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CORRELATION AND PATH ANALYSIS FOR YIELD PERFORMANCE AND YIELD COMPONENTS OF CHICKPEA (*CICER ARIETINUM* L.) GENOTYPES CULTIVATED IN CENTRAL ANATOLIA

OMER SOZEN[1*] AND UFUK KARADAVUT[2]

[1]*Ahi Evran University, Faculty of Agriculture, Department of Field Crops, Kirsehir, Turkey*
[2]*Ahi Evran University, Faculty of Agriculture, Department of* Biometry and Genetics, *Kirsehir, Turkey*
[*]*Corresponding author's email: eekim_55@hotmail.com; Phone: +00905366327555*

Abstract

A total of 22 genotypes, including 18 chickpeas varieties registered by Private Sector and Agricultural Research Institutes and 4 domestic populations were studied under Central Anatolian ecological conditions, in 2013 and 2014. The aim of this study was to determine the effects of the genotypes affecting the yield and the agronomic characters, and the direct and indirect effects of these characters on yield in these genotypes. Differences were determined by applying variance analysis of the data. Means were grouped by performing the LSD test. In addition, a correlation analysis, in which the relations between the examined characters the first pod height, number of pods per plant, number of seeds per plant, 100-seed weight, seed yield per plant, biological yield, yield, protein ratio, water absorption capacity, swelling capacity, water absorption index and swelling index, and path analysis, in which the direct and indirect effects plant height, the first pod height, number of pods per plant, number of seeds per plant, seed yield per plant, 100-seed weight and biological yield were applied. In this study, Hisar, Cagatay, Azkan, ILC-483 chickpea cultivars and Hacıbektas-2 local chickpea populations were observed for yield and the characters affecting yield.

Correlation analysis showed that the positive and significant relationships were determined between the number of pods per plant and the number of seeds per plant (r=0.934**), 100-seed weight (r=0.826**), the number of seeds per plant and yield per plant (r=0.908**), and seed yield per plant and 100-seed weight (0.614**), yield (0.602**). Path analysis detected that the direct effect of plant height on the yields was negative with -0.124, whereas the direct effects of the first pod height, the number of pods per plant and the number of seeds per plant were found as positive with 0.096, 0.079 and 0.841, respectively.

Key words: Chickpea, Genotype, Yield, Quality, Correlation, Path analysis.

Introduction

Chickpea has been the second most important edible legume plant grown worldwide. It has an important role in meeting the protein needs of people in undeveloped countries in the world, especially where the income imbalance is experienced, since people need protein for a balanced and adequate nutrition. Accordingly, protein and vitamin rich foods should have priority in human diet (Bozoglu & Ozcelik, 2005).

Chickpea has been in the second place after beans in the world with 13.9 million ha plantation area and 13.7 million tons production, while it has been the first with 388.169 ha planting area and 450.000 tons production in Turkey. While the global yield average was 98 kg da^{-1} for chickpea, this value in Turkey reached 116 kg da^{-1} as a result of successful breeding studies, especially conducted in recent years (Anonymous, 2015).

In Turkey, chickpea is cultivated in the Central and Eastern Mediterranean Regions in winter, whereas in Central and Eastern Anatolia Regions and Transitional Zone Regions in early spring. Since the plants are exposed to drought and temperature stress after a certain period in the spring planting, serious losses are experienced in the yield (Duzdemir & Akdag, 2007). However, in recent years, winter sowing has become more widespread due to the development of cold tolerant and, especially, high tolerance varieties to anthracnose since winter sowing plants have higher and more stable productivity characteristics (Yucel *et al.,* 2006).

Genetic variation has a great importance for researchers conducting breeding trials. On the other hand, as a result of the analysis of the relationship between the characters belonging to the genotypes that are subjects of the studies, the important developments will be possible in the determination of the selection criteria (Firouzabadi *et al.,* 2011). As a result of the correlation and path analysis, it was more successful to select the characters that affected the yield (Ozdemir & Karadavut, 2003). Noor *et al.,* (2003) determined that number of flowering days, the number of branches and 100-seed weight had high inheritance degrees. They, also determined a positive and a very significant relationship between the number of pods per plant and 100-seed weight. Alake *et al.,* (2012) explained the number of pods per plant exhibited a high positive direct effect on pod yield. Ciftci *et al.,* (2004) found out that the positive and strong correlations between the seed yield and plant height, the number of branches, the number of pods per plant, biological yield, harvest index, the number of seeds per plant in the chickpea, and negative relations with 100-seed weight. Al-Rifaee *et al.,* (2007) concluded that there were variability's in seed and the properties that affected the yield. Tawaha *et al.,* (2005) studied on chickpea plants in the Mediterranean Region and found out that the environmental factors affected their investigated characters. Singh *et al.,* (1997) demonstrated that biological yield and harvest index had both strong correlations with the yield and the highest direct effects. Anlarsal *et al.,* (1999) found that there was a negative relationship between plant height and harvest index, whereas a positive relationship was present between the total number of pods and the number of seeds.

