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Research Article (Araştırma Makalesi)

Investigation of Some Agricultural Performances of Lavender Varieties

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Abstract: During the period from 2014 to 2017 year in the region of Dobrich, Bulgaria, a field experiment has been conducted with the aim to determine some agricultural characteristics of lavender varieties. The following characters have been investigated: number of flowers/plant, length of the flowering stem, number of flower clusters/plant, weight of flowers/plant (g), yield of flowers (kg ha^{-1}), essential oil content %, extraction essential oil yield (kg). The experiment has been carried out according the randomized block design in four replications and plot size of 10 m^2. Four lavender varieties have been used- Hemus, Yubileyna, Druzhba and Sevtopolis. From the performed analyzes, it was established, that the variety Druzhba distinguished from the other varieties in term of yield of fresh flowers, not only by years, but also on average for the study period, as the higher productivity of this variety is due to the higher values of the structural elements of the yield. The highest percentage of essential oil content for the three-year period with 2.1% was realized from the variety Sevtopolis, and the lowest with 1.6% from the variety Hemus.

Lavanta Çeşitlerinin Bazı Tarımsal Özelliklerinin İncelenmesi

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Anahtar kelimeler

Lavanta,
Verim yapısal elementleri,
Taze çiçek verimi.

Öz: Bulgaristan'ın Dobrich bölgesinde 2014-2017 döneminde lavanta çeşitlerinin bazı tarımsal özelliklerini belirlemek için bir saha denemesi yapılmıştır. Aşağıdaki göstergeler incelenmiştir: çiçek/bitki sayısı, çiçek sapının uzunluğu, çiçek demeti/ bitki sayısı, çiçek/bitki ağırlığı (g), çiçek verimi (kg/ha), uçucu yağ içeriği % ve ekstraksiyon uçucu yağ verimi (kg). Deneme tesadüf blokları deneme desenine göre dört tekerrürlü olarak ve 10 m^2 parsel büyüklüklerinde gerçekleştirilmiştir. Dört çeşit lavanta kullanılmıştır: Hemus, Yubileyna, Druzhba ve Sevtopolis. Yapılan analizlerden, Druzhba çeşidinin diğer çeşitlerden sadece taze çiçek verimi açısından sadece yıllara göre değil, aynı zamanda çalışma dönemi ortalaması olarak farklı olduğu belirlenmiştir; çünkü bu çeşit verim açısından daha yüksek yapısal değerleri yüzünden daha yüksek verimliliğe sahip olmuştur. Üç yıllık dönem için en yüksek uçucu yağ yüzdesi % 2.1 değeri ile Seuthopolis çeşidinden ve en düşük değer ise % 1.6 değeri ile Hemus çeşidinde gerçekleşmiştir.

1. Introduction

Bulgaria is among the world leaders in the production and export of high quality lavender oil. In recent years, the increased interest from farmers has led to a progressive increase in lavender areas and as a consequence the crop starts to spread in untraditional areas. A typical example is the region of Dobrich, where lavender begins to replace the traditional cultivation of cereals

Lavender is one of the most used aromatic and medicinal plants with great economic value for the pharmaceutical, food, cosmetic and perfume industries (Aprotosoaie et al., 2017). The genus Lavandula, originated in the Mediterranean region, includes 39 species (*Lavandula* sp.) and about 400 registered varieties (Benabdelkader et al., 2011). They are perennial semi-shrub plants that form small rounded shrubs called tuffs, which differ in morphological and chemical composition (Lesage-Meessen et al., 2015).

The variety has a significant effect on the content of the essential oil (Erland and Mahmoud, 2016). Lavender plants grown at higher altitudes are richer in essential oil. Da Porto et al. (2009) reported doubled content of essential oil by Italian lavender, grown at 500 m above the sea level compared to plants grown at 20 m (1 vs. 0.5%). Generally, it is considered, that the high content of lavender essential oil requires a warm and dry climate and medium altitudes (700-1200 m) (Carrasco et al., 2015).

