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The relationships between some phenological and morphological properties of chickpea (*Cicer arietinum* L.) and the possibilities of using these properties in selection: The Western Mediterranean Region Model

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Abstract

In this study, the relationships between grain yield and yield characteristics were analyzed by running correlation and linear regression analyses. In the study, the herbal properties of 18 registered chickpea varieties and 3 local chickpea lines were used. The trials were continued for two years in two locations in the transitional zone of the Antalya-Korkuteli-Ulucak village and the coastal conditions of Antalya Aksu in the western Mediterranean region. According to the results of correlation and regression analysis, significant correlations were found between the yield and the number of the days to 50% emergence ($r = -0.6707$ and $p<0.01$), the number of days to 50% flowering ($r = -0.6446$ and $p<0.01$), number of days to maturity ($r = -0.7303$ and $p<0.01$), plant height ($r = 0.4304$ and $p<0.01$), first pod height ($r = 0.5990$ and $p<0.01$), number of pods per plant ($r = -0.1681$ and $p<0.05$) and the number of seeds per pod ($r = 0.2696$ and $p<0.01$). Although the data obtained as a result of the regression analysis did not exactly match the data determined, it was determined that close or average values could be reached, which may be beneficial for breeding activities.

Keywords: Correlation, Chickpea varieties, Linear regression analysis

Introduction

Due to the narrowness of adaptation boundaries (Şehirali and Özgen, 1988; Singh and Bejiga, 1990; Bozoğlu and Gülümser, 2000; Sayılğan and Kocatürk, 2019), it is more appropriate to carry out breeding activities in the chickpea plant as sub-programs and regionally. In genotype choices with high adaptability in regional breeding studies, the yield is generally emphasized as the final output, and in the existing ecological conditions, the varieties with the highest yield and high stability are preferred. The genetic structure of the plant, the effect of the environment and the effects of cultural processes separately or together have an impact on the yield. These effects make themselves felt in different parts of the plant during the plant development period and directly or indirectly influence the yield. Although this situation brings about a variety of disadvantages, it also provides future-oriented inferences based on predictable results that facilitate breeding. In the observation garden stage of breeding programs initiated using thousands of genotypes, the work schedule is shortened, the workload is reduced, and more efficient outputs can be achieved thanks to the fast, easy-to-diagnose and convenient separation criteria. The phenological and morphological features that are thought to be effective on especially the yield are emphasized in these studies.-

Correlation coefficients, direction and significance level between these plant characteristics were determined. The significance level provides us with some clues as to whether the relationship between variables can be taken into account. In the case of high probability (95-99%) relationships, modeling can be made with the regression analysis to make predictions about

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future situations based on the existing variable data. The effect of the properties, which were found to have high correlation, was determined by conducting the linear regression analysis. Evaluations were made through the model formulas obtained as a result of the regression analysis.

Materials and Methods

In this study, were used eighteen registered varieties and three local populations In the study, plot observation averages of plant properties belonging to two years, two different locations and eighteen registered varieties and three local populations were evaluated. The trials of the study from which the data were obtained were established in the coastal zone of Aksu district of Antalya province and in the transitional zone of Ulucak village of Korkuteli district of Antalya province. Trials were carried out for two years at two locations. In this study, evaluations were made for each property according to the technical instruction principles for chickpea issued by the "Seed Registration and Certification Center", for morphological properties according to plot averages determined over 10 plants, and for phenological values by using 336 observation data per each related to daily averages. Correlation analyses between the plants and regression analyses and relevant tables and graphs were created by using the appropriate statistical analysis package program JUMP.

Results and Discussion

Correlation analysis is a useful method used to determine the relationship, strength and direction between multiple variables. The measurement of the relationship between the two variables is the correlation coefficient (r).

