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Full Length Research Paper

Genetic analysis of common bean agronomic traits in stress and non-stress conditions

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Water stress is vital factor limiting bean production wherever beans are grown. The development of bean cultivars having resistance to this stress is a cost-effective tools to address this constraint. This study assessed the performance of gene action and heritability in stress and non-stress conditions. The experiment was designed in randomized complete block design with three replication of two types of common bean including Taylor (P_1) and Aracuanol (P_2). These parents were crossed and then F_2, F_3, BC_1 and BC_2 generation were derived. Then yield and vegetative traits include: Number of days to germination (V_1), number of days to appearance of primary leaves (V_2), number of days to appearance of a first trifoliate (V_3); number of days to appearance of a third trifoliate (V_4), height of plant and yield were considered. The genetic components of generation mean analysis were included: Mean (m), additive effect (d), dominate effect (h), additive × additive effect (i), additive × dominate effect (j) and dominate × dominate effect (l). These components were evaluated for all traits, while all the gene effects were not observed simultaneously in all traits. The dominant effect of genes was the most important genetic parameter for controlling the majority of the traits. Despite the significant result for additive effect the importance of dominant effect was more. The results of this study present that in the study of traits in both stress and non-stress conditions not only the additive and dominant effects are important but also the epistasis effect is considerable as well. Moreover, because of the high heritability of most of the traits, it may improve the resistance to drought in breeding projects.

Key words: Common bean, generation mean analysis, heritability, stress and non-stress conditions, action gene.

INTRODUCTION

Gene action quantitative traits like vegetative traits can be evaluated by generation mean analysis. Several models have been tested by Hayman (1958), Gamble (1962) and Mather and Jinks (1982) to analyze mean generation. Mean analysis is developed for estimation of the genetic component variance. Furthermore component variance provides essential information about gene action for the very important characters of crop species (ASRAT and KIMANI, 2005). As a result, estimation of genetic parameters has a significant role in plant breeding. In recent decays due to fast population growth, many developing countries have faced with consequences such as food shortages and malnutrition. So plant breeding can be used as a substantial programme to decrease food shortage by potential yield enhancement (Bongaarts et al., 2009). More than twenty percent of the population in developing countries cannot get enough food due to lack of agricultural resources (Chopra et al., 2002). According to UN reports, the population of Iran during the 1980 to 1985 had a growth rate of 2.89% that in comparison to world population, Asia and developing countries with rates about 1.67, 1.74 and 2.01%, respectively is much greater (Omobowale et al., 2009).

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Table 1. Mean Genetic evaluation for evaluated traits in non-stress and stress conditions.

	M	[d]	[h]	[I]	[j]	[l]	x2
				Stress conditions			
V1	4.32±0.53**	0.62±0.85	8.16±3.01**	1.01±0.52*	-1.34±0.99	3.99±2.63**	0
V2	10.09±0.22**	-0.23±0.17	1.61±0.65*	1.11±0.27**	2.31±1.43	—	1.54
V3	17.34±0.24**	-0.34±0.24	-6.78±1.68**	—	5.18±1.49**	6.66±2.76*	1.21
V4	25.18±0.68**	-0.41±0.21*	-11.85±3.76**	-1.67±0.64*	2.84±1.37*	14.10±4.92**	0
Height	53.91±1.83**	26.88±1.83**	131.12±15.58**	—	-138.91±15.12**	-256.97±30.10**	0.03
Yield	36.29±6.82**	4.07±1.54**	-109.17±3.78**	-17.06±6.75*	—	128.44±45.82**	1.30
				Non-stress conditions			
V1	3.73 ± 0.92**	-0.38±0.18*	16.26±4.68**	2.68±0.90**	7.09±1.43**	-20.42±5.88**	0
V2	6.36±0.83**	0.05±0.20	26.72±4.28**	4.42±0.81**	7.03±1.38**	-38.36±5.41**	0
V3	16.28±0.25**	0.47±0.25*	4.53±1.80*	—	1.50±4.67**	-12.32±3.00**	1.92
V4	25.16± 0.96**	-0.66 ±0.17**	-11.82±4.65 **	-1.74 ± 0.93*	—	15.88±5.64**	0.84
Height	-5.14±10.96	24.42±2.22**	426.11±59.20**	58.63±10.73**	-96.53±19.299**	-602.23±77.14**	0
Yield	14.82±0.69**	1.38±1.92	—	7.56±2.21**	—	—	7.52

There are many methods to overcome these problems such as, population control, agricultural land expansion and increase yield potential per plant (Thornton et al., 2011). Water deficiency is one of the most important factors that limit crop production. Drought occurs when the combination of physical and environmental factors cause water stress in plants and thus reduce production. The duration and severity of drought is very variable from one area to another, which in parts of South Asia, India, Africa and the Middle East and other parts of Northern Argentina and Brazil to Mexico, mainly food production is limited to non-regular rainfall, so drought is considered a serious threat for agricultural production in most countries of this areas (Kreuzwieser et al., 2010). Common bean (*Phaseolus vulgaris* L.) is one of the important legumes for direct human consumption while compared to other grain legumes such as cowpea, peanut or pigeon pea, it usually have high water requirements and vulnerable to drought stress (Broughton et al., 2003; Blair et al., 2010). Drought stress on crops is defined as an insufficiency of water availability that restricts the appearance of the full genetic potential of a cultivar (Taiz and Zeiger, 2006). Inheritance of drought tolerance in common beans has been known to be quantitative with regular selection as an effective breeding strategy (Beebe et al., 2008; Blair et al., 2010). Present work was conducted to assess the performance of action gene in stress and non-stress condition. Moreover this study aimed to the heritability and number of traits control genes in mentioned conditions.