An essential oil content of between 0.44 and 1.89% has been reported by some local populations of *L. angustifolia* grown in Greece at altitudes between 330 and 710 m. Larger amounts of essential oil accumulate when the weather is quiet and sunny at full flowering, and with the progression of the vegetation the content decreases (Masetto et al., 2011).

The selection of lavender for essential oil continues in direction of creating new varieties with a complex set of economically important features - high yield and quality of the essential oil, increased vitality and resistance to adverse weather conditions, suitability for mechanized harvesting. As a result of selection, the approved forms are included in the next stage of research (Stanev and Dzhurmanski, 2011). Bulgaria has tradition in the cultivation of lavender (*Lavandula angustifolia* Mill) and the production of essential oil. Stanev et al. (2016), present the main trends in the development of the lavender industry in Bulgaria in the 21st century. The data show the advantages of vegetative propagated varieties instead of lavender populations obtained from seeds.

The yield of fresh flowers and essential oil of six Bulgarian varieties of lavender have been investigated in the region of Kazanlak and it was found that the tested characters are most strongly influenced by the specific interaction between the genotype and the climatic conditions of the year (69% and 80.4%). The varieties "Druzhba", "Sevtopolis", "Yubileyna" and "Hebar" are characterized by high adaptability but retained their stability of yield only when the soil and climatic conditions of cultivation are good. The varieties "Hemus" and "Raya" provide very stable yields even under more unfavorable growing conditions (Stanev, 2010).

A study in the region of Plovdiv with several varieties of lavender report, that the highest yield of fresh inflorescences was obtained from the variety Druzhba - 6.4 t/ha, the highest percentage of essential oil by - Sevtopolis - 2%, the highest content of linalil acetate was reported by the variety Hemus - 39.6%. The analysis of the oil confirms that the Bulgarian varieties are characterized by high quality indicators and are competitive on the international market (Yanchev, 2017).

The specific soil and climatic conditions in different regions of the country affect the growth, development and productivity of the lavender. Therefore, research related to the cultivation of varieties of lavender in different districts of the country have a certain scientific and practical significance. . The cultivation of the culture in different regions of the country requires more investigation for determining which varieties are most adapted to the local environmental conditions. In this connection the aim of the present research is to define some agricultural characteristics of four different lavender varieties, cultivated in the untraditional region of Dobrich.

2. Material and Methods

In order to achieve the aims of the study, a field experiment has been conducted during the period from 2014 to 2017 in the region of Dobrich – Northeastern Bulgaria. Four varieties of lavender have been used - "Hemus", obtained by individual and branch selection; "Yubileyna" and "Druzhba",

created by hybridization and "Sevtopolis", created by chemical mutagenesis combined with clonal selection. The experiment was arranged according the randomized block design (Raghavarao et al., 2005) in four replications and plot size of 10 m^2. The cultivation of the varieties was performed according to the adopted technology (Yankov, et al., 2013). To achieve the goal of the study, the following characters were reported: number of flowers/plant, length of the flowering stem, number of flower clusters/plant, weight of flowers/plant, yield of flowers (kg/ha), essential oil content %, extraction essential oil yield (kg).

The experimental data were processed by the method of analysis of variance (Anova), and the differences between the variants were established by the multi-rank LSD test. The dependents between the yield and the investigated characters have been calculated with a correlation analysis, performed with XLSTAT Version 2016.02.

2.1. Soil and climatic characteristics of the region

The studies were performed on slightly leached chernozem, characterized by a relatively strong humus horizon, which extends on average in the range of 60-80 cm. These soils are uniform in mechanical composition - heavy sandy-clayey along the entire depth of the profile. The amount of humus for the upper horizons by Turin ranges from 3.79 to 3.47%. The total nitrogen reserve in the surface layers varies from 156 to 166 mg/100 g soil by Kjeldal and characterizes the soil as moderately stocked with nitrogen. In terms of mobile phosphorus content (according to Egner-Reim) it belongs to the group of poorly stocked, and in terms of mobile potassium content to medium stocked soils (Valcheva et al., 2013).