The aim of this study was, therefore, to determine the direct and indirect effects of the characters affecting the yields of chickpea genotypes brought from different ecological regions in Central Anatolian conditions. Another aim of this study, which would be the first on this subject in this region, was to guide the producers in the region with respect to chickpea farming.

Study Area

Soil analysis of trial field showed that the soil had 7.86 pH, 1.85% organic matter a sandy-loamy structure with medium calcareous (15.34%) and salt-free structure. The soil had sufficient potassium level (1.44 Me/100 g) whereas it had insufficient phosphorus content (2.16 ppm). Kirsehir is located in the middle of the Central Anatolia Region, in general, summers are hot and dry, springs are rainy and winters are severe and cold. The average annual precipitation was 379 mm during the study.

Climate data for the years 2013 and 2014 when the study was carried out and for the long-term growing season are given in Table 1. There are similarities between the values of two years and long-term periods in terms of monthly average temperature values. In terms of total amount of precipitation, it can be seen that 2012 received two times more rainfall and 2014 received four times more rainfall. In terms of relative humidity value, it can be seen that there are similarities between the values of long-term period and the values of two years as it is in average temperature values (Table 1).

Materials and Methods

This study was conducted in two years 2013 and 2014 under the ecological conditions of Kirsehir possessing all characteristics of climate conditions of the Central Anatolia Region and being responsible 5% of Turkey's chickpea sowing area. The trials for each year were established on the Research Farm of Ahi Evran University's Bagbasi campus.

In this study, a total of 22 genotypes (Hisar, Isik-05, Yasa-05, Azkan, Cakir, Akca, Cagatay, Sezenbey, Zuhal, Gulumser, Inci, Hasanbey, Sucking, ILC-482, Diyar-95, Ilgaz, Gokce, Aksu, Local 1 (Hacibektas/Nevsehir), Local 2 (Hacibektas/Nevsehir), Local 3 (Hacibektas/Nevsehir), Local 4 (Derbent/Konya)), including 18 chickpeas registered by Research Institutes and 4 domestic populations widely grown in the Central Anatolia Region were used.

The trial was established with 3 replicates according to the randomized complete block design and the sowing time was on 25 March in 2013 and on 21 March in 2014. The seeds were planted manually with 40 cm inter-row spacing using a marker. The plot size was set as 1.6 m x 5 m=8 m². In each plot consisting of 4 rows, the last rows at each side of the plots and 50 cm distances from the starting point of each plot were removed from the observations as the edge impact, and all of the procedure was performed in 0.8 m x 4 m=3.2 m² remaining area. With the seeding process, a 3 kg da^{-1} pure N was applied while Di ammonium phosphate fertilizer was applied with 6 kg da^{-1}. No irrigation was applied for two years. Weed control was done once a year after the emergence of plants.

During the two years of research, the plant height (cm), the first pod height (cm), the number of pods per plant (number plant^{-1}), the number of seeds per plant (number plant^{-1}), 100-seed weight (g), yield (kg da^{-1}), biological yield (g plant^{-1}) and the yield per plant(g plant^{-1}) values were determined for each of the 10 selected plants. The average values were calculated. In addition, quality parameters protein ratio (%), water absorption capacity (g seed^{-1}), water absorption index (%), swelling capacity (ml seed^{-1}) and swelling index (%) values of the seeds obtained from each plot were also determined.

The data obtained from the study were analyzed by ANOVA procedure of MINITAB 17 V statistical software. LSD test ($p>0.05$) was used for comparing means. Correlation analysis was conducted for the linear relations between the variables and path analysis was conducted for the indirect impacts (Duzgunes *et al.,* 1987).

Results and Discussion

The two-year average values of plant height, the first pod height, the number of pods and seeds per plant, 100-seed weight, biological yield, yield per plant and seed yield characters observed in this study are shown in Table 2. There is a big variation in all the examined characters. The plant height values, which have an important place in the criteria affecting the yield, varied among the all genotypes within the range of 26.4-42.4 cm. When considering all genotypes, it was found that the average plant height was 30.71 cm. The highest plant was obtained from the Hisar genotype, whereas the lowest plant was determined in the ILC-483 genotype. Zafaranieh (2015) determined that the plant length values varied between 20-57 cm in 88 cold-tolerant chickpea genotypes. They reported that plants grown on dry and light soil had rapidly flowered and showed pod setting, whereas flowering and pod setting were delayed in plants grown on heavy and damp and soil; plants grown on very rich soil showed little pod setting because of the excessive humidity of the soil (Mart *et al.,* 2016). The dry soil properties of the study area caused a wide variation in plant height (Table 2).