MATERIALS AND METHODS

Plants population and study design

The experiment was designed in randomized complete block design with three replications of two types of common bean including Taylor (P_1) and Aracuanol (P_2). These parents were crossed and then F_2, F_3, BC_1 and BC_2 generation were derived from 2007 to 2010. For each one of the $P_1$and P_2 generations two lines, BC_1 and BC_2 three lines and F_2 and F_3, six lines in each replication were planted. The distance between lines was 20 cm, in lines was 5 cm and the length of each line was 3 m. Furthermore, after the seedling settled down (in the time of third foliage appearance), the water stress was applied and continued to end of the agricultural season (Blum 1998; Blum, 2001). Data collection was performed from all the study population. Generation mean analysis was applied for each trait using Mather and Jinks method (Mather and Jinks, 1982; Evans, 2002; Weerapun et al., 2010). We considered yield and vegetative traits such as: Number of days to germination (V_1), number of days to appearance of primary leaves (V_2), number of days to appearance of a first trifoliate (V_3), number of days to appearance of a third trifoliate (V_4), height of plant and yield. The genetic components of mean for the selected traits observed using joint scaling test include: Mean (m), additive effect (d), dominate effect (h), additive × additive effect (i), additive × dominate effect (j) and dominate × dominate effect (l).

Statistical analysis

The data was analysed using Minitab 15.0 software package. The goodness of fit for additive-dominance model was observed using joint scaling and chi-square tests. In case that the additive-dominance model has not revealed all the genetic changes in the trait of interest, the six-parameter fitness model was used. In order to measure the gene effect and genetic variation components, the generation variance also has been studied using Kearsy et al. formulas (Kearsy et al., 2003). The heritability in broad sense and narrow (h^2_b and h^2_n, respectively) was observed using Warner method (Warner 1952). The P-value less than 0.05 and 0.01were considered as significant.

RESULTS

All the possible models were fitted for the traits of interest and those models which showed significant gene actions were selected (Table 1). The (d) component was

Table 2. Comparison of the statistically fitted models based on the traits of interest in this study and those significant effects.

Traits	Fitted models and those relative significant effects			
	Non-stress condition		Stress condition	
	Fitted model	Significant effect	Fitted model	Significant effect
V1	Six-parameter (m-[d]-[h]-[i]-[j]-[l])	[h] and [i] component has similar sign, the variance increasing for segregate generations, the selection for this trait in First generations is not effective because [d] component was not significant	Six-parameter (m-[d]-[h]-[i]-[j]-[l])	[h] and [i] component has similar sign, the variance increasing for segregate generations, the selection for this trait in First generations is effective because [d] component was significant
V2	Five-parameter (m-[d]-[h]-[i]-[j])	[h] and [i] component has similar sign, the variance increasing for segregate generations, the selection for this trait in First generations is not effective because [d] component was not significant	Six-parameter (m-[d]-[h]-[i]-[j]-[l])	[h] and [i] component has similar sign, the variance increasing for segregate generations, selection is not effective in First generations because [d] component was not significant
V3	Five-parameter (m-[d]-[h]-[j]-[l])	the selection for this trait in First generations is not effective because [d] component was not significant	Five-parameter (m-[d]-[h]-[j]-[l])	the selection on this trait is effective because [d] component was significant
V4	Six-parameter (m-[d]-[h]-[i]-[j]-[l])	[h] and [i] component has similar sign, the variance increasing for segregate generations, the selection on this trait is effective because [d] component was significant	Five-parameter (m-[d]-[h]-[i]-[l])	[h] and [i] component has similar sign, the variance increasing for segregate generations, selection is effective in First generations because [d] component was significant
The height of bush	Five-parameter (m-[d]-[h]-[j]-[l])	selection is effective in First generations because [d] component was significant	Six-parameter (m-[d]-[h]-[i]-[j]-[l])	[h] and [i] component has similar sign, the variance increasing for segregate generations, the selection on this trait is effective because [d] component was significant
Yield	Five-parameter (m-[d]-[h]-[i]-[l])	[h] and [i] component has similar sign, the variance increasing for segregate generations, the selection is effective in First generations because [d] component was significant	Three-parameter (m-[d]-[i])	selection is not effective in First generations because [d] component was significant

V1, Number of days to germination; V2: number of days to appearance of primary leaves; V3: number of days to appearance of a first trifoliate; V4: number of days to appearance of a third trifoliate.