The main climatic factors determining the growth, development and productivity of lavender are temperatures and precipitation, as well as their combination and distribution during the growing season (Stanev, 2005). The average monthly temperatures in the survey years did not differ significantly from those of the long-term period (Figure 1). From the beginning of the vegetation to the beginning of flowering, the required temperature amount for the lavender is 1000-1100 ºC (Yankov et al., 2013). During the years of study, it is 1193 ºC, 1223 ºC and 1083 ºC respectively for 2015, 2016 and 2017, and it is sufficient for the development of the plants during the phases of leafing, budding and beginning of flowering. During flowering and harvesting, higher temperatures contribute to the accumulation of more essential oil in the flowers (Nedkov et al., 2005). During the period of 2014-2017, the average daily temperature values exceed the perennial ones, not only in the region of Dobrich, but also in the typical region for the cultivation of the lavender - Kazanlak, so that the requirements of the culture for heat during the flowering can be met. The amount of precipitation during the experimental period has values close to or slightly higher than those of the long-term period.

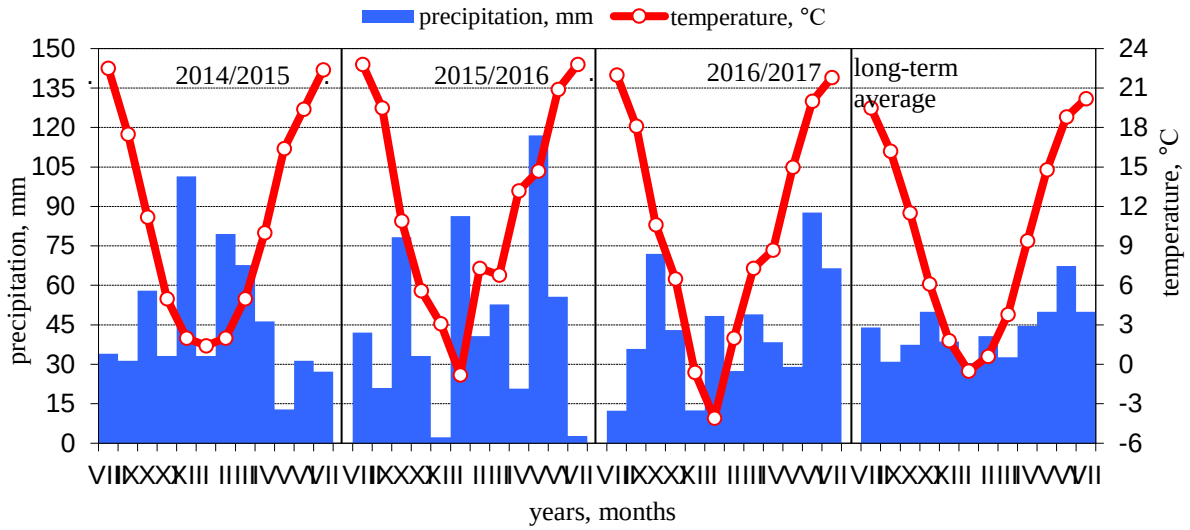

Figure 1. Climatogram of the Dobrich region.

3. Results and discussion

One of the important traits determining the yield is the number of flowers. The results show that this character is influenced by both, the variety and the climatic conditions of the year (Table 1). The largest number of fresh flowers was reported in 2015, when precipitation was moderate, and temperatures were relatively high. By the tested varieties this character is in the range from 630 (by the variety Hemus) to 785 flowers/plant (by the variety Druzhba). The number of fresh flowers has the lowest values in 2016 and varies from 530 to 680 flowers/plant, which is by about 13% and 5% less, than in 2015 and 2017, respectively. On average for the experimental period, depending on the variety, the number of fresh flowers is from 721.7 to 576.7. The smallest number of flowers/plant forms the variety Hemus, as by the varieties Yubileyna, Sevtopolis and Druzhba an increase in the values of the tested parameter with respectively 8, 13 and 25% is observed.

