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# Determination of the Relationship between Yield and Yield Components of Winter Red Lentil Genotypes under the Conditions of Amik Plain

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**Abstract**

The study was carried out for two years under the farming conditions in Kırıkhan/Hatay, Turkey with 16 red lentil genotypes including 14 lines and two control varieties, during the 2013-2014 and 2014-2015 cultivation seasons. The study aimed to determine responses of the lentil genotypes to cold stress during cultivation and was replicated four times in randomized blocks trial design. Two-year study showed that properties of the genotypes varied: plant height was between 22.0 and 28.1 cm, the first pod height was between 10.3 and 18.4 cm, number of pods per plant was between 19.6 and 30.2, 1000-seed weight was between 23.9 and 36.9 g and seed yield per decare was between 68.9 and 106.1 kg da$^{-1}$. The correlation analysis to determine the relationship between yield characteristics showed a positive and important relationship between yield and number of flowering days, number of maturation days, the first pod height, number of branches per plant, number of pods per plant, biological yield and 1000-seed weight. When the path analysis is evaluated, the highest positive direct effect on yield was observed in 1000-seed weight with 0.337 and, with 0.115, the lowest positive direct effect was observed in plant height.

**Keywords:** Hatay, lentil, genotype, yield, correlation, path analysis

# Amik Ovası Koşullarında Kışlık Kırmızı Mercimek Genotiplerinin Verim Performansları ile Verim Öğeleri Arasındaki İlişkilerin Belirlenmesi

**Özet**

Bu çalışma 2013-2014 ve 2014-2015 yetiştirme sezonunda 14'ü hat ve ikisi kontrol çeşidi olmak üzere 16 adet kırmızı mercimek genotipi ile Kırıkhan/Hatay mevkiinde çiftçi şartlarında iki yıl süre ile yürütülmüştür. Mercimek genotiplerinin yetiştirme süresince karşılaştıkları soğuk stresine tepkilerinin belirlenmesi amacıyla yürütülen çalışma tesadüf blokları deneme deseninde 4 tekrarlamalı olarak kurulmuştur. İki yıllık araştırma sonucunda birleştirilmiş veriler değerlendirildiğinde genotiplerin bitki boyunun 22.0-28.1 cm, ilk bakla yüksekliğinin 10.3-18.4 cm, bitkide bakla sayısının 19.6-30.2 adet, bin tane ağırlığının 23.9-36.9 g ve tane veriminin 68.9-106.1 kg/da arasında değişim gösterdiği belirlenmiştir. Verim özellikleri arasında ilişkilerin belirlenmesi amacıyla yapılan korelasyon analizi sonucunda verim ile çiçeklenme gün sayısı, olgunlaşma gün sayısı, ilk bakla yüksekliği, bitkide dal sayısı, bitkide bakla sayısı, biyolojik verim ve bin tane ağırlığı arasında olumlu ve önemli ilişkiler tespit edilmiştir. Path analizi değerlendirildiğinde ise verim üzerinde en yüksek olumlu doğrudan etki 0.337 ile bin tane ağırlığında gözlenirken, en düşük olumlu doğrudan etki ise 0.115 ile bitki boyunda gözlenmiştir.

**Anahtar Kelimeler:** Hatay, mercimek, genotip, verim, korelasyon, path analizi

**Introduction**

Lentil is an edible grain legume plant which, after chickpea, has the broadest cultivation area in Turkey because of its important agricultural characteristics such as its durability against adverse environmental conditions and its lack of selectivity in terms of soil requirements. As a matter of fact, 4 million hectares of cultivation area and 4 million tons of production in the world puts lentils in the fifth place around the world, while in Turkey, 281 thousand ha cultivation area and 417 thousand tons of production puts it in the second place after chickpea (Anonymous, 2015). Import and export figures of red lentils from the world and Turkey are as important as lentil cultivation area and production amount. In 2013, the total import of lentils in the world was 2.51 million tons, which corresponded to a monetary value of 1.9 billion dollars. In the same year, 200 thousand tons of lentils were imported and 132 million of dollars were gained. The total amount of lentils exported in the world is 2.66 million tons, which corresponds to a monetary value of 1.8 billion dollars, while Turkey earned 168 million dollars in 2013 for 179 thousand tons of lentil production (Anonymous, 2013). The 24 varieties of registered lentils 15 of which are red and 9 of which are green contribute greatly to the agricultural development of Turkey (TUIK, 2016).

