Gene Effect on Yield and Yield Components Combining Ability and Fusarium Wilt Disease Resistance of Pigeon pea in Tanzania

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Abstract: *Pigeon pea, (Cajanus cajan (L.) Millspaugh) is one of the grain legume crops grown in many countries in the tropics and subtropics. The crop is reported to have wide adaptability in different climatic and soil conditions. The perennial nature of pigeon pea allows farmers to take multiple harvests with surpluses traded in both local and international markets. However, it has not benefited from intensive scientific research worldwide, a situation which results into a large gap between potential yield and actual yields obtained on farmers' fields. A study was conducted to assess the combining ability in yield and yield components including fusarium wilt on pigeon pea during the dry season in 2011. A diallel crosses was performed for evaluation of number of days to 50% flowering, days to 85% maturity, the number of branches, plant height, pods per plant, seeds per pod, 100 seed weight, yield and an assessment of fusarium wilt impact. Estimate of General and Specific Combining Ability revealed high significant difference in all yield components except the number of branches and seeds per pod. This implies that, both additive and non-additive gene action in these characters were expressed. Thus more backcrosses and selections are recommended to meet the need of yield improvement.*

Key words: *Combining ability, pigeon pea, Cajanus cajan, gene action, diallel crosses, fusarium wilt*

Introduction

Pigeon pea, (*Cajanus cajan* (L.) Millspaugh) is a leguminous crop which plays a significant role in human nutrition, especially in tropical and subtropical countries where its consumption is high (Saeed *et al*., 2007). Pigeon pea is grown as monocrop and also intercropped with other crops like maize with negligible effects on yield and yield components (Vange and Moses, 2009). It is prepared into various meals and served as substitute for cowpea. It also provides fuel wood and fodder for the small - scale farmers (Vanisree *et al*., 2013). Despite their importance for regional food security in the world's poorest regions (Varshney *et al*., 2010), pigeon pea is one of a range of orphan (neglected) crops that have not benefited from intensive scientific research. This situation has resulted into a large gap between potential yield (2,500kg/ha) and yields currently obtained on farmers' fields (866.2Kg/ha) in Asia and (736.2Kg/ha) in Africa. Thus, plant breeders are interested in estimating the gene effects in order to apply the most effective breeding procedure for improvement of the attributes in question. The choice of the most effective breeding methodology mainly depends upon the type of gene action controlling the genetic variation. Unambiguous tests of the genetic components help the breeder to make correct decisions about the most effective breeding method to be applied (Bayoumi and El- Bramawy, 2007).

The study on combining ability provides useful information on selection of parents in terms of performance of their hybrids and elucidates the nature and magnitude of various types of gene action involved in the expression of the quantitative traits. The limited studies on the combining ability contribute to limited selection of the best genotypes for specific traits in pigeon pea. The objective of this study was to determine combining ability of yield and Fusarium wilt disease resistance in East African and Indian pigeon pea populations.

Methodology

Seeds of six parents (KAT60, ICP7035, ICEAP00557, ICPL96061, ICPL20108 and ICEAP00540) and their F_1 were planted in the field at Sokoine University of Agriculture for evaluation of their combining ability. The experiment was laid out in randomized complete block design (RCBD) in three replications. Ten randomly selected competitive plants from each genotype were used in recording observations on the characters including days to 50% flowering, days to 85% maturity, plant height, the number of branches per plant, seeds per pod, 100 seed weight and yield per ha in Kg.

Screening for Fusarium Wilts

Seeds of the same pigeon pea genotypes and their F_1 were planted in polythene bags containing sterilized sand, after seven days of germination the seedlings were removed from the sand by shaking and washed in sterile distilled water. The plants were immersed in sterile distilled water to remove sand then using sterile scissors, 1cm length of the distal ends of the roots system were cut. The cut plants were then dipped in the inoculum at a concentration of 1.0×10^6 conidial ml^{-1} for 10 minutes to allow the conidia to enter the wounds created in the root systems. Resistant and susceptible genotypes were used as control to evaluate the severity of the disease. The plants were then transplanted in 2L plastic pots filled with a mixture of sterile soil and sand (3:1 v/v) with extra handling.

The pots were arranged in a Complete Randomized Design (CRD) with three replications. Immediately after transplanting, watering was done at an interval of two days. After 2 months re- isolation of the *Fusarium udum* pathogen from diseased plants which developing typically wilts was carried out to assure the existence of the pathogen (Plate 1). The reaction of these genotypes with wilt disease was evaluated using the scale indicated as follow. A 0-30% mortality was considered as highly resistant, 31-40% mortality =moderately resistant, 41-60% mortality = moderately susceptible and 61% -100% mortality = highly susceptible.

Plate 1: Conidial spores of Fusarium udum re-isolated from F1 population derived from cross between ICP 7035x ICEAP00540 at X40.