Regarding the character length of the flowering stem, varietal specificity has been determined, which is also influenced by the conditions of the year. From the tested varieties – the variety Druzhba has the longest stems, ranging from 26.5 to 28.0 and 29.5 cm, respectively for 2016, 2017 and 2015. Depending on the year this variety exceeds by up to 4 cm the length of the flowering stems by the varieties Yubileyna, Sevtopolis and Hemus. On average for the experimental period, by the variety Hemus (24.4 cm) the length of the flowering stems is shorter with 1.3, 1.9 and 3.6 cm compared to the varieties Sevtopolis, Yubileyna and Druzhba, respectively. The character has values of 26.3 and 25.7 cm by the varieties Yubileyna and Sevtopolis and 28.0 cm –by the variety Druzhba.

The density of the spike is determined by the length of the flowering stem and the number of flower clusters. The number of flower clusters depends on the genotype, but is influenced by the weather conditions, as well as the application of appropriate agronomic measures during the cultivation of the lavender. The smallest number of flower clusters from 4.7 by the variety Hemus to 6.5 clusters per plant by the variety Druzhba was observed during the second year of the investigation. In the third year, the values of this character vary from 5.3 to 8.0 and exceed on average by 15.3% those reported in the previous year. On average for the three- year period the largest number of flower clusters were reported by the variety Druzhba - 7.8 clusters/plant, followed by the varieties Sevtopolis and Yubileyna (6.2 and 6.8 clusters/plant), and the smallest value was observed by the variety Hemus - 5.3 clusters/plant.

The character weight of flowers/plant changes over the years depending not only on the weather conditions, but also on the variety. The highest values of this character were reported in the first experimental year, when the vegetation of the lavender occurs by favorable conditions - optimal temperature values and evenly distributed rainfall. Depending on the variety, the weight of the flowers/plant in 2015 is from 305 g by the variety Hemus to 357 g – by the variety Druzhba, in 2016 it is in the range between 233 - 290 g, and in 2017 it varies from 252 to 309 g. During the period of the experiment, the variety Druzhba exceeded the varieties Hemus, Yubileyna and Sevtopolis on average by 55.4 g, 32.7 g and 20.7 g, respectively.

The data in Table 2 show that the variety Druzhba distinguished from the other varieties in term of yield of fresh flowers, not only by years, but also on average for the study period and the differences with the other varieties are statistically proven. The higher productivity of this variety is due to the higher values of the structural elements of the yield. The favorable combination of the meteorological conditions in 2015 is a requirement for obtaining higher yields of fresh flowers compared to 2016 and 2017. The values obtained vary between 6400 kg ha^{-1} by the variety Hemus and 7500 kg ha^{-1} by the variety Druzhba. In the third experimental year, the yields obtained from the tested varieties were on average 15.2% lower than in the first studied year.

Table 1. Yield structural elements of lavender varieties

Characters	2015	2016	2017	Average
Number of flowers/plant				
Hemus	630^{d}	530^{d}	570^{d}	576.7^{D}
Yubileyna	650^{c}	590^{c}	625^{c}	621.7^{C}
Druzhba	785^{a}	680^{a}	700^{a}	721.7^{A}
Sevtopolis	690^{b}	620^{b}	650^{b}	653.3^{B}
LSD 5%	19	22	25	22
Length of the flowering stem(cm)				
Hemus	25.8^{d}	23.5^{c}	24.0^{c}	24.4^{C}
Yubileyna	28.0^{b}	25.0^{b}	26.0^{b}	26.3^{B}
Druzhba	29.5^{a}	26.5^{a}	28.0^{a}	28.0^{A}
Sevtopolis	27.0^{c}	24.5^{b}	25.5^{b}	25.7^{B}
LSD 5%	1.1	1.0	1.3	1.1
Number of flower clusters				
Hemus	6.0^{c}	4.7^{b}	5.3^{d}	5.3^{C}
Yubileyna	7.5^{b}	6.0^{a}	7.0^{b}	6.8^{A}
Druzhba	9.0^{a}	6.5^{a}	8.0^{a}	7.8^{A}
Sevtopolis	7.0^{b}	5.5^{a}	6.0^{c}	6.2^{B}
LSD 5%	1.3	1.1	0.8	1.1
Weight of flowers/plant (g)				
Hemus	305^{c}	233^{c}	252^{c}	263.3^{C}
Yubileyna	328^{b}	257^{b}	273^{b}	286.0^{B}
Druzhba	357^{a}	290^{a}	309^{a}	318.7^{A}
Sevtopolis	333^{b}	276^{a}	285^{b}	298.0^{A}
LSD 5%	22	21	23	22