significant for v_4, height and yield traits in non-stress condition, while v_1, v_3 and height were significant in stress condition (Table 1). The (h) component was significant for all traits in both non-stress and stress condition except in stress condition this component was not fitted to the model for yield trait (Table 1). In case of [i] component V_1, V_2, V_4 and yield traits were significant, while this component was not fitted to the model for V_3 and height traits in non-stress condition. Moreover, the (i) component was not fitted to the model for only V_3 trait and all the rest traits were significant in stress condition (Table 1). The (j) component was not fitted to the model for only yield trait and V_3, V_4 and height traits were significant in non- stress condition, while in stress condition this component was not fitted to the model for V_4 and yield traits and all the rest traits were significant (Table 1). The (l) component was not fitted to the model for only V_2 trait and all the rest traits were significant in non-stress condition, hence in stress condition this component was not fitted to the model for only yield traits and all the rest traits were significant (Table 1). In this study two, three, four, five and six-parameter models were used to better understand genetic system that control all the traits of interest (Table 2). In case of V_1 and V_3 traits in stress condition the (d) component was significant, but in non-stress condition these component was not significant, which revealed that the selection of first generations for this trait in stress condition is effective (Table 2). In contrast, In case of yield trait in stress condition the (d) component was not significant, while in non-stress condition these component was significant, which revealed that for yield improvement only in non-stress condition the selection of first generations was effective (Table 2). According to the obtained results about the heritability, because h^2_b and h^2_n had no considerable difference for V_1 trait, thus the additive variance was high that showing a high breeding value (Table 3). In the rest traits the heritability study showed considerable difference between h^2_b and h^2_n, which revealed that both dominant and epistasis

Table 3. The heritability of traits of interest in stress condition compared to non-stress one.

		V1	V2	V3	V4	height	yield
Non stress conditions	h^2 (Broad-sense)	0.411218	0.603508	0.573314	0.684231	0.760695	0.753076
	h^2 (narrow-sense)	0.407697	0.547489	0.42964	0.535602	0.331556	0.180282
Stress conditions	h^2 (Broad-sense)	0.440922	0.520978	0.474417	0.358861	0.630411	0.502999
	h^2 (narrow-sense)	0.401619	0.458819	0.431551	0.285387	0.329495	0.122784

V1: Number of days to germination; V2: number of days to appearance of primary leaves; V3: number of days to appearance of a first trifoliate; V4: number of days to appearance of a third trifoliate.