Table 1. Climate data for Kirsehir Province*

Months	Average temperature (ºC)			Total rainfall (mm)			Average relative humidity (%)		
	2013	2014	Long years	2013	2014	Long years	2013	2014	Long years
March	7.2	7.4	6.3	14.2	52.2	9.3	63	64.3	67.5
April	12	13.2	11.4	45.1	20.2	7.7	62.8	54.9	59.7
May	19.3	16.9	16.2	15.1	46.6	10.7	44.7	59.5	56.2
June	21.4	20.8	20.6	1	36	13.9	42	51.6	50.9
July	24.1	27.6	24.8	6.6	13	2.9	37.1	33.6	38.4
Average	16.8	17.2	15.9				52.5	52.8	54.5
Total				**82**	**168**	**44.5**			

*Kirsehir provincial meteorology directorate

Table 2. Multiple comparison test results for some yield characteristics of genotypes

Genotypes/ Parameters	Plant height	The first height	Number of pods per plant	Number of seeds per pod	100-seed weight	Yield per plant	Biological yield	Yield
Hisar	42.4 a	22.0 b	23.6 b	19.3 b	45.5 c	8.7 a	21.8 a	70.2 b
Isik-05	30.9 c	17.7 d	14.6 d	12.6 de	42.4 e	5.1 c	12.7 d	51.8 e
Ilgaz	30.7 c	17.9 d	15.5 d	11.6 e	54.0 a	5.9 bc	12.6 d	68.4 cd
Cagatay	35.1 b	20.0 c	22.1 b	17.0 c	44.5 c	8.6 a	17.4 bc	67.9 cd
Azkan	34.1 b	24.1 a	16.1 d	14.1 d	41.5 e	7.8 b	13.6 d	57.9 e
Hacibektas-1	27.5 de	17.4 d	14.9 d	13.2 d	48.3 b	5.3 c	15.8 c	62.5 d
ILC-483	26.4 e	15.8 e	31.4 a	27.4 a	29.5 f	7.8 b	18.9 b	71.2 b
Sezenbey	31.3 c	18.2 d	16.5 d	13.7 d	48.0 b	6.8 b	16.3 c	82.4 a
Yasa-05	33.6 b	18.8 cd	14.8 d	12.9 de	41.1 e	5.4 c	16.3 c	62.9 d
Diyar-95	30.7 c	21.1 bc	12.9 e	12.3 de	45.2 c	3.6 e	14.2 c	54.0 e
Inci	31.3 c	20.0 b	12.4 e	12.6 de	37.1 e	4.8 cd	15.1 c	54.6 e
Hasanbey	30.2 c	18.1 d	12.1 e	11.0 e	41.7 d	4.6 cd	12.7 d	49.7 ef
Cakir	27.9 de	16.5 e	14.7 d	12.8 de	45.0 c	6.3 bc	15.4 c	56.3 e
Seckin	31.6 c	21.2 bc	12.5 e	11.3 d	53.2 a	6.6 b	18.7 b	47.2 ef
Gokce	29.7 cd	17.2 de	14.5 d	12.5 de	49.3 b	5.4 c	17.3 bc	42.7 f
Akca	29.1 cd	18.0 d	9.2 f	7.5 g	42.5 d	2.6 e	11.4 d	52.8 e
Zuhal	27.5 d	11.5 f	20.2 c	16.3 c	38.1 e	5.7 c	18.8 b	62.4 d
Aksu	29.3 cd	19.7 bc	12.8 e	11.2 e	40.7 d	2.4 e	8.7 e	52.2 e
Hacıbektas-3	28.1 d	19.1 bc	14.5 d	13.5 d	44.2 c	4.1 d	12.6 d	83.7 a
Gulumser	29.4 cd	18.3 d	16.8 d	15.3 cd	39.1 de	5.8 c	18.2 b	52.7 e
Derbent/Konya	29.9 cd	17.4 d	11.3 e	9.6 f	41.3 d	3.3 e	9.7 e	67.6 cd
Hacibektas 2	29.0 cd	16.5 e	20.7 c	19.2 b	44.3 cd	8.3 a	17.9 bc	72.5 b
Mean	30.71	18.47	16.17	13.95	43.47	5.67	15.35	61.07