*Values with the same letters do not differ significantly.

Table 2. Yield of fresh flowers, kg ha^{-1}

Variety	2015	2016	2017	Average
Hemus	6400^{b}	4900^{c}	5300^{b}	5533^{c}
Yubileyna	6870^{b}	5400^{c}	5740^{b}	6003^{c}
Druzhba	7500^{a}	6100^{a}	6500^{a}	6700^{a}
Sevtopolis	7000^{b}	5800^{b}	6000^{b}	6267^{b}
LSD 5%	486	294	479	420

*Values with the same letters do not differ significantly.

The mathematical processing of the data shows that the differences between the varieties Hemus and Yubileyna are statistically unproven, not only by years, but also for the tree- year period of the study. The yield of fresh lavender flowers from the tested varieties in 2016 is lower by 25% and 18% compared to 2015 and 2017 and varies from 4900 kg ha^{-1} (by Hemus) to 6100 kg ha^{-1} (by Druzhba).

Table 3. Two-way ANOVA analysis of variance.

Source of Variation	SS	df	MS	F	P-value	F crit
Years	16904467	2	8452233	323,70	0,00*	3,26
Varieties	8586767	3	2862256	109,62	0,00*	2,87
Interaction	126733	6	21122	0,81	0,57^{ns}	2,36
Within	940000	36	26111			
Total	26557967	47				

* - significance at 0.05 level; ^{ns} – no significance.

The differences between the varieties are proven. For the tested period the variety Druzhba statistically proven distinguishes with the highest yield of fresh flowers – 6700 kg ha^{-1}, followed by the variety Sevtopolis – 6267 kg ha^{-1}, and with the lowest values the variety Hemus – 5533 kg ha^{-1}.

Previous studies reported values of the yield of fresh flowers between 5.57-14.99 t ha^{-1} (Arabaci and Bayram, 2005). Karik et al. (2017) estimated the yield of some lavender species under the ecological conditions of Bornova and reported values from 0.21 to 0.62 t ha^{-1}. Our observation, that the environmental conditions of the year and the genotype have influence on the yield and its structural components confirm the reports of other researchers (Seidler-Łożykowska et al., 2014; Stanev et al., 2016; Degu et al., 2017; Özel, 2019).

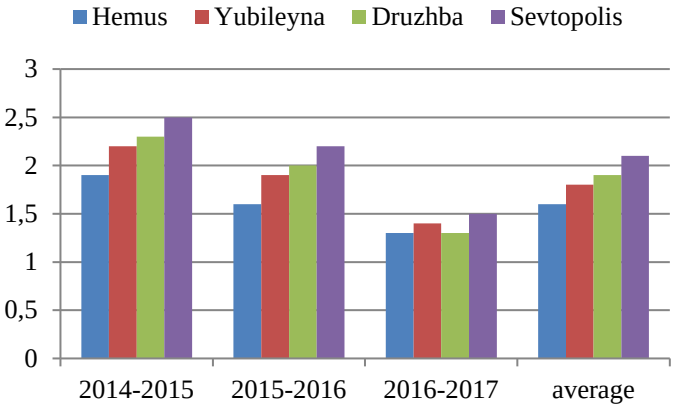

Figure 2. Content of essential oil (%).