Data Collection and Analysis

Data collected were days to 50% flowering, days to 85% maturity, the number of branches per plant, the number of pods per plant, seeds per pod, 100 seed weight, yield and percentage plant death. The data collected were subjected to a diallel analysis outlined by Griffin (1956) to determine the combining ability.

Results

Analysis of variance for combining ability

Mean squares due to General Combining Ability (GCA) and Specific Combining Ability (SCA) were highly significant ($p \leq 0.001$) in all yield components and Fusarium wilt resistance except the number of seeds per pod (Table 1). The analysis of variance indicated that GCA variances were higher than their corresponding SCA for days to 50% flowering, days to 85% maturity, the number of pods per plant, 100 seeds weight, yield and Fusarium wilt. GCA was greater than SCA hence the ratio of GCA mean square to SCA mean square was more than unit value for all variables except plant height and seeds per pod.

Table 1: Analysis of variance for Combining Ability for 6 x 6 F1 diallel in Pigeon Peas Populations

Source of variation	df	Mean Squares: Number of days to 50% flowering	Number of days to 85% maturity	Plant height (cm)	Number of Pods per plant	Number of Seeds per pod	100 Seed weight (g)	Yield Kg/ha	F.W.D Incidence (%)
GCA	5	586.17***	1,017.19***	8,024.27***	5,778.60***	2.68	11.96***	15.21***	332.61***
SCA	15	584.29***	520.79***	13,944.93***	761.09***	3.72***	8.13***	6.18***	147.22***
error	20	45.57		524.84	92.87***		0.75		4.95
GCA: SCA		1	1.95	0.57	7.59	0.72	1.47	2.46	2.25

Significant ($p \leq 0.001$)

Estimates of General Combining Ability effects for the yield components

The GCA effect of six parents studied for days to 50% flowering showed negative GCA and significantly different ($p \leq 0.001$) for P1, P2, P5 and P6. Among these parents, P5 showed the highest negative value (-27.6339) (Table 2a and Figure 1).

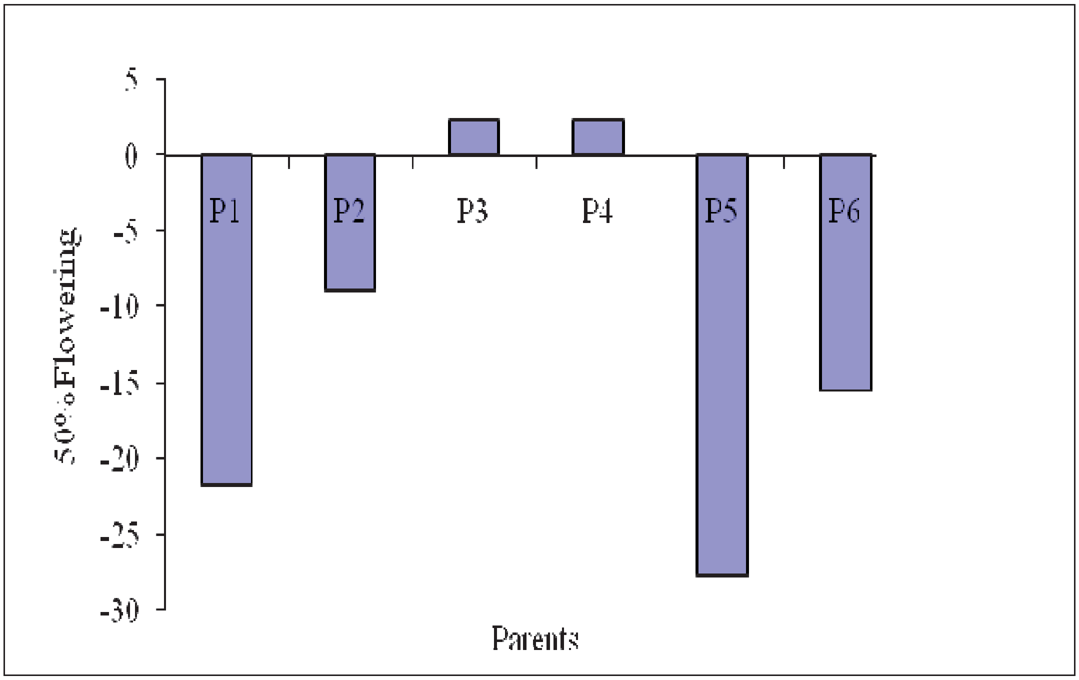

Figure 1: Relative GCA effects for days to 50% flowering

All parents used in this study showed negative and significant effects ($p \leq 0.001$) on days to 85% flowering/ maturity. Among all parents used P4 (-21.9431) showed the highest negative value followed by P1 (-18.6887) and P5 (-16.3649) (Table 2 and Figure 2)