The first pod height, which is an important property in the yield components, draws attention as an important feature for machine farming. The present study showed that the first pod height of the chickpea genotypes varied between 11.5-24.1 cm (18.47 cm in average). The Azkan genotype had the highest pod, while the Zuhal genotype had the lowest height. Generally, the first pod height values of plants with tall and large vegetative parts are relatively higher. Although the first pod height is a first-order feature of the genetic structure, environmental conditions also significantly affect the first pod height (Karakoy, 2008). The irregularity of climate data affects negatively chickpea cultivation in the growing season. These values revealed that many genotypes were suitable for machine harvesting in terms of winter sowing. Dogan *et al.,* (2015) determined that the highest first pod length was observed in Diyar 95 genotype (16.9 cm) while the lowest first pod length was observed in the Aziziye 94 genotype (11.4 cm). Togay *et al.,* (2005) determined that first pod length varied between 15.8-17.3 cm. Results of above studies for the first pod height values support our results. The number of pods per plant is one of the most important factors affecting the yield. It was determined that there was a big variation among genotypes with respect to this trait.

The number of pods of the plants from different genotypes varied between 9.2-31.4 (16.17 in average). The ILC-483 (31.4 number), Hisar (23.6 number) and Cagatay (22.1 number) genotypes ranked in the first three in terms of the number of pods of a plant, while, with 9.2 pods, the Akca genotype had the lowest number of pods. Kayan & Adak (2012) determined that pod number per plant was 12.9 in the first year and 16.7 in the second year under the ecological conditions of Ankara. Thangwana & Ogola (2012) obtained 14.5-30.5 pods number; whereas Kulaz & Erdin (2014) obtained pod numbers between 8.03-19.3. The values were obtained in our study support the values obtained by above researchers.

The number of seeds per plant, which always shows an important and positive relationship with the number of pods in terms of yield components, depending on the number of pods in the plant. The number of seeds per plant obtained in our research varied between 7.5-27.4. In terms of the number of seeds per plant, the ILC-483 (27.4) and Hisar (19.3) cultivars ranked at the first two, whereas Akca (7.5) and Derbent/Konya domestic populations (9.1) showed the lowest number of seeds per plant. In terms of the relationship between the number of seed per plant and the number of pods per plant, it is noteworthy that the genotypes with the highest number of seeds per plant values also had the highest number of pods per plant. Saxena (1980) reported that irrigation increased the number of seeds per plant, resulting in yields increase. Bakhsh *et al.,* (2004) and Yucel *et al.,* (2006) reported that there was a high correlation between the number of pods and the number of seeds per plant. We obtained the similar results as other researchers did. However, because of no irrigation, the number of seeds per plant in the genotypes was below the required values.

100-seed weight is one of the most important traits affecting the seed yield. The 100-seed weight values varied between 29.5-54.0 g. The Ilgaz genotype (54.0 g) had the highest 100-seed weight, followed by Gokce genotype (49.3 g). In all genotypes, ILC-483 genotype was the genotype with the lowest 100-seed weight value with 29.5 g. 100-seed weight trait gives us detailed information about plant growth. The high 100-seed values indicate a successful development in plants, whereas the low values indicate the opposite. The results we obtained for 100-seed weights here were lower than the general average. This can be interpreted as an indication of the lack of adequate rainfall and irregularity in the rainfall. Ali *et al.,* (2009) reported that there was a high correlation between the 100-seed weight and the number of pods per plant, the number of seeds per plant, yield. Similar results were reported by Saleem *et al.,* (2002) and Noor *et al.,* (2003).

Jeena *et al.,* (2005) determined that 100-seed weight varied between 12.00-38.13 g and the average 100-seed weight was 21.56 g., Malik *et al.,* (2010) reported 22.28-38.63 g 100-seed weight whereas Atta *et al.,* (2008) reported 10.83-27.40 g 100-seed weight. The present results are within the range of previous results.

The biological yield of the plant is defined as the all plant parts above the soil. The results for biological yield in our study varied between 8.7-21.8 g (15.35 g in average). The highest biological yield value was obtained from the Hisar genotype, whereas the lowest biological yield value was determined in Aksu genotype. According to these results, it can be said that Hisar genotype exhibited a better adaptation in terms of development in comparison to the other genotypes. It has been reported that genotypes with high and broad adaptation abilities are more successful under different environmental conditions (Ozdemir & Karadavut, 2003). It will be more accurate to evaluate Hisar cultivar from this perspective.

