-pruning method in December.

According to the results of the research, it was concluded that lavandin can be renewed without the need for re-planting by rejuvenation pruning to the aged plantations. But, if there is disease and pest such as stolbur phytoplasm (*Stolbur phytoplasma*) and dwarf cicada (*Hyalestes obsoletus*) in the lavandin field, free-disease lavandin seedlings must be planted instead of rejuvenating pruning.

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