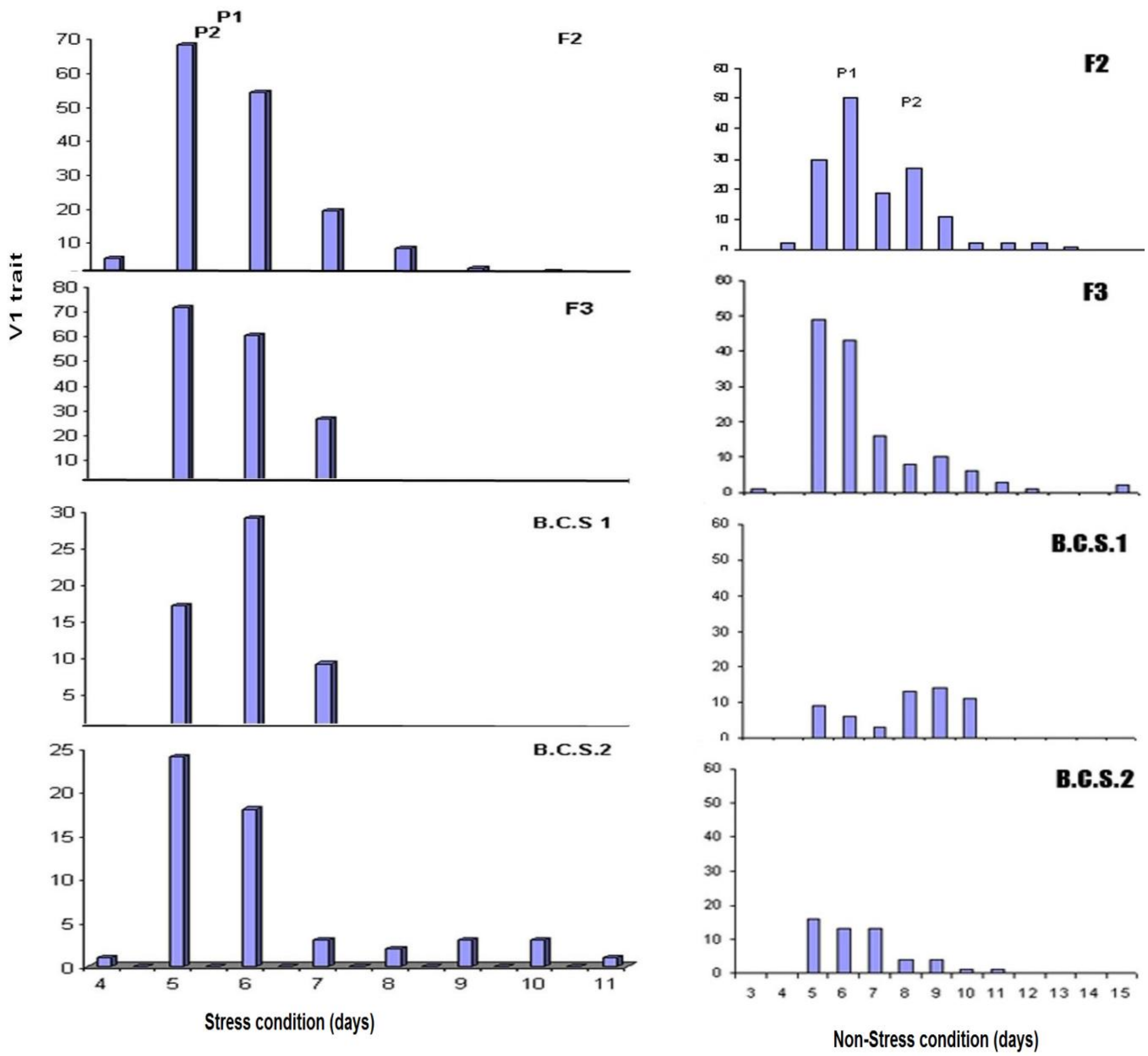

Figure 1. Frequency distribution of number of days to germination (V_1) trait P_1 and P_2 (both parents) compared with the F_2, F_3, BCS_1 and BCS_2 generations of the cross Taylor (P_1) × Aracuanol (P_2) in stress and non-stress conditions.

variances were effective (Table 3). The high decrease in heritability in case of stress condition in all traits and yield especially may show considerable effects of environment on these traits. The difference in germination between P_1 and P_2 for V_1 trait was not considerable in both stress and non-stress conditions. But in F_2 generation there was a normal distribution of this trait that might show transgressive segregation. In F_3 generation decreasing in V_1 value is the most concern. Moreover in BCS_1, V_1 trait increased in majority of the plants in contrast of decreasing of it in BCS_2 (Figure 1). In F_3 generation, the majority of plants tend to the parent who had lower level

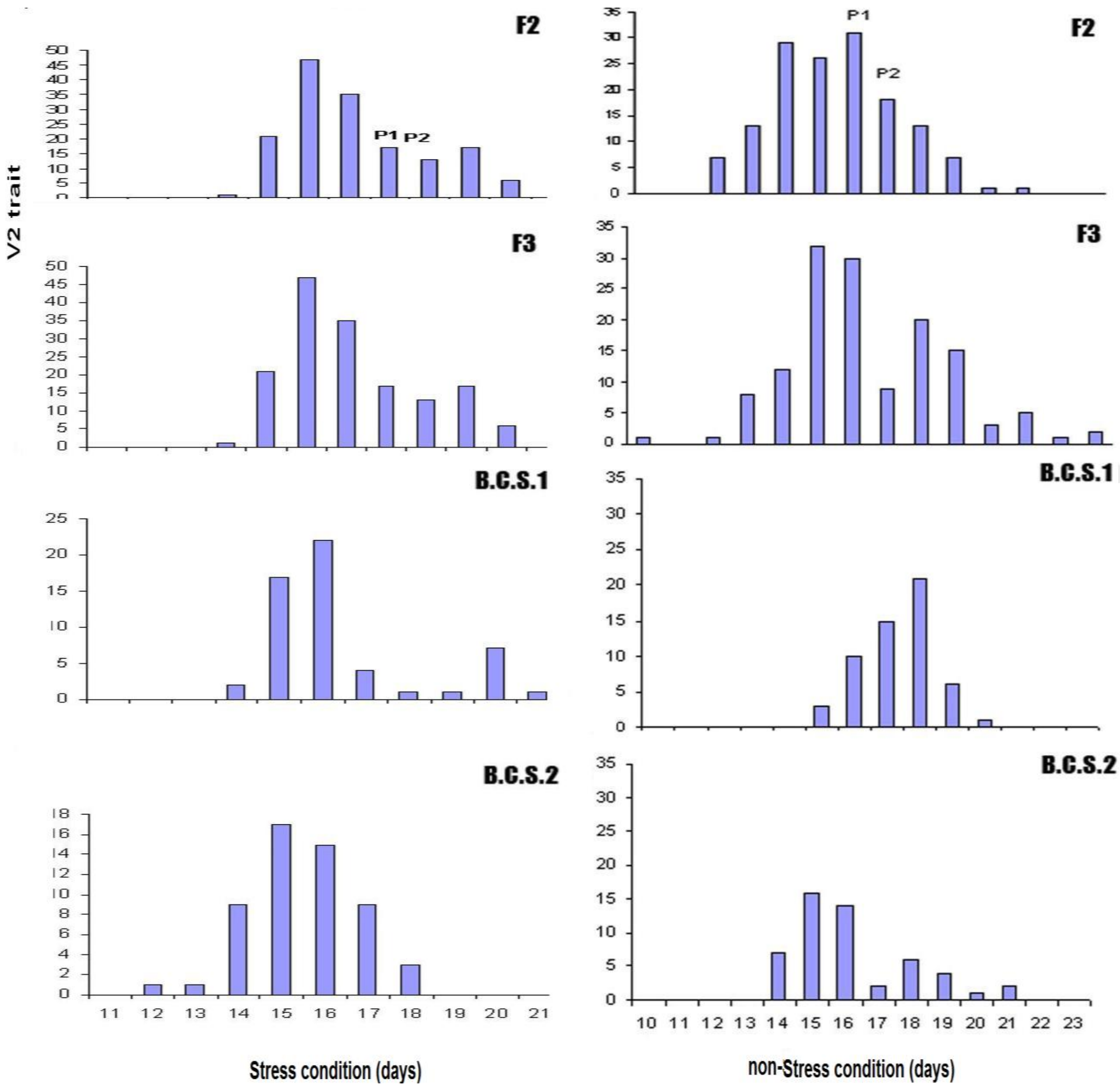

Figure 2. Frequency distribution of number of days to appearance of primary leaves (V_2) trait P_1 and P_2 (both parents) compared with the F_2, F_3, BCS_1 and BCS_2 generations of the cross Taylor (P_1) × Aracuanol (P_2) in stress and non-stress conditions.