During the vegetation period, lentil plants can be grown very successfully in regions with annual temperatures summation of 1500-1800 °C and an annual rainfall of 750 mm (Sepetoglu, 1992). It can be cultivated in a variety of soil types but requires neutral or slightly alkaline soil sand the effect of the assimilation agents stored during the vegetation period on the grain is lower compared to other legumes (Bozoglu and Peksen, 1997). Since it is a leguminous plant, it is of immense importance in crop monitoring systems and in the evaluation of fallow fields. Subhani et al. (2007) stated that lentil is the main plant of low-yielding soils. Shah et al. (2013) stated that lentil could be successfully cultivated in areas where the rain regime is irregular, rainfall is low and ecology limits vegetation.

Today, the biggest problem encountered in the cultivation of lentil is the failure at achieving yield stability (Karadavut and Palta, 2010). The local varieties in Turkey sometimes suffer a considerable damage from cold and fungal diseases, depending on ecological conditions. Therefore, the development of genotypes that are resistant to adverse conditions or have tolerant and yield stability is important for lentil farming in Turkey. Agrawal (2009) stated that lentil yields will increase by at least 30% with the development of new varieties that are not affected by cold and high temperatures and suitable for different climatic conditions. Rao and Yadav (1988) pointed out that achieving this is not too difficult because the genetic variability in the lentil plant is high enough.

With the introduction of new varieties that are resistant to arid, cold and high temperatures, great contributions can be made to the agriculture in Turkey. While the ecology of Hatay province is very suitable for growing lentils in winter, factors including mostly growing local varieties instead of registered varieties, the damage caused by cold conditions and the problems encountered in weed control limit cultivation during winter. It is possible to reach the desired results by ensuring the continuity of lentil breeding programs via systematic studies (Bicer and Sakar, 2008). Path analysis is used in breeding studies because it determines direct and indirect effects. The practicality and practicality of the results achieved has expanded the use of path analysis.

This study aimed to determine winter farming in Amik Plain/Hatay and yield performances of high yield and cold-tolerant red lentil genotypes obtained from ICARDA as well as to determine the relationship between characteristics affecting the yield and the direct and indirect effect of these characteristics on yield.

**Materials and Methods**

Field trials were carried out for two years under the farming area conditions of Kırıkhan/Hatay Topbogaz location with 16 red lentil genotypes, including the 14 line provided by the company with the short name ICARDA **(**International Center for Agricultural Research in the Dry Areas) during the cultivation season of 2013/2014 and 2014/2015 (Figure 1). Analyses showed that the soil had a clay-loamy structure, pH was 7.72, organic matter content was as low as 1.75, the medium was calcareous (9.34%) and salt-free, the level of potassium was sufficient (1.24 Me/100 g) and the phosphorus was insufficient (2.02 ppm).

The Mediterranean climate prevails in Hatay, which is in the Eastern Mediterranean Region, the south of Turkey. Summers are hot and dry and winters are cold and rainy. Snowfall is only observed for a few days in a year. The temperature is between -6.3 °C and 43 °C. Temperatures at the mountains are lower than that at plain fields. The annual rainfall is 877-1174 mm. For the cultivating season in which the experiment is conducted; in the first year, the lowest average temperature was 9.8°C and observed in January, while the highest average temperature was 26.4 °C and observed in

June. In the second year, the lowest average temperature was 10.3 °C and observed in February and the highest average temperature was 27.3 °C and observed in June.

These values are very close to the average value measured for long term periods. The highest amount of rainfall was in November (130.5 mm), and the lowest amount of rainfall was in February with a lowest rainfall of 11.5 mm. In the second year, the highest rainfall was observed in January with 117.6 mm, while the lowest rainfall was observed in June (27.3 mm). There was no significant change in the amount of moisture between two years and the relative humidity values were between the ranges of 70-75%. The fact that climate data is very close to the values determined for longer periods indicates that there is no extreme change between two years.