The seed yield is among the most important elements in breeding studies and the all studies are based on the improvement of the yield components. The variation in seed yields of genotypes were 42.7-83.7 kg da^{-1}. The responses of the genotypes during vegetation were not significantly different. Especially, Hacibektas-3 domestic population and Sezenbey and ILC-483 genotypes become prominent in terms of seed yield, whereas the Gokce, Seckin and Hasanbey genotypes performed poorly. The average seed yield of the present genotypes was 61.07 kg da^{-1} while 4 domestic genotypes exceeded this average and considered candidate cultivars with high adaptation abilities in the region. The seed yield values were determined by Karakoy (2008), Bakoglu (2009), Bicaksiz (2010) and Babagil (2011) were 91-211.0, 61.57-109.93, 77.07-138.27, and 94.4-138.1 kg da^{-1}, respectively. The differences in the values in terms of seed yield showed that this variation is shaped under the influence of factors including variety, climate, soil, etc (Dogan *et al.,* 2015).

Table 3 shows the protein ratios, swelling capacities, water absorption indexes and swelling indexes of the genotypes determined in the present study. Table 3 reveals that the crude protein ratios of the genotypes varied between 19.9-24.5%. With 24.5%, the highest protein ratio was obtained in the Azkan genotype, followed by the ILC-483, Akca, Hacibektas-1, Yasa, Diyar 95, Inci, Hasanbey and Seckin genotypes. Hacıbektaş-3 domestic population had the lowest protein ratio with 19.9%. The variation between genotypes in terms of protein ratios was not very high. The limited variation in protein ratios was due to the fact that the genotypes failed to extend their genetic variation in response to the environmental conditions. Arshad *et al.,* (2002) reported that the low variation could lower the heritability, while Patil & Phandis (1997) stated that genotypic variation had an influence on protein content.

Table 3. Multiple comparison test results for some quality characters of genotypes

Genotypes/Parameters	Protein rate	Water intake capacity	Swelling capacity	Water intake index	Swelling index
Hisar	21,8 b	0,49 b	0,52 b	1,02 b	2,20 a
Isik-05	22,4 ab	0,45 bc	0,51 b	0,98 c	2,28 a
Ilgaz	22,3 ab	0,44 bc	0,50 bc	1,03 b	2,01 c
Cagatay	22,6 ab	0,47 b	0,51 b	0,93 cd	1,92 d
Azkan	24,5 a	0,40 cd	0,48 c	0,88 de	2,03 c
Hacibektas-1	23,1 a	0,46 bc	0,52 b	0,89 de	1,99 c
ILC-483	23,3 a	0,34 e	0,35 e	1,04 b	2,11 b
Sezenbey	22,9 ab	0,51 ab	0,55 ab	1,04 b	2,10 c
Yasa-05	23,4 a	0,51 ab	0,53 ab	1,05 b	2,10 c
Diyar-95	22,8 a	0,49 b	0,51 b	1,06 ab	2,02 c
Inci	24,3 a	0,39 d	0,42 d	1,10 a	2,21 a
Hasanbey	22,9 a	0,44 bc	0,46 cd	0,95 c	2,01 c
Cakir	21,2 b	0,48 b	0,43 d	0,92 cd	1,95 d
Seckin	24,3 a	0,46 bc	0,46 cd	0,78 f	1,90 d
Gokce	20,1 b	0,45 bc	0,47 cd	0,86 e	1,67 f
Akca	22,5 ab	0,55 a	0,58 a	1,07 ab	2,01 c
Zuhal	22,6 ab	0,48 bc	0,48 c	1,02 b	2,05 bc
Aksu	20,6 b	0,51 ab	0,50 bc	0,91 d	2,11 b
Hacibektas-3	19,9 b	0,43 c	0,42 d	0,77 f	1,52 g
Gulumser	22,1 ab	0,42 c	0,42 d	0,80 f	1,74 e
Derbent/Konya	21,3 ab	0,40 cd	0,42 d	0,88 de	1,55 g
Hacibektaş-2	20,2 b	0,39 d	0,40 d	0,81 f	1,38 h

Table 4. The coefficients of correlations between yield and factors affecting yield

Parameters	The first pod height	Number of pods per plant	Number of seeds per plant	Seed yield per plant	100-seed weight	Biological yield	Yield	Protein ratio	Water absorption capacity	Swelling capacity	Water absorption index	Swelling index
Plant height	0.317*	0.243	0.203*	-0.106	-0.463	0.211	-0.255	0.116	0.003	0.239	-0.020	0.058
The first pod height	-	-0.080	-0.012	-0.059	-0.222	0.217	-0.115	0.064	-0.073	0.108	-0.125	0.026
Number of pods per plant		-	0.934**	0.413	0.826**	0.318	0.363	-0.151	-0.294*	-0.223	0.044	-0.011
Number of seeds per plant			-	0.908**	0.327	0.347	0.469	-0.030	-0.330**	-0.277	-0.012	-0.064
Seed yield per plant				-	0.614**	0.512**	0.602**	0.916**	0.874**	0.796**	0.812**	0.806**
100-seed weight					-	0.412*	0.584**	-0.489*	0.760**	-0.741**	0.877**	0.538**
Biological yield						-	0.312	0.144	0.118	0.054	0.211	0.048
Yield							-	0-.612**	0.674**	0.586**	0.711**	0.683**
Protein ratio								-	-0.180	-0.042	0.038	0.165
Water absorption capacity									-	0.834**	0.221	0.268*
Swelling capacity										-	0.351**	0.445**
Water absorption index											-	0.639**
Swelling index												-