Table 1. The table showing the relationship, strength and direction of plant properties

	NDE	NDF	NDM	PH	FPH	NBRPP	NPOPP	NSEPPO	100SW	HS
NDE										
NDF	0.4679**									
NDM	0.6369**	0.4853**								
PH	-0.4842**	-0.1889*	-0.2248**							
FPH	-0.6484**	-0.3552**	-0.3930**	0.8224**						
NBRPP	-0.0409ns	0.2009*	0.0023 ns	0.3545**	0.2186**					
NPOPP	0.2457**	0.3735**	0.0858 ns	0.0690 ns	-0.1555*	0.6136**				
NSEPPO	-0.4062**	-0.3923**	-0.2427**	0.2935**	0.3613**	-0.1219*	-0.3393**			
100SW	-0.0234 ns	-0.2479**	0.0823 ns	0.1526*	0.0220 ns	-0.0715 ns	0.0402 ns	0.1794*		
HS	0.0327ns	-0.0202 ns	0.0846 ns	-0.0519 ns	-0.0548 ns	-0.0456 ns	-0.1276*	0.1481*	0.0689 ns	
Y	-0.6707**	-0.6446**	-0.7303**	0.4304**	0.5990**	-0.0291	-0.1681*	0.2696**	0.0666	-0.1004 ns

* and ** indicates significance at p<0.05 and p<0.01, respectively, ns: indicates not significant. NDE: Number of day to 50% emergence (day), NDF: Number of day to 50% flovering (day), NDM: Number of days to maturity (day), PH: Plant height (cm), FPH: First pod height (cm), NBRPP: Number of branches per plant (average), NPOPP: Number of pods per plant (average), NSEPPO: The number of seeds per pod (average), 100SW: 100 seed weight (gr), HS: The humidity of seed at harvest (%), Y: Yield (kg.ha^{-1}).

The correlation coefficient is a value between -1 and +1, and the exact state of -1 (negative) and +1 (positive) are the indicators of perfect correlation. There can also be no relationship between the variables (r = 0). In general, in negative correlation, one of the variables increases while the other one decreases. In positive correlation, one of the variables increases while the other one also increases. Correlation analysis results of the properties discussed in this study are given in Table 1.

Although the number of similar studies has decreased in the last two decades, the relationships between yield and some phenological and morphological vegetative properties have been examined in the studies conducted since 1970s. Although there are some studies reporting that the relationship between yield and the number of days to 50% flowering is significant and positive (Ali, 1990) or insignificant (Singh, 1978), there also exist some study results which are similar to the significant and negative relationship we identified in this study (Salih, 1982; Wahid and Ahmed 1999; Yeşilgün, 2006). When the determination process is analyzed in a historical perspective, it can be seen that the results found in this research are similar to the recent research results.

In this research, the number of the studies that reported a significant and positive relationship between the yield and the number of branches per plant, which we determined as insignificant, (Sharma et al., 1970; Mishra, 1973; Gufta et al., 1974; Eser, 1975; Khorgade et al., 1985; Uddin et al., 1990; Özdemir 1996; Khorgade et al., 1988; Khedar & Maloo, 1999; Atta et al., 2008) is higher. Sing (1978) also reported the same

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relationship as significant without specifying its direction.

Despite the significant and negative relationship we found between the yield and the number of pods per plant, the number of studies which determined this relationship as significant and positive (Sharma et al., 1970; Joshi, 1972; Mishra, 1973; Dabholkar, 1973; Eser, 1975; Chand et al., 1975; Uddin et al., 1990; Abdali, 1992; Özdemir, 1996; Anlarsal et al., 1999; Khorgade et al., 1988; Wahid and Ahmed 1999; Arshad et al., 2002; Karaköy, 2008) is quite high. Naidu et al. (1987) reported that the same relationship was insignificant.

The significant and positive relationship between yield and the number of seeds per pod we identified in this study is in compliance with many studies conducted in the past (Singh, 1978; Joshi, 1972; Gufta et al., 1974; Dabholkar, 1973; Eser, 1975; Abdali, 1992; Özdemir, 1996; Anlarsal et al., 1999). Khorgade et al. (1988) found that the relationship between yield and the number of seeds per pod is also significant and negative in their study. The relationship between yield and plant height which we determined in our study and in many other studies was significant and positive (Sharma et al., 1970; Work, 1975; Ali, 1990; Özdemir, 1996; Wahid and Ahmed, 1999). However, this relationship was reported to be significant but negative by Mishra (1973).