14 lentil genotypes obtained from ICARDA and Fırat 87 and Şakar varieties were used as controls in the experiment (Table 1).


**Figure 1.** Topbogazı location which was carried out of research

**Table 1.** Some characteristic features of red lentil varieties included in the study

| Cultivar Name | Characteristic Features | Registrant Institution |
|---|---|---|
| Fırat 87 | It has a semi-upright form. It has 40-50 cm plant height. The first pod height is 16-20 cm, the number of pods per plant is 22-35, and 1000-seed weight is 35-40 g. | GAP International Agricultural Research and Training Center |
| Şakar | It has a semi-upright form. It has 25-45 cm plant height. The first pod height is 15-21 cm, the number of pods per plant is 20-34, and 1000-seed weight is 39-41g. | Dicle University Faculty of Agriculture |

The study was conducted in randomized blocks trial design with 4 replications. The plots were planted in six rows of 5 meters long and with an inter row space of 20 cm. The rows were opened with a marker and the seeds were planted manually on November 6 in the first year and on November 11 in the second year. Plot sizes were arranged as 1.2 m x 5 m = 6 m². Plants that are within 50 cm of each of the two rows and row-heads on both sides of 6 rows forming the parcel were excluded from the observation as edge effect and all operations were implemented on an area of 0.8 x 4 = 3.2 m². Each plot was equally fed with DAP fertilizer containing 2.5 kg of pure nitrogen and 5 kg of pure phosphorus. Irrigation was not carried out during the study and weed control was carried out twice by hand weeding. 50% flowering and pod binding day periods were determined based on the entire plot. For the measurements of plant height, the first pod height, number of branches and pods per plant, 1000-seed weight, biological yield and harvest index, 10 plants were randomly selected from 2 rows in the middle of each plot and their mean values were calculated. Seed yield per decare was determined based on an area of 3.2 square meters. The data obtained from the study for each year were combined and evaluated with the analysis of variance and ANOVA was used to statistically control the difference between the obtained data. The LSD test (P>0.05) was used to determine the source or sources of the differences between significant variables, then the correlation analysis was used for the linear relationships between the variables and the path analysis was used for the indirect effects (Duzgunes et al., 1987). All statistical analyses were performed with the MINITAB 16 V statistical package program.

**Results and Discussion**

As can be seen in Table 2 and Table 3, the results of the combined variance analysis and the mean values of the analyzed yield items in the study carried out under the conditions of Hatay province for 2 years showed that all properties are statistically significant at the level of 0.05. The results revealed that that there were significant differences among the examined properties. Since the genotypes used in the study were from different ecological regions and studied under the conditions of a different environment, obtained significant differences is an expected outcome. The average number of flowering days was 124.6 days and the genotypes bloomed within 112-132 days. With 132 days, the ILL 465 and ILL 857 genotypes took the longest time to bloom and with 112 days, the L 21 genotype took the shortest time to bloom. Early blooming is also an indicator of earliness. Therefore, the ILL 323 genotypes can also be taken into account with 117 days according to earliness.

The average number of maturation days was 165.8 days and the genotypes matured within 148-175 days. In terms of days until maturation, the L 21 genotype was the earliest maturing genotype with 148 days. Similarly, the latest maturation was observed in the ILL 759 and ILL 780 genotypes with 175 days. Although the ILL 465 genotype, which bloomed the latest, had a maturation period of 173 days, it was not statistically different from the other genotypes. In terms of days until blooming and maturation, Fırat 87 and Şakar control varieties were below the average values, with 121/122 and 160/160 days, respectively.

Plant height did not significantly vary average of two years data. The average plant height of the genotypes was 24.4 cm and the plant height ranged from 22 cm to 28.1 cm. The lowest plant height was observed in the ILL 468 genotype with 22 cm, while the highest plant height was observed in the SLL genotype with 28.1 cm. It was observed that the control varieties in the study were above the average in terms of plant height. The lack of rainfall during the cultivation period hindered the increase in plant height. In terms of plant growth and development, rather than the amount of rainfall, the time and precipitation type is more important. Rainfall during a period in which plants cannot benefit from the rain or rainfall exceeding the requirements of the plants will not result in a significant increase in height.