The results from the performed two-way ANOVA analysis of variance (Table 3) confirm that both factors year and variety proven influence the yield of fresh lavender flowers itself, but their interaction is unproven. The content of essential oil is favored by the warm, sunny and dry weather at harvest. In this aspect, the obtained results (Figure 2) show that the highest content of essential oil was reported in the first harvest year and the values vary depending on the variety from 1.9% (by Hemus) to 2.5% (by Sevtopolis). The lowest values of this character were reported in 2017, when the precipitation was significant during the stages flowering and harvesting of the lavender. The content of essential oil in the tested varieties has similar values of 1.3% by the varieties Druzhba and Hemus, 1.4% - by the variety Yubileyna and 1.5% by the variety Sevtopolis. Our results confirm the observations of Hassiotis et al. (2014), who reported that the content of essential oil is positively regulated by the temperature at flowering stage development and is negatively affected by rainfall during the flowering period. In 2016 the content of essential oil is in the range of 1.6% by the variety Hemus to 2.2% by the variety Sevtopolis. On average, for the three years of the research, the variety Sevtopolis exceeds by 10.5%, 16.6% and 31.2% the varieties Druzhba, Yubileyna and Hemus. Yanchev (2017) researched the productivity and quality of four Bulgarian lavender varieties and reported values of essential oil in the range of 1.9 to 2.6 %, as the amount of the harvested flowers varied between 560 to 690 kg da $^{-1}$. Some previous researcher reported content of lavender essential oil at least 3.2 % (Nurzynska and Zawislak, 2016), between 2.10- 9.62 % (Kara and Baydar, 2011), between 1.32- 3.10 % (Karik et al., 2017). Our observations, that the essential oil content varies depending on the variety and the climate conditions of the year, agree with the observation of other authors (Kara and Baydar, 2013; Stanev et al., 2016).

The extraction yield is the amount of raw material necessary to produce a liter of essential oil. The yield depends on the lavender variety but is also influenced by the climatic conditions of the year. According to this character, the obtained data show that in the year with heavy rainfall (2017) during the stages flowering and harvesting, its values are higher compared to 2015 and 2016 and vary between 66.7 and 76.5 kg (Figure 3). During the same year the extraction yield is the lowest by the variety Sevtopolis, followed by the varieties Yubileyna and Hemus, as by the variety Druzhba the values of the indicator are the highest. A very good yield with values from 40 to 53.5 kg was reported in 2015 and in 2016 the extraction yield varied from 45.7 to 61.3 kg. The average data for the three - year period show that the variety Sevtopolis proven is the variety with the lowest extraction yield with values of 50.8 kg, followed by the varieties Druzhba and Yubileyna (57.1 and 57.2 kg). By the variety Hemus the values of the character are the highest (63.4 kg).

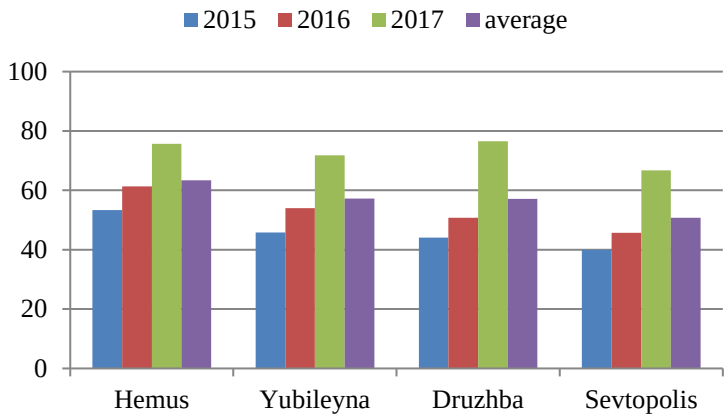

Figure 3. Extraction yield, kg.