This study showed that the variations in water absorption capacity and swelling capacity supported each other. The water absorption capacity varied between 0.34-0.55 g $seed^{-1}$ while the swelling capacity varied between 0.35-0.58 ml $seed^{-1}$. The highest values for both quality measures were obtained in the Akca genotype, whereas the lowest values were obtained in the ILC-483 genotype.

The water absorption index varied between 0.80-1.10%. The variation in this character also shows the changes between the amount of water absorption. The swelling index values, depending on the water absorption index, showed a large variation by 1.52-2.20%. Under ecological conditions of Ordu, Ozbekmez (2015) determined that water absorption capacity varied between 0.146-0.809 g $seed^{-1}$, water absorption index varied between 0.323-1.780%, swelling capacity varied between 0.104-0.574 ml $seed^{-1}$ and swelling index varied between 0.468-2.581%. He stated that the water absorption capacity varies depending on composition of seeds, cell wall structure and condition of cells in the seed. Kaur & Sing (2006) reported the strong and positive correlation between seed mass and water absorption capacity and the increasing swelling capacity values with the increasing 100-seed weight which was in agreement with our findings.

The results of correlation analysis between the characters studied are shown in Table 4. The positive and significant relationships were found between the number of pods per plant and the number of seeds per plant (r=0.934**), 100-seed weight (r=0.826**). The strength of these relationships indicates that the number of pods per plant significantly affects both variables and that the improvement in the number of pods per plant, will have important and a positive effect on these two properties. A significant and positive relationship was found between the number of seeds per plant and the yield per plant (r=0.908**) whereas a significant but a negative relationship was found between the number of seeds and water absorption capacity (r=-0.330**). Accordingly, the number of seeds per plant increased the yield per plant whereas the water absorption capacity of the seeds was decreased as the number of seeds per plant increased. The decrease in water absorption capacity means delaying in germination and emergence times, which are considered as the first development period. Therefore, the balance must be well established. Taking climate characteristics into consideration, this property can be used to avoid premature emergence in areas where the rainfall is constantly fluctuating and hence prevent plants from suffering from cold.

When examining yield parameters, it was seen that this parameter had a positive and significant relationship with all yield components. Indeed, the yield per plant has positive and significant correlation coefficients with a 100-seed weight (r=0.614**), a biological yield (r=0.512**), yield (r=0.602**) value, which is a morphological property. In addition, positive and significant correlation coefficients were determined between yield per plant and protein ratio (r=0.916**), water absorption capacity (r=0.874**), swelling capacity (r=0.796**), water absorption index (r=0.812**) and swelling index (r=0.806**) which are seed characteristics. According to these results, it can be said that, in breeding of the chickpea, all the characteristics of the plant would be improved genetically to serve to get higher seed yield.

When examining the relationship between the 100-seed weight and other characters, significant differences were found. Positive and significant relationships were determined between 100-seed weight and the biological yield (r=0.412**), yield (r=0.584**), water absorption capacity (r=0.760**), water absorption index (r=0.877**), swelling index (r=0.538**). However, there were also significant but negative correlations between 100-seed weight and the protein ratio (r=-0.489**), swelling capacity (r=-0.741**). If the goal in breeding is to increase the yield, 100-seed weight can be focused on (Table 4).

If quality is to be focused on breeding studies, it is important to note that an increase in 100-seed weight will particularly affect the protein ratio in the negative direction. Because, the high percentage of protein, which is one of the most important properties of edible grain legumes, distinguishes these plants from other plants and makes them priority. Therefore, the protein ratio is crucial. As in all plants, yield, which is the most important parameter in chickpea we focused on in our study, is in a positive and significant relation with other quality parameters, except the protein ratio. The water absorption capacity, swelling capacity, water absorption index and swelling index values increase accordingly as the yield increases. However, the protein ratio starts to decrease with the increasing yield. In fact, this isa disadvantage. There are two options present in this situation. One of these options is to try to increase the yield by risking the decrease in the protein ratio and the other is to increase the protein ratio and not to increase the yield. These options will be preferred depending on priority of organization or the State considering her needs.