of v_2 trait in non-stress condition that showed the higher dominancy of this parent compared to P_2. This trait increased in majority of the plants In BCS_1 while V_2 decreased in BCS_2 simultaneously (Figure 2). Furthermore the majority of plants tend to the parent who had lower level of v_2 trait (P_1). In stress condition for F_3 and BCS_1 generations. Many numbers of plants had heterosis to P_2. In BCS_2 also the majority of plants tended to this parent (Figure 2). In stress condition the majority of plants had heterosis to P_2 in all F_2, F_3, BCS_1 and BCS_2 generations of v_3 trait and many numbers of plants had similar phenotype to P_1 that might show the P_1 was more dominant compared to P_2 (Figure 3). In case of V_4 trait in non-stress conditions no considerable mean difference in P_1 and P_2 generations was observed. In F_2 and F_3 generations heterosis to P_2 could be seen more, while BCS_2 generation tends to P_2. In stress conditions in F_2 and F_3 generations heterosis to both parents could be seen (Figure 4). According to the results, it was observed that plant height trait in both parents had many differences. In F_2 and F_3 generations higher variability of this trait was observed (Figure 5). The difference between P_1 and P_2 for yield trait was not considerable in both stress and non-stress conditions, but in F_2 and F_3 generations there was a normal distribution of this trait that might show transgressive segregation (Figure 6).