From the performed correlation analysis, it can be concluded, that there exist a positive correlations between the yield of fresh flowers and some of its structural components - number of flowers/plant, length of the flowering stem, number of flower clusters and weight of flowers/plant (Table 4). The strongest relation is observed between the variables yield of fresh flowers and weight of flowers/plant (1.0*). Strong negative correlation is determined between the content of essential oil and the other variables, except the extraction yield, where the relation is positive and moderate (0.409). Analogical to the content of the essential oil, the values of the variable extraction yield have the tendency to decrease, when the values of the yield of fresh flowers, number of flowers/plant, length of the flowering stem, number of flower clusters and weight of flowers/plant increase, because of the determined negative correlation.

Table 4. Correlation matrix (Pearson)

Variables	1. Yield of fresh flowers	2. Number of flowers/ plant	3. Length of the flowering stem	4. Number of flower clusters	5. Weight of flowers/plant	6. Content of essential oil	7. Extraction yield
1		0.909	0.923	0.858	1.000	-0.801	-0.520
2			0.918	0.898	0.905	-0.889	-0.360
3				0.976	0.922	-0.872	-0.320
4					0.857	-0.821	-0.206
5						-0.798	-0.523
6							0.409
7							

*Values in bold are different from 0 with a significance level alpha =0.05.

With larger values of number of flowers/plant, the values of the variables - length of the flowering stem, number of flower clusters and weight of flowers/plant have also tendency to increase. The scatterplots illustrate the determined relations (Figure 4) and define the strong positive relation between the yield of fresh flowers and weight of flowers/plant as roughly linear.

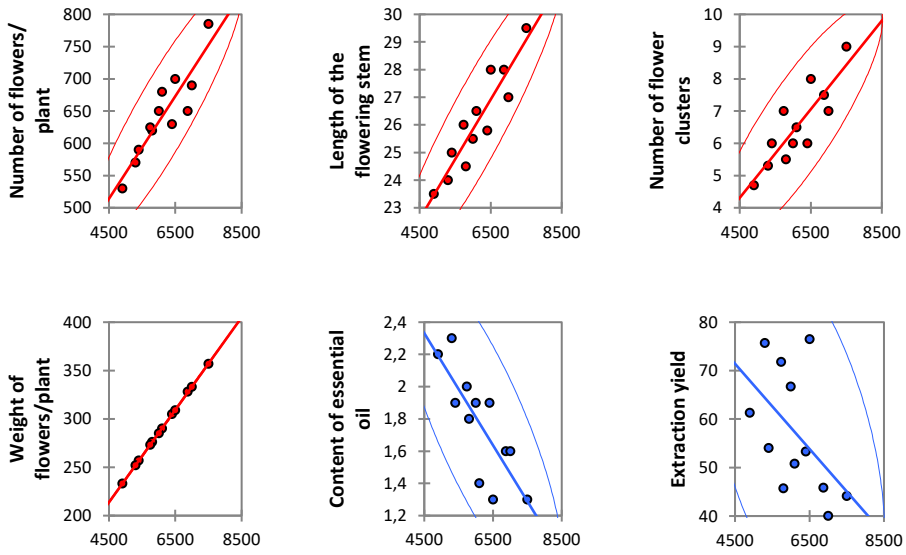

Figure 4. Correlation scatter plots between Yield of fresh flowers and other indices.

4. Conclusion

The performed experiment evidenced that the tested lavender varieties can be successfully cultivated in the untypical region of Northeastern Bulgaria, as on average for the examined period, the best performance shows the variety Druzhba. The higher yield of Druzhba variety in comparison with the others - is due to the higher values of its structural elements – number of flowers/plant, length of the flowering stem number of flower clusters and weight of flowers/plant. During the study period the highest percentage of essential oil was realized from the variety Sevtopolis, and the lowest from the variety Hemus. As a result, for the region of Dobrich, we could recommend the variety Druzhba for yield of fresh flowers and the variety Sevtopolis for oil production.

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