The significant and negative relationship between yield and maturity is similar to that reported by Berger et al. (2004). The same relationship was reported to be significant and positive in many previous studies (Uddin et al., 1990; Salih, 1982; Ali, 1990; Khorgade et al., 1988; Wahid and Ahmed, 1999; Atta et al., 2008); however, Singh (1978) reported this relationship as insignificant.

Similar to our findings, there are studies that determined the relationship between yield and 100 seeds as insignificant (Eser, 1975; Naidu et al., 1986; Anlarsal et al., 1999). The same relationship was mainly reported as significant and positive in various studies (Sharma et al., 1970; Joshi, 1972; Mishra, 1973; Khorgade et al., 1985; Uddin et al., 1990; Eser et al., 1991; Khorgade et al., 1988; Khedar and Maloo, 1999; Karaköy, 2008; Atta et al., 2008).

The linear regression analysis was performed in order to reveal the properties of the plant which, as a result of correlation analysis, were found to have high probability of relationship by 95-99% with yield (the number days to 50% emergence (days), the number of days to 50% flowering (days), maturity days (days), plant height (cm), first pod height (cm), the number of pods per plant (number), the number of seeds per pods (number), 100 seed weight (gr)) and strengthen the predictions about future conditions (Table 2).

Table 2. Regression control values for the relationship between yield and plant properties

Properties	Properties	R^2	$\underline{R}^2$	MSE	F	p
Y(kg.ha^{-1})	NDE (day)	0.449853	0.448206	78.1341	273.1101	**
Y(kg.ha^{-1})	NDF (day)	0.415487	0.413737	80.75077	237.4159	**
Y(kg.ha^{-1})	NDM (day)	0.533292	0.531894	72.15599	5.2619	**
Y(kg.ha^{-1})	PH (cm)	0.185225	0.182786	95.33852	75.9292	**
Y(kg.ha^{-1})	FPH (cm)	0.358771	0.356851	84.57776	186.8747	**
Y(kg.ha^{-1})	NPOPP (average)	0.028256	0.025346	104.118	9.7118	ns
Y(kg.ha^{-1})	NSEPPO (average)	0.072703	0.069927	101.7089	261.867	**

*and **: indicates significance at $p<0.05$ and $p<0.01$, respectively, ns: indicates not significant. MSE: Means square error

The number of parcel emergence days detected in the trials was completed between 9 and 21 days. There is a negative relationship between yield and the number of days to 50% emergence. It is seen that the efficiency is decreased significantly when emergence is completed in 14 days. This may have stemmed from many factors, from variety characteristics to soil temperature and humidity. However, in any case, it can be expected that extension of the number of days to 50% emergence in the Western Mediterranean will lead to decrease in yield as it will mean that it will take longer than other phases in the vegetation process.

When the expected values to be obtained as a result of the formula were analyzed, the expected yield value for genotypes that complete the number of days to 50% emergence in 9 days was predicted as 2980 kg.ha^{-1}, and for genotypes completing it in 21 days, it was predicted as 1190 kg.ha^{-1}.

Mainly two groups were formed as 9-10.5 days and 11.5-16 days. It is seen that this situation is in parallel with the early completion of the emergence at the coastal location and the later completion in the transitional zone and that as the number of days to %50 emergence increases, the intensity in Figure 1 decreases.

The number of days to 50% flowering ranged from 37 to 68 days (Figure 2). The relationship between yield and the number of days to 50% flowering is negative. As the number of days to 50% flowering increases, the yield decreases. Concentration was formed in three groups between 37-38, 40-52 and 55-64 days. The expected yield value for the number of 50% flowering days is expected to be 2940 kg.ha^{-1} for the genotypes which complete it in 37 days and 1420 kg.ha^{-1} for those which complete it in 55 days. There are considerable differences between the detected and expected values. The varieties giving the highest yield average (Çakır, 2390 kg.ha^{-1}; Çağatay, 2380 kg.ha^{-1}) completed their 50% flowering in 47.7 days and 46.4 days, respectively, whereas the local population with the lowest yield (Aksu B1, 1340 kg.ha^{-1}) completed it in 45 days.