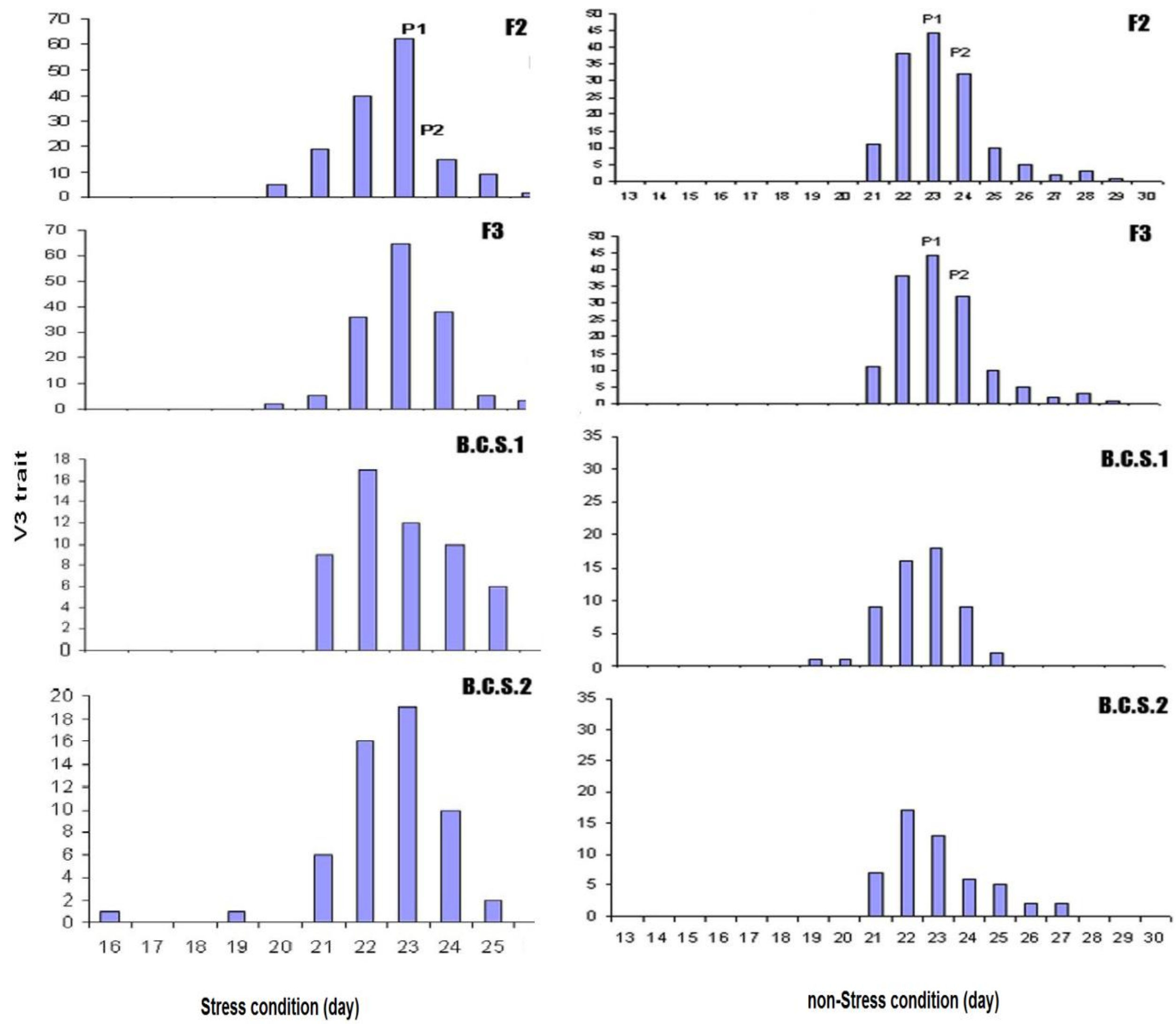

Figure 3. Frequency distribution of number of days to appearance of a first trifoliate (V_3) trait P_1 and P_2 (both parents) compared with the F_2, F_3, BCS_1 and BCS_2 generations of the cross Taylor (P_1) × Aracuanol (P_2) in stress and non-stress conditions.

DISCUSSION

This study assessed the performance of action gene in stress and non-stress conditions and studied the heritability and number of traits control genes. In some traits, after excluding components that were non-significant, the value was still non-significant, which indicated that model was not appropriate. Thus the model did not follow Mather and Jinks method (Mather and Jinks, 1982). Therefore the trigenic interaction, linkage, or both existed. In fact, with the use of all possible models the best model with goodness of fitness was obtained and selected. These findings might reveal that to achieve a proper model and to prevent the trigenic interaction or linkage it is necessary to fit all the available models. Furthermore in stress or non-stress condition at least a significant interaction effect existed. Thus epistasis gene effect (even if it is large) was the average for all resistance genes and in some cases this effect might be remained unclear by the background of genotype. If the opposite effects (especially effects of (j) parameter) exist or majority of the genes act as additive and a number of genes show epistasis, these effects might neutralize each other. Moreover, significant dominance × additive interaction in both stress and non-stress conditions showed the effect of environmental on epistasis. The findings of this research were fairly close to other researchers. Welsh et al. (1995) and Brett et al. (1981) declared that to obtain high-yielding and resistant varieties, parents with high yielding potential and resistant must be selected. In the present study high yielding varieties were obtained that had significant