The average the first pod height of the genotypes was 14.3 cm and the genotype with the highest first pod height was the IL 465 genotype (18.4 cm), followed by the ILL857 genotype with 17.6 cm; the ILL 857 genotype had the lowest first pod height. The first pod height of the control varieties varied between 15.3 cm (Fırat 87) and 15.2 cm (Şakar). The first pod height is an important indicator of suitability for harvesting with machinery. Therefore, genotypes with high first pod height should be considered in a selection for machinery harvesting.

The number of pods per plant is one of the most important properties affecting the yield in lentil breeding. The results on the number of pods per plant showed that there was a significant variation among the genotypes. The number of pods per plant ranged from 19.6 to 30.2 and the average number of pods per plant was 25.8. The ILL 465 (30.2 number), ILL 975 (30.1 number) and ILL 857 (29.1 number) genotypes had the highest pod number per plant, while the L 21 (19.6 number) genotype had the lowest number of pods per plant. With 25.5 and 24.8, respectively, the Fırat 87 and Şakar varieties had a pod count below the average. In their studies on the number of lentils per a plant, Milani et al. (2013), Colkesen et al. (2014), and Kaplan (2015) determined 18.23, 24.75-52.50, and 17.8-24.3 pods per plant. The number of pods per plant was determined in the present study in agreement with researchers.

Lentil is capable of forming numerous branches when in a suitable environment. The study showed that lentil plants included in the study had a high branch count. In arid and cold conditions, plants avoid branching, if possible. In the present study, the plants showed high levels of branching as a result of not suffering from severe cold or drought conditions. The highest number of branches was 6.8 and obtained in the ILL 590 genotype, while the lowest number of branches was 3.8 and obtained in the L 21 genotype. The number of branches also affects the number of pods, which was not well reflected in our results. This is attributable to the extreme temperatures and drought encountered during pod formation.

Biological yield is the weight of the plant parts above the soil. The amount of biological yield is an indicator of the adaptation of a plant to an environment. Genotypes had a very wide variation in terms of biological yield. Biological yield values ranged from 156.7 (ILL 975) to 268.4 (ILL 759) kg da$^{-1}$. This change in variability is the most important indicator of the degree of the differences among the responses of the genotypes to environment. The ILL 759, ILL 669 and ILL 458 genotypes were more successful in adaptation to the environment, while the ILL 975 genotype was the most unsuccessful genotype.

**Table 2.** Values of some features in some red lentil cultivars and multiple range test results according to means of two years

| Genotypes | 50% NFD | NMD | PH | FPH | NPP |
|---|---|---|---|---|---|
| ILL 52 | 128 b | 172 ab | 22.6 c | 12.1 c | 22.6 d |
| ILL 323 | 117 d | 158 c | 23.1 b | 12.9 bc | 21.9 d |
| ILL 465 | 132 a | 173 ab | 23.4 b | 18.4 a | 30.2 a |
| ILL 468 | 127 b | 172 ab | 22.0 c | 11.2 c | 24.8 c |
| ILL 590 | 114 de | 158 c | 26.5 ab | 11.6 c | 25.5 bc |
| ILL 662 | 126 b | 172 ab | 27.1 a | 17.6 a | 27.5 b |
| ILL 669 | 126 b | 174 a | 24.0 b | 15.8 ab | 26.8 b |
| ILL 759 | 128 b | 175 a | 23.1 b | 11.6 c | 24.9 c |
| ILL 780 | 127 b | 175 a | 23.5 b | 15.2 b | 28.9 ab |
| ILL 857 | 132 a | 171 b | 23.8 b | 17.6 a | 29.1 a |
| ILL 975 | 131 a | 170 b | 22.5 bc | 15.3 b | 30.1 a |
| L 21 | 112 e | 148 d | 23.6 b | 15.8 ab | 19.6 e |
| ILL 1918 | 125 bc | 158 c | 25.6 ab | 10.3 c | 24.3 c |
| SLL | 126 b | 157 c | 28.1 a | 12.9 bc | 23.8 cd |
| Fırat 87 | 121 c | 160 c | 24.6 b | 15.3 b | 25.5 bc |
| Şakar | 122 c | 160 c | 27.0 a | 15.2 b | 24.8 c |

NFD: Number of flowering days, NMD: Number of maturation days, PH: Plant height, FPH: The first pod height, NPP: Number of pods per plant

The harvest index is obtained by determining the proportion of the seed amount obtained from the plants above the ground to biological yield. Obtaining a high harvest index shows that grain yield had a high share in biological yield and obtaining a low harvest index shows that grain yield had a low share in biological yield. In the study, the harvest index values ranged from 0.25% (SLL) to 0.37% (ILL 323/ILL 662).