Positive and significant relationships were also found between the water absorption index and swelling capacity; swelling capacity and water absorption capacity, swelling index; water absorption capacity and swelling index. However, none of these properties had a significant relationship with the protein ratio, either positively or negatively. From this point of view, the change in protein ratios will not affect other quality characteristics of the seed. Therefore, this subject should be considered in studies on protein ratios solely.

The correlation coefficient between the yield and the plant parameters reveals the relationship between independent variables and direct relationships between them (Duzdemir, 2016). As the adaptation limits of chickpea are narrow, different results can be obtained in different environments with the same varieties (Muhammad *et al.,* 2004). Ozdemir & Karadavut (2003) suggested that variety breeding should be carried out separately for summer and winter environmental conditions. Specific analyzes for morphological characters are recommended for chickpea varieties that are adaptable to specific environments (Al-Rifaee *et al.,* 2007).

The direct and indirect effects of the characters investigated with the exception of the quality criteria are shown in Table 5. The quality properties were not taken into consideration as it was thought that they would not have a direct effect on the yield. Accordingly, while the direct effect of plant length was negative with -0.124, the highest indirect effect was shown by the number of seeds per plant (0.217). Examining the effect ratios, plant height had a direct effect of 39.12% on the yield while the highest indirect effect was through the number of seeds per plant with 24.17% and through the first pod height with 21.80%.

The direct effect coefficient of the first pod height on the yield was found as 0.096. The direct effect of this property on yield was determined as 19.77%. The highest pod height had the highest indirect effect of 45.76% on the number of seeds per plant. This trait was followed by an indirect effect of 21.62% through the plant height.

The direct effect coefficient of the number of pods on the yield was 0.079, which had a relatively low value of 12.38%. However, the number of seeds per plant showed a very high indirect effect of 77.13% through the number of seeds per plant. The indirect effects were very low. This high indirect effect of the number of seeds per plant through the number of pods per plant actually indicates that the number of pods in the plant will increase as the number of seeds in the plant increase, and, consequently, the yield will increase.

When the seed number per plant was taken into consideration, it was seen that the direct effect coefficient hada very high coefficient 0.841. The direct effect of the number of seeds in the plant was as high as 81.26%. In terms of indirect effect, it was 9.13% through the number of seeds in the plant. The high direct effect of the number of seeds in the plant suggests that this property should be studied in particular. The increase in the number of seeds in the vegetation causes the yield to be obtained from the plant to increase to a certain point. Therefore, this character is always important and should be studied on. Seed yield per plant has a relatively low direct effect, in contrast to the number of seeds per plant. The seed yield per plant had a direct effect of 8.82% on yield, as well as an indirect effect of 65.47% through the number of seeds per plant. The seed yield per plant shows increasing effect in terms of the yield. Apart from this, it had a 12.16% indirect effect through the first pod height. The effect through biological yield and 100-seed weight was almost non-existing. The indirect effect through the 100-seed weight is negligible and can be considered as an indication that there is no relationship between the seed yield and this trait or feature.The number of seeds per plant and the height of the first pod are important parameters for breeding studies on seed yield.

The direct effect coefficient of 100-seed weight was determined as 0.016. The ratio was determined as 14.52%. While 100-seed weight had an indirect effect through the number of seeds in a ratio of 44.71%, this was followed by indirect effects, the plant height with 17.68% and the first pod height with 15.49%.

The low coefficiency of direct effect of-100-seed weight on biological yield was determined as 0.022. The amount of direct effect on yield was determined as 24.81%. However, the biological yield was 52.15% with an indirect effect through the number of seeds per plant. This was followed by the first pod height of 13.79%. However, the indirect effects of other properties of biological yield was found very low.

Table 5. The direct and indirect impacts of the examined parameters on yield.