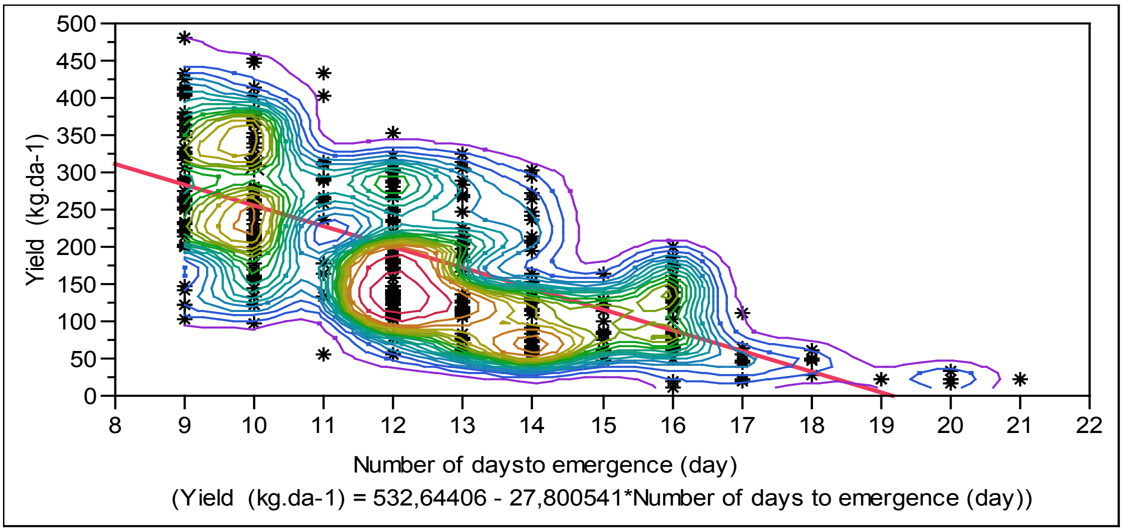

Figure 1. Linear change that occurs in yield based on the number of days to 50% emergence, its density and formula

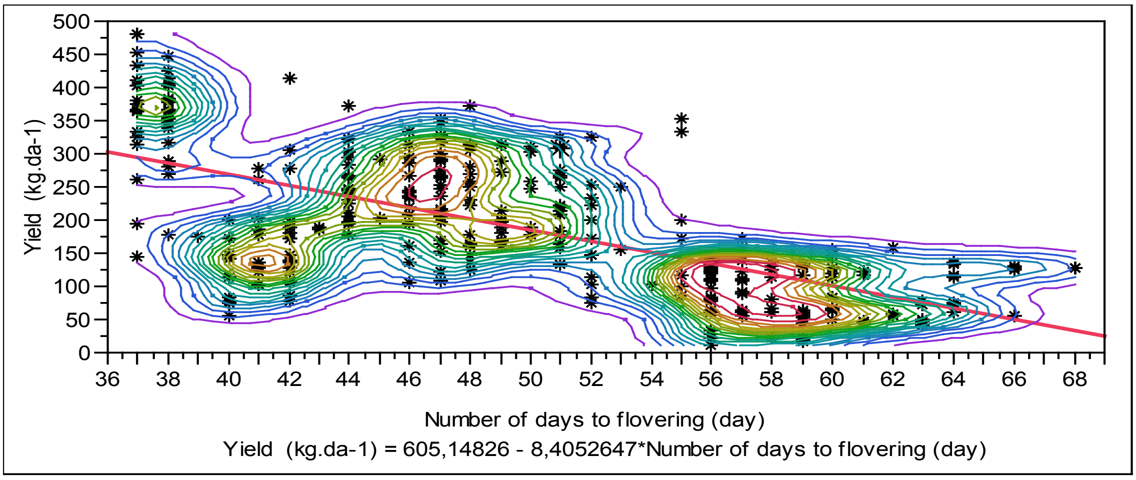

Figure 2. Linear change that occurs in yield based on the number of days to 50% flowering, its density and formula

Although the yield values are different, it can be said that the yield decreases as the number of days to 50% flowering is prolonged according to the data obtained with the prediction formula.

The number of days to maturity ranged from 77 to 119 days (Figure 3). It can be said that the relationship between yield and maturity is more linear. The maturity period affects the yield up to day 89, the efficiency decreases as it is prolonged, and the yield decreases sharply over 93-108 days. The expected yield value for genotypes reaching maturity in 77 days was 3150 kg.ha^{-1}, and it was estimated that there was a risk of getting no yield for the genotypes which matured in longer than 105 days (940 kg.ha^{-1}).

Plant heights ranged from 21.5 to 84.5 cm (Figure 4). The relationship between yield and plant height is positive. In other words, it can be said that as the plant height increases in the region, the yield increases. However, the main factor preventing the yield is the high temperature effects in the region which the plant is exposed to during the maturity process. Many genotypes dried up before completing the vegetation period. For all genotypes, the fact that they were at their highest level at this stage of development or completion of development can be considered as the reason for this situation. However, the main concentration occurred between 38 and 58 cm plant heights and around the yield between 100 and 3500 kg.ha^{-1}. The expected yield value for 21.5 cm. is 630 kg.ha^{-1} and for 84.5 cm it is 2760 kg.ha^{-1}.

The first pod height ranged from 10 to 52.3 cm (Figure 5). The relationship between yield and the first pod height is positive. A continuous increase in yield is observed up to the first pod height of 39 cm. All genotypes with the first pod height of 25 cm and above yielded 1000 kg.ha^{-1} and above. The main genotype density is 10 to 28 cm of the first pod height. The genotypes of high yield with the first pod height of 28 cm (2200 kg.ha^{-1}) and 39 cm (3100 kg.ha^{-1}) were observed to be dense. The expected estimated yield value for the first pod height of 10 cm is 750 kg.ha^{-1}, and for the first pod height of 52.3 cm, it is 4110 kg.ha^{-1}. Here, the relationship between the first pod height and yield may be valid for the genotypes that have completed their physiological development, because it was observed that the yields of the genotypes drying early, which could not complete the maturity period even though the height of the first pod was high, were quite low.

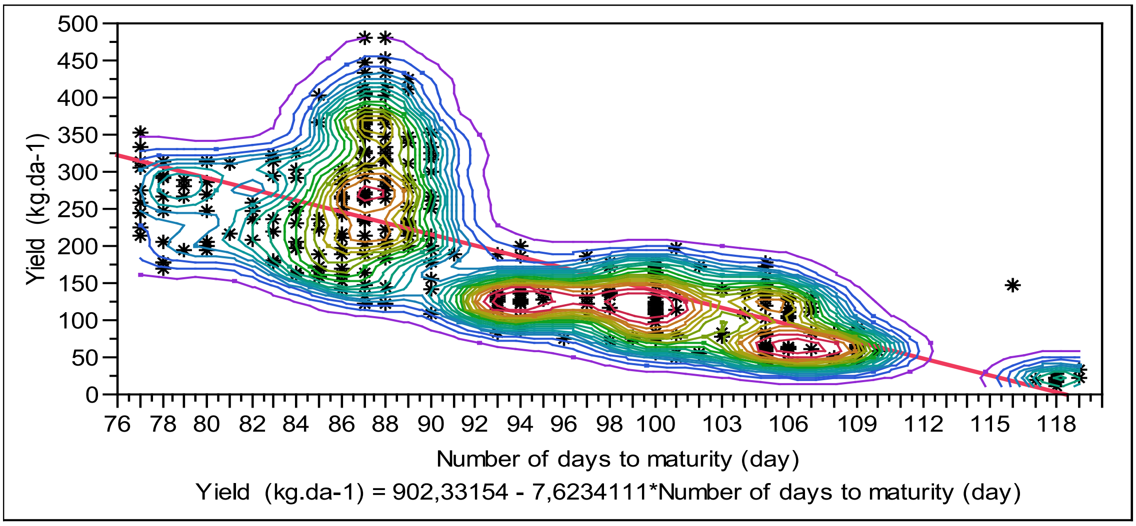

Figure 3. Linear change in the yield based on the number of days to maturity, its density and formula

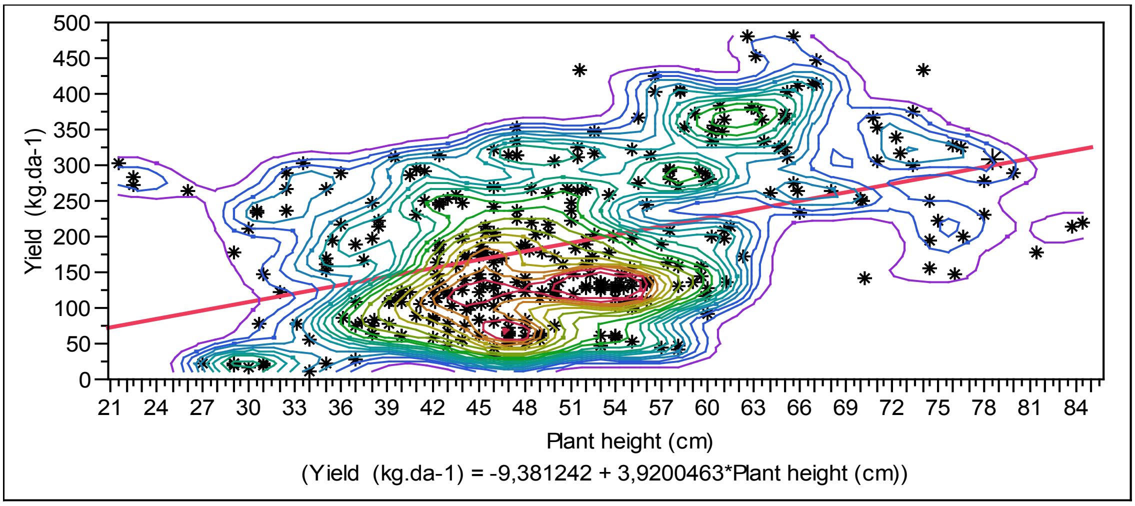

Figure 4. Linear change occurring in yield based on plant height, its density and formula

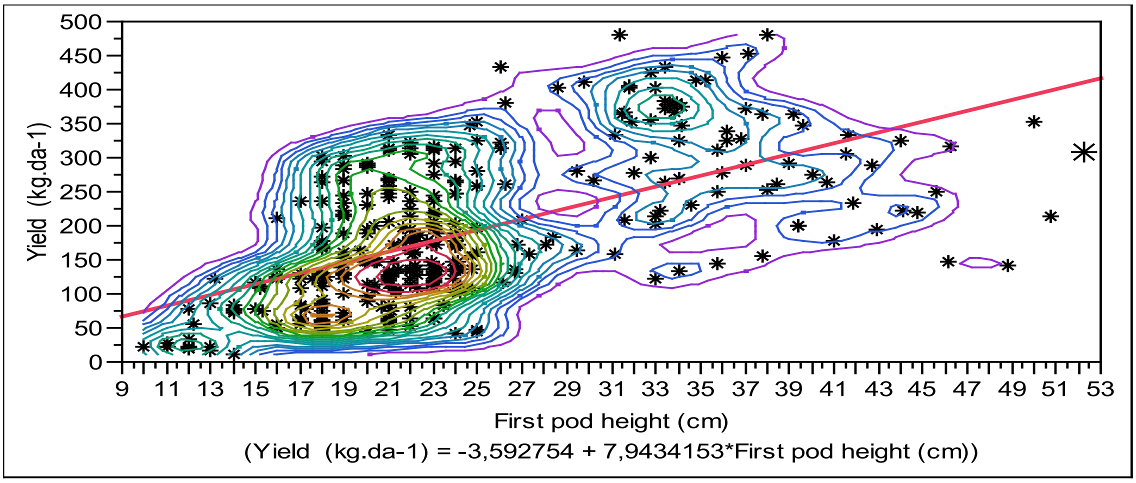

Figure 5. Linear change occurring in the yield depending on the first pod height, its density and formula

The correlation ($p<0.05$) with the number of pods per plant was significant and (-r) negative, but it was determined that it did not have a significant effect on yield as a result of the regression analysis (Figure 6).

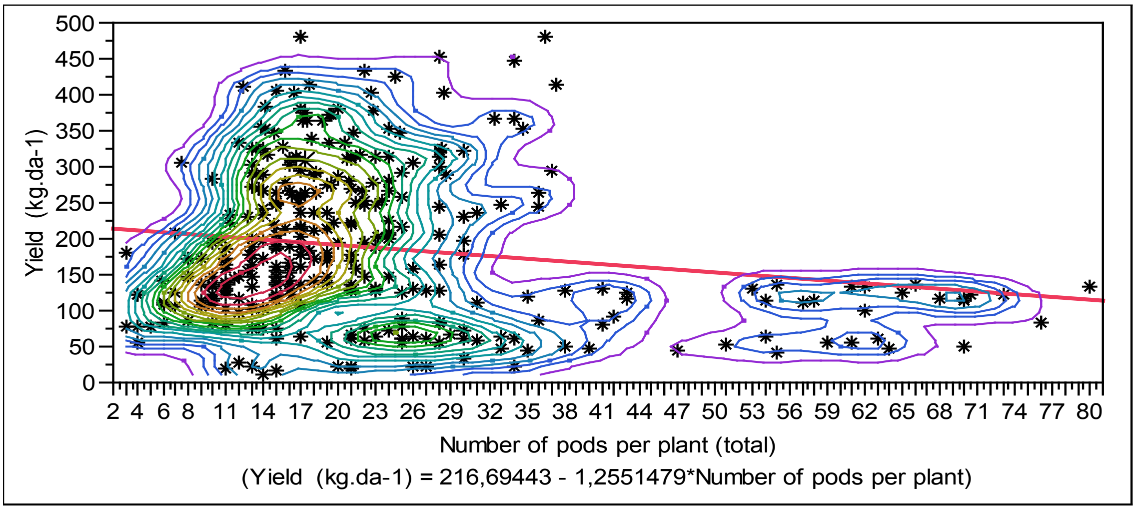

Figure 6. Linear change occurring in the yield depending on the number of pods per plant, its density and formula

The number of the filled pods which should be in the genotypes that normally survive the maturity period without any problem is positively related with the yield. However, regarding the number of pods per plant, which belonged to the trial material varieties, there was no significant difference between the high-yielding and low-yielding genotypes. It was observed to be more important to determine the rate of the filled pods rather than the genotypes with high number of pods. Although some of the genotypes had many pods in the plant, it was observed that the number of seeds per pod remained low due to early drying. This already manifested itself in the yield in which the number of seeds per pod was important and positive.

The number of seeds per pod ranged from 0.1 to 2.2 (Figure 7). The relationship between yield and the number seeds per pod is positive. The highest yields are observed in the genotypes with 1.1 and 1.3 seeds per pod. In general, it is seen that, as the rate of fullness increases, the yield also tends to increase. The expected yield value depending on the number seeds per pod for 0.1 seeds/pod is 1180 kg.ha^{-1}, and for 2 or more seeds per pod, it is 2590 - 2730 kg.ha^{-1}. In general, the majority of the genotypes yields as low as 1.0 seeds per pod.

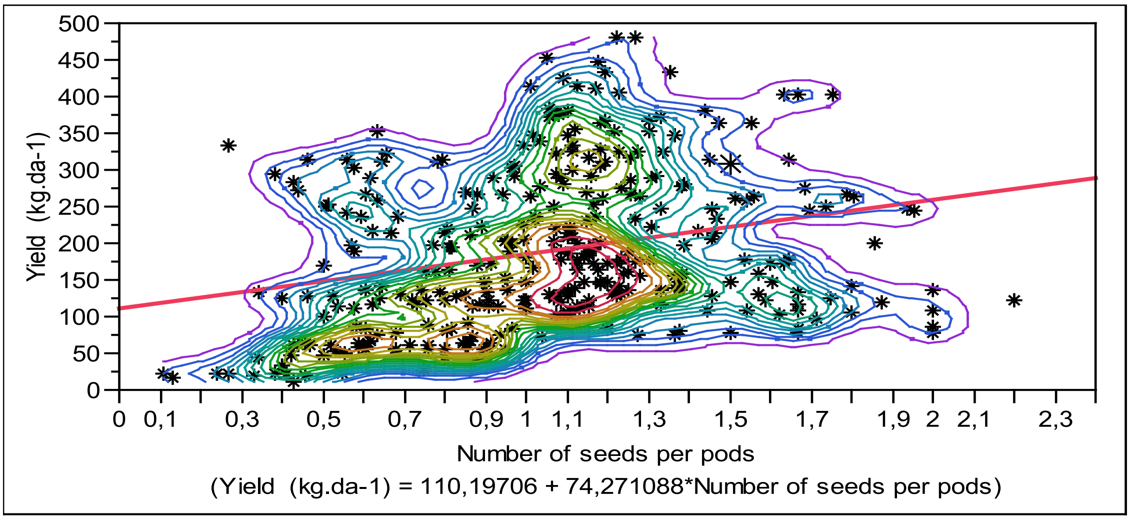

Figure 7. Linear change occurring in the yield depending on the number seeds per pod, its density and formula

Conclusion

It is understood that the number of days to 50% flowering , the number of days to maturity, first pod height, the number of pods per plant, the number of seeds per pod, plant height, the number of branches per plant and 100 seed weight for chickpea are the most researched features in relation to the yield. The results of the studies can be said to have been successful considering the increases in yields per unit area from past to present. It is observed that while the researches related to yield and facilitating selection studies were carried out intensely until 1999, they decreased from 2000 and onward. It is known that earliness in maturity has increased and maturity periods are reduced due to the effects of phenological deviations resulting from global climate change, which has accelerated recently (Penuelas and Filella 2001; Walther et al., 2002; Craufurd and Wheeler, 2009; Visser et al., 2010; Sayılğan, 2016; Yavaş and Ünay, 2018; Gülser et al., 2019). In order to develop varieties with high adaptation to these conditions, revealing the effects of phenological features and new developments in plant morphology on yield is important in terms of the success of the breeding programs and prospective predictability.

Multidimensional evaluation of the data obtained and updating the situation by comparing it with the data obtained in the past are especially important for long-term breeding programs, because the temporal change in environmental and genotype characteristics causes the plants to acquire features that can adapt to new situations. Or those which cannot adapt disappear in this process. Today, the so-called "data mining" work saves a lot of time and labor when they are utilized well. In this study, a total of 3696 observation data of plant characteristics obtained from the present research and the results of similar studies conducted on chickpea plant starting from 1960s till today were used. The correlation coefficients of plant properties and their significance levels were determined.

As the facilitating separation features in the selection with a purpose of efficiency in breeding activities in the Western Mediterranean, it was determined that the genotypes which complete the number of days to 50% emergence early (9 - 12 days), reach the number of days to 50% flowering early (35-50 days), have physiological maturity days less than 100 days, complete the plant height early (30 - 80 cm) and passes to physiological maturity stage, has the first pod height between 20 and 45 cm, has higher number of filled pods rather than the number of pods, and has the number of seeds per pod between 0.7 and 1.9 pods may be more productive.

As a result of the linear regression analysis, the causal relationship between the yield and such plant properties as the number of days to 50% emergence (Yield = 532.64406 - 27.800541 * the number of days to 50% emergence), the number of days to 50% flowering (Yield = 605.14826 - 8.4052647 * the number of days to 50% flowering), the number of days to maturity (Yield = 902.33154 - 7.6234111 * the number of days to maturity), plant height (Yield = -9.381242 + 3.9200463 * Plant height), the first pod height (Yield = -3.592754 + 7.9434153 * the first pod height), the number of pods per plant (Yield = 216.69443 - 1.2551479 * the number of pods per plant) and the number of seeds per pod (Yield = 110.19706 + 74.271088 * the number of seeds per pod) was tried to be estimated. Although the results of the linear regression performed with full reality do not coincide with the data determined, it was determined that the results could be obtained at the level of average values, which can be very beneficial for breeding activities.

Compliance with Ethical Standards

Conflict of interest

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Author contribution

The author read and approved the final manuscript. The author verifies that the Text, Figures, and Tables are original and that they have not been published before.

Ethical approval

Not applicable.

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Data availability

Not applicable.

Consent for publication

Not applicable.

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