**Table 3.** Values of some features in some red lentil cultivars and multiple range test results according to means of two years

| Genotypes | NBP | BY | HI | TSW | SYPP |
|---|---|---|---|---|---|
| ILL 52 | 5.1 b | 191.2 e | 0.34 a | 30.2 b | 76.2 e |
| ILL 323 | 5.3 b | 194.5 de | 0.37 a | 36.9 a | 74.5 e |
| ILL 465 | 5.7 b | 244.8 b | 0.28 bc | 32.6 ab | 103.7 a |
| ILL 468 | 6.2 a | 257.6 ab | 0.29 b | 25.4 cd | 81.5 d |
| ILL 590 | 6.8 a | 215.4 c | 0.30 b | 36.8 a | 76.2 e |
| ILL 662 | 6.5 a | 247.6 b | 0.37 a | 30.1 b | 84.9 cd |
| ILL 669 | 5.8 ab | 255.2 ab | 0.36 a | 31.2 b | 84.2 d |
| ILL759 | 4.5 c | 268.4 a | 0.32 ab | 27.5 c | 77.2 e |
| ILL780 | 5.8 ab | 247.5 b | 0.31 ab | 29.1 bc | 103.1 a |
| ILL 857 | 6.2 a | 251.6 b | 0.30 b | 36.4 a | 101.7 a |
| ILL 975 | 6.1 a | 156.7 h | 0.27 c | 32.8 ab | 106.1 a |
| L 21 | 3.8 d | 186.5 f | 0.31 ab | 24.3 d | 68.9 f |
| ILL 1918 | 5.4 b | 193.8 de | 0.28 bc | 25.1 cd | 88.2 c |
| SLL | 6.3 a | 201.4 d | 0.25 c | 23.9 d | 81.6 d |
| Fırat 87 | 6.0 ab | 256.2 ab | 0.26 c | 32.3 ab | 99.8 ab |
| Şakar | 5.9 ab | 162.7 g | 0.33 a | 31.8 b | 98.6 b |

NBP: The number of branches per plant, BY: Biological yield, HI: Harvest index, HSW: 1000-seed weight, SYPP: Seed yield per plant

1000-seed weight of the plants ranged from 23.9 g to 36.9 g and the average 1000-seed weight was 30.4 g. The genotype with the largest grains was the ILL 323 (36.9 g) genotype and the genotype with the smallest grains was the SLL (23.9 g) genotype. 1000-seed weight of the control varieties were 31.8 g (Şakar) and 32.3 g (Fırat 87), respectively, and above the average weight. 1000-seed weight shows whether the plant developed healthy and whether it was exposed to any stress during the grain formation period. These differences in 1000-seed weight are considered as a result of the responses of the plants to environmental conditions. 1000-seed weight has the ability to directly affect the yield. High 1000-seed weight can increase the yield. However, the number of pods and seeds per plant can also increase the yield and assessing these results alone can result in drawing wrong conclusions.

In the study, the highest yield per decare was obtained from the ILL 975 genotype with 106.1 kg, while the lowest grain yield was determined in the L 21 genotype with 68.9 kg. There is a big variation in the yield values, as it is the case in other properties. The genotypes responded differently to the environmental conditions and they clearly showed this difference in every property.