Direct impact	Indirect impact	Direct impact quantity	Indirect impact quantity	Impact ratio (%)
Plant height		-0.124		39.12
	The first pod height		- 0.068	22.80
	Number of pods per plant		0.186	4.47
	Number of seeds per plant		0.217	24.17
	Seed yield per plant		0.198	5.15
	100-seed weight		0.158	3.48
	Biological yield		0.017	0.81
The first pod height		0.096		19.77
	Plant height		- 0.177	21.62
	Number of pods per plant		0.044	4.38
	Number of seeds per plant		- 0.095	45.76
	Seed yield per plant		- 0.103	1.82
	100-seed weight		0.099	4.17
	Biological yield		- 0.016	2.48
Number of pods per plant		0.079		12.38
	Plant height		0.166	2.27
	The first pod height		- 0.121	4.65
	Number of seeds per plant		0.721	77.13
	Seed yield per plant		0.038	2.82
	100-seed weight		- 0.048	0.27
	Biological yield		0.002	0.48
Number of seeds per plant		0.841		81.26
	Plant height		0.017	2.01
	The first pod height		- 0.118	6.36
	Number of pods per plant		- 0.081	9.13
	Seed yield per plant		0.016	0.38
	100-seed weight		- 0.021	0.48
	Biological yield		0.004	0.38
Seed yield per plant		0.041		8.82
	Plant height		0.066	6.81
	The first pod height		- 0.041	12.16
	Number of pods per plant		- 0.115	6.18
	Number of seeds per plant		0.369	65.47
	100-seed weight		0.016	0.27
	Biological yield		0.014	0.29
100-seed weight		0.016		14.52
	Plant height		- 0.061	17.68
	The first pod height		0.042	15.49
	Number of pods per plant		0.018	4.23
	Number of seeds per plant		- 0.186	44.71
	Seed yield per plant		0.074	0.68
	Biological yield		0.041	2.69
Biological yield		0.022		24.81
	Plant height		0.024	0.76
	The first pod height		- 0.031	13.79
	Number of pods per plant		- 0.062	3.76
	Number of seeds per plant		0.071	52.15
	Seed yield per plant		- 0.011	1.92
	100-seed weight		0.026	2.81

According to path analysis, a negative coefficient indicates that the character will develop in negative direction whereas a positive coefficient indicates that the parameter will develop in the positive direction. The direct effect of plant height on yield was determined as -0.124. Accordingly, the plant size has a direct negative effect on yield. Similarly, the plant height indirectly reduces the yield through the first pod height. While the first pod height directly increases the yield, it has an indirect reduction effect of 21.77% through the plant height. It was determined that it can reduce the yield about 45.76% through the number of seeds per plant. The direct effect of the number of seeds in the plant was much higher than those of the other characters (82.26%). However, this character had an indirect reduction about 15.49% through the first pod height and the number of pods in the plant. Similarly, 100-seed weight tended to decrease the yield by 44.71% through the number of seeds. Biological yield, on the other hand, appears to have a direct effect on the yield as well as an indirect effect (52.15%) on increasing the yield through the number of seeds.

The current results are similar to the findings of Sagir *et al.,* (2004), Duzdemir *et al.,* (2009) and Karadavut (2009). The adaptation limits of the chickpea plant are not very wide; it can give different results in different environments. It is important to know the relationships between the characters and their effects on yield, in terms of breeding strategy in adaptation studies on chickpeas (Younis *et al.,* 2008). Both the results of the correlation analysis and the results of the path analysis are in line with findings of previous studies. Especially in studies conducted at sowing time, it can be seen more clearly that the seed yield changes according to sowing time in studied plants (İliadis, 2001; Ozdemir & Karadavut, 2003).

The yield per plant was positively and significantly correlated with characters affecting yield. Similarly, positive and significant relationships were determined between the seed yield in the plant and the number of seeds in the plant, and the yield. The relationship between 100-seed weight and the yield was determined as significant and positive whereas the relationship between the biological yield and yield was not significant. Similar results were also determined by Jeena *et al.,* (2005); Joshi *et al.,* (2006); Singh (2007); Rokonuzzaman *et al.,* (2008); Thakur and Sirohi (2009) and Kumar & Lavanya (2012). Priority should be given to the properties specified for sustainability in the implementation of any product development program. Seed yield is controlled by highly complex genes (Vaghela *et al.,* 2009). Accordingly, it will be healthier to evaluate - different factors in the breeding studies by considering that they will have an effect on the yield and the character that affect the yield.

Conclusions

In the present study, 22 genotypes were used including 18 varieties and 4 local populations. The yields of the genotypes and the factors affecting the yield were determined. Hisar, Cagatay, Azkan, ILC-483 and Hacıbektaş-2 genotypes were superior in terms of yield and the factors affecting the yield.

The present results showed that the plant parameters affecting the yield of chickpea varied. Regarding the breeding studies to be carried out to develop varieties in chickpea plants, it is necessary to take the changed environmental conditions into consideration while selecting the desired type of plant. In the studies to develop new chickpea genotypes, it is necessary to focus on seeds and 100-seed weight in plant. Taking only the correlation coefficients into consideration, it is not possible to exactly determine the proportions of the effects of all properties in the formation of seed yield and their reciprocal relations. Therefore, path analysis has been found to be more effective in revealing vegetative characters to be considered as selection criteria in the selection of chickpea. In addition, it has been observed that the taking consideration of the number of seeds in the examination of the yield parameters in the plant would be valid due to the high and positive significant indirect effects.

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