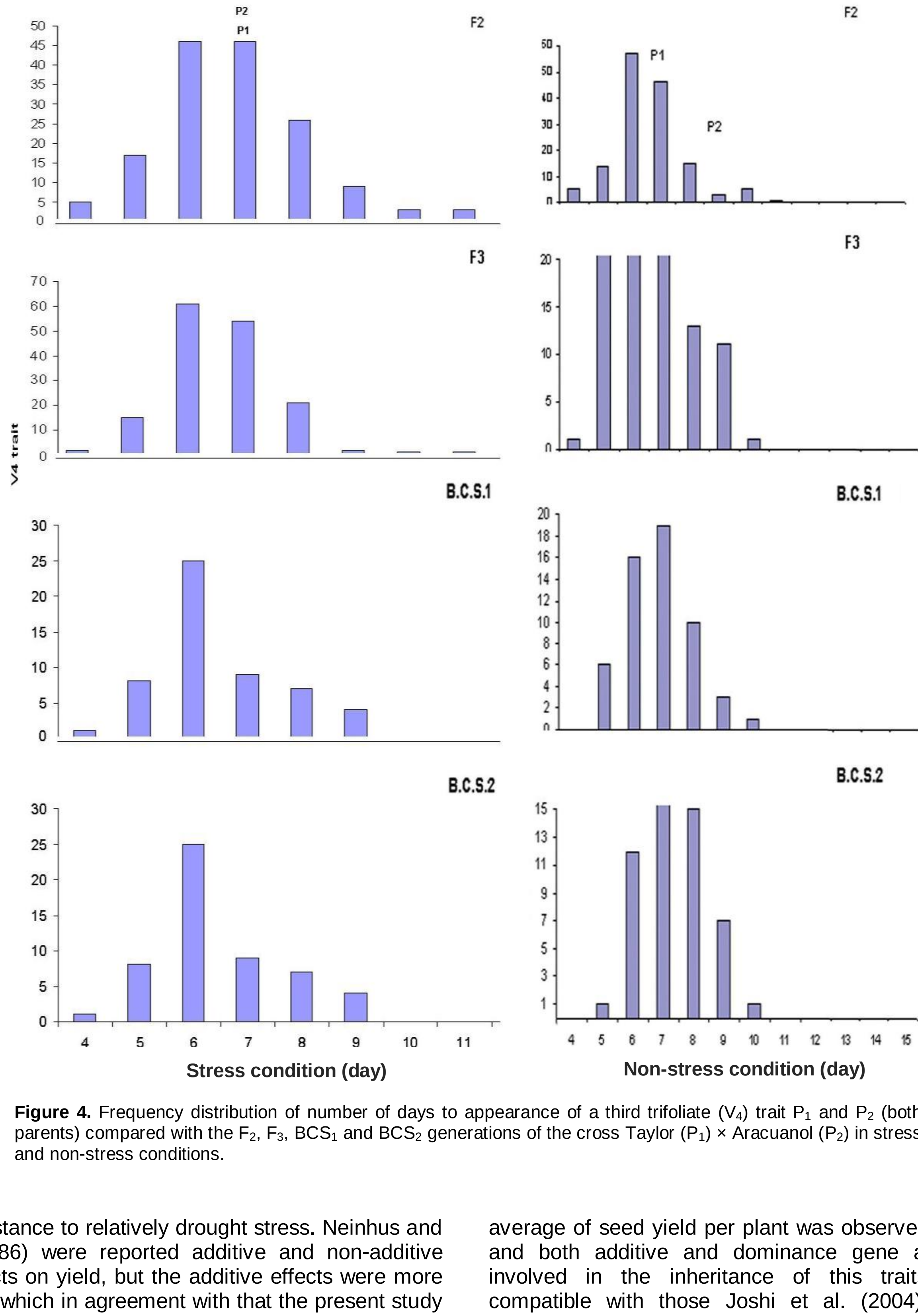

Figure 4. Frequency distribution of number of days to appearance of a third trifoliate (V_4) trait P_1 and P_2 (both parents) compared with the F_2, F_3, BCS_1 and BCS_2 generations of the cross Taylor (P_1) × Aracuanol (P_2) in stress and non-stress conditions.

genetic distance to relatively drought stress. Neinhus and Singh (1986) were reported additive and non-additive gene effects on yield, but the additive effects were more observed, which in agreement with that the present study in non-stress condition V_4, height and yield traits were affected by both additive and dominant effects, hence in stress condition in V_1, V_3, V_4 and height were affected by both additive and dominant effects. Moreover, the average of seed yield per plant was observed significant and both additive and dominance gene action were involved in the inheritance of this traits that are compatible with those Joshi et al. (2004), Alghamdi (2009) and Weerapun et al. (2010) had found. In conclusion, the results of this study presented that in the studied traits in both stress and non-stress conditions not only the additive and dominant effects are important the

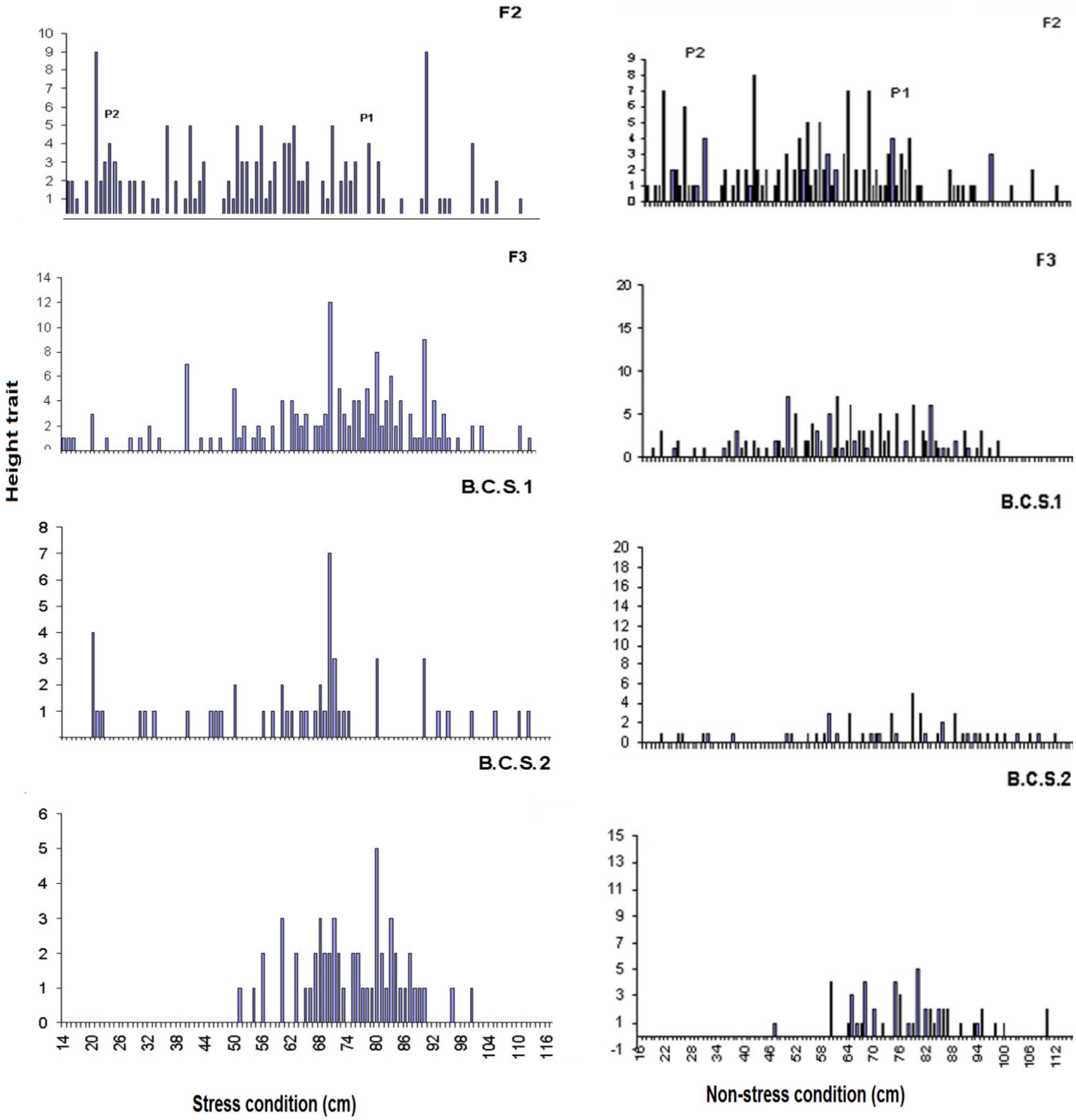

Figure 5. Frequency distribution of height trait P_1 and P_2 (both parents) compared with the F_2, F_3, BCS_1 and BCS_2 generations of the cross Taylor (P_1) × Aracuanol (P_2) in stress and non-stress conditions.

epistasis effect is considerable as well. Moreover, the hybridization concomitant with selection standard methods was effective in the yield improvement in both stress and non-stress conditions. However, because of the high heritability of most of the traits, it might be possible to improve the yield through the routine selection methods.

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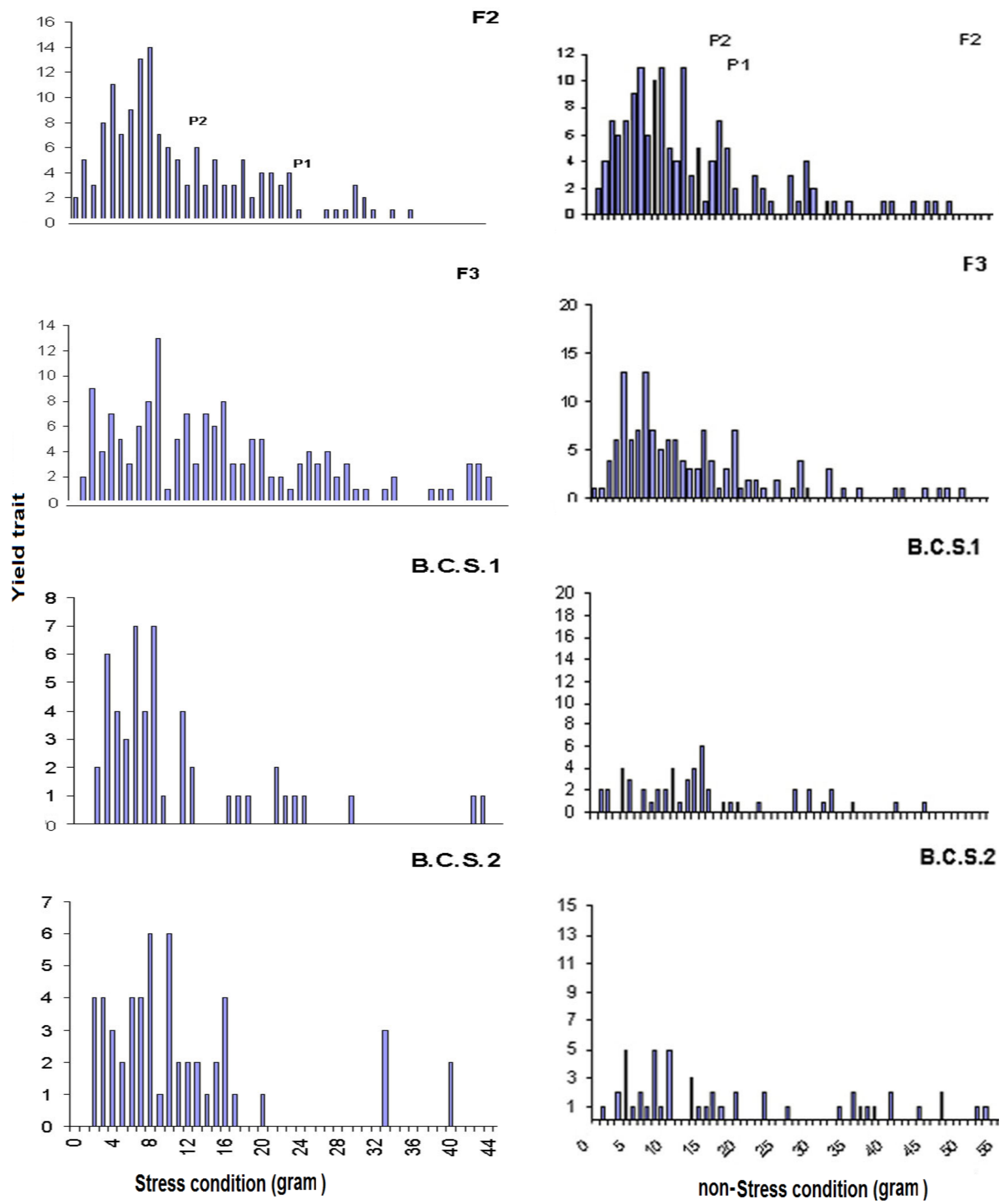

Figure 6. Frequency distribution of yield trait P_1 and P_2 (both parents) compared with the F_2, F_3, BCS_1 and BCS_2 generations of the cross Taylor (P_1) × Aracuanol (P_2) in stress and non-stress conditions.

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