**Table 4.** The results of correlation analysis between variables

| | NFD | NMD | PH | FPH | NBP | NPP | BY | HI | HSW | SYPP |
|---|---|---|---|---|---|---|---|---|---|---|
| NDF | - | 0.412* | 0.118 | - 0.106 | 0.518** | 0.617** | 0.584** | 0.681** | 0.456** | 0.497** |
| NMD | | - | 0.315 | 0.276 | - 0.116 | 0.096 | - 0.155 | - 0.411** | - 0.521** | - 0.488** |
| PH | | | - | 0.511** | 0.265 | - 0.192 | 0.149 | 0.416** | -0.255 | 0.327 |
| FPH | | | | - | 0.365 | 0.416* | 0.617** | 0.189 | 0.212 | 0.471* |
| NBP | | | | | - | 0.755** | 0.591** | 0.415* | 0.315 | 0.641** |
| NPP | | | | | | - | 0.643** | 0.435* | - 0.431* | 0.536** |
| BY | | | | | | | - | 0.392 | - 0.488** | - 0.558** |
| HI | | | | | | | | - | 0.229 | 0.329 |
| HSW | | | | | | | | | - | 0.641** |
| SYPP | | | | | | | | | | - |

NFD: Number of flowering days, NPP: Number of pods per plant, NMD: Number of maturation days, BY: Biological yield, PH: Plant height, HI: Harvest index, FPH: The first pod height, HSW: 1000-seed weigh, NBP: The number of branches per plant, SYPP: Seed yield per plant

The relationship between the variables are shown in Table 4 and the relationship between the number of flowering days and number of branches per plant, number of pods per plant, harvest index, 1000-seed weight and yield was important and positive. In general, in terms of number of maturation days, there were negative and significant correlations. As the number of maturation days increased, the value of harvest index, 1000-seed weight and seed yield significantly decreased. Plant height, the first pod height and harvest index values were positively and significantly affected; these variables increased, as the first pod height increased. The first pod height positively and significantly affected the number of pods per plant, biological yield and seed yield in plants. The positive and significant relationship between number of branches per plant and number of pods per plant, biological yield, harvest index, yield indicated that the branch count of a plant was among the factors determining the yield. The increase in the number of pods per plant resulted in a decrease in the 1000-seed weight, which calls for approaching the increase in pod count in a plant with caution. Biological yield reduced both 1000-seed weight and seed yield of the plants. This effect was also statistically significant. It is concluded that 1000-seed weight significantly increased the yield.

Table 5 showed the path analysis results, which shows the direct and indirect effects on the investigated properties, and according to Table 6, with 0.337, 1000-seed yield had the highest positive direct effect and plant height had the lowest positive direct effect with 0.115. With -0.311, the number of maturation days had the highest negative direct effect, while harvest index had the lowest negative direct effect with -0.107. The number of flowering days had the highest positive direct effect on 1000-seed weight with 0.294, while it had the lowest positive effect with 0.086. The number of flowering days had an indirect and negative effect on plant height, the first pod height and biological yield.

The number of maturation days had a negative and direct effect on yield, while it had a high indirect positive effect on pod number per a plant with 0.405. However, the number of maturation days generally had an indirect reducing effect on yield through other characteristics.

The delay in maturity can cause plants to undergo stress especially as a result of drought and high temperatures and negatively affect many characteristics, especially yield and other characteristics affecting the yield. Therefore, the number of flowering and maturation days is among the important criteria for yield and earliness. Late maturity is not a desired property.

Plant height negatively and indirectly affected the number of branches and pods per plant, while, in general, it had an indirect and positive effect on most properties. Especially the fact that indirect effects were higher on biological yield and number of maturation days necessitates emphasizing these properties in studies on plant height. The direct effect of the first pod height on yield (-0.184) was negative, while it had positive indirect effects through other properties, except for the number of flowering days and harvest index. The high levels of indirect effects on number of branches and biological yield were noteworthy. In the studies focused on the first pod height, which is another important criterion for machinery harvesting, emphasis should be put on number of branches per plant and biological yield.

The number of branches per plant is an important character in terms of yield. Especially under suitable climatic conditions, as the number of branches increases, blooming and, consequently, number of pods increases, which, in turn, results in increased yield.

**Table 5.** Effects of direct and indirect on yields of lentils

| | NFD | NMD | PH | FPH | NBP | NPP | BY | HI | HSW |
|---|---|---|---|---|---|---|---|---|---|
| The number of flowering days | **0.216** | 0.175 | -0.145 | -0.186 | 0.228 | 0.316 | -0.196 | 0.086 | 0.294 |
| The number of maturation days | 0.106 | **-0.311** | 0.184 | -0.211 | 0.091 | 0.405 | -0.146 | -0.028 | -0.211 |
| Plant height | 0.015 | 0.170 | **0.115** | 0.176 | -0.211 | -0.162 | 0.171 | 0.124 | 0.084 |
| The first pod height | -0.096 | 0.116 | 0.312 | **-0.184** | 0.306 | 0.107 | 0.217 | -0.165 | 0.124 |
| The number of branches per plant | -0.171 | -0.315 | -0.054 | -0.270 | **0.144** | 0.316 | 0.304 | 0.223 | 0.168 |
| The number of pods per plant | 0.218 | 0.117 | -0.047 | -0.195 | -0.175 | **0.176** | 0.310 | 0.207 | 0.112 |
| Biological yield | -0.066 | 0.144 | -0.211 | 0.039 | 0.288 | 0.082 | **0.247** | 0.155 | 0.243 |
| Harvest index | 0.220 | -0.209 | 0.312 | -0.161 | 0.058 | 0.277 | 0.167 | **-0.107** | 0.192 |
| 1000-seed weight | 0.068 | 0.214 | 0.185 | -0.222 | 0.324 | 0.089 | 0.152 | -0.216 | **0.337** |

NFD: Number of flowering days, NMD: Number of maturation days, PH: Plant height, FPH: The first pod height, NPP: Number of pods per plant, NBP: The number of branches per plant, BY: Biological yield, HI: Harvest index, HSW: 1000-seed weight

The number of branches per plant had a high indirect effect on yield through the number of seeds per plant, biological yield and harvest index, whereas it negatively affected yield through number of flowering days, number of maturation days, plant height and the first pod height.

Increasing number of branches per plant reduces plant height and therefore, in the studies on the number of branches per plant, branching should not be encouraged if the climatic conditions are not suitable. Although the indirect effects through yield and harvest index were positive, under ecological stress, yield loss can occur.

While the number of pods per plant had a direct positive effect on yield, it had a negative effect on the first pod height, number of branches and plant height. It especially had a high indirect negative effect (-0.195) through the first pod height. Indirect and positive effects through biological yield (0.310) and harvest index (0.207) were again at a high level.

Biological yield had a direct positive effect on yield (0.247). While it had a negative effect (-0.2111) on plant height, it had an indirect and positive effect on other properties. Accordingly, in breeding studies, focusing on biological yield is more advantageous because an improvement in any of the other characters will result in an improvement in yield. However, it can also be considered as the most disadvantageous property because any negativity occurring in another character will also occur in biological yield.

The harvest index is an important characteristic affecting yield. In the study, harvest index reduced yield (-0.107), although we were not able to fully explain this outcome. However, the harvest index had an indirect positive effect on all properties, except on the first pod height and number of maturation days. Especially its indirect effect on plant height was positive and quite high

(0.312). The direct effect of 1000-seed weight on yield was quite high and positive (0.337). The indirect effect of 1000-seed weight on the first pod height and harvest index was negative, while it had a positive indirect effect on other characteristics.

**Conclusion**

The study aimed to determine the responses of red lentil plants winter farming of which is especially carried out in Hatay province in the Eastern Anatolia Region to heavy winter conditions. The general overview of the study in which 16 genotypes were used showed that there was a great variation in all traits. Diversity in variation indicated that cultivars responded differently to changing environmental conditions. On the other hand, since climate data was close to long-term averages and no extreme value was observed, the plants were under relatively comfortable winter conditions. In terms of bilateral relationships, yield decreased in all genotypes as the maturation period increased. In a similar manner, as the biological yield increased, yield decreased. In the study, 1000-seed weight had the highest positive direct effect on yield, while the lowest positive direct effect was observed in plant height. The number of maturation days had the highest negative direct effect, while harvest index had the lowest negative direct effect. Considering these properties in further studies will contribute to the success of the studies. In yield studies, especially focusing on 1000-seed weight will serve as a guide in the plant breeding studies on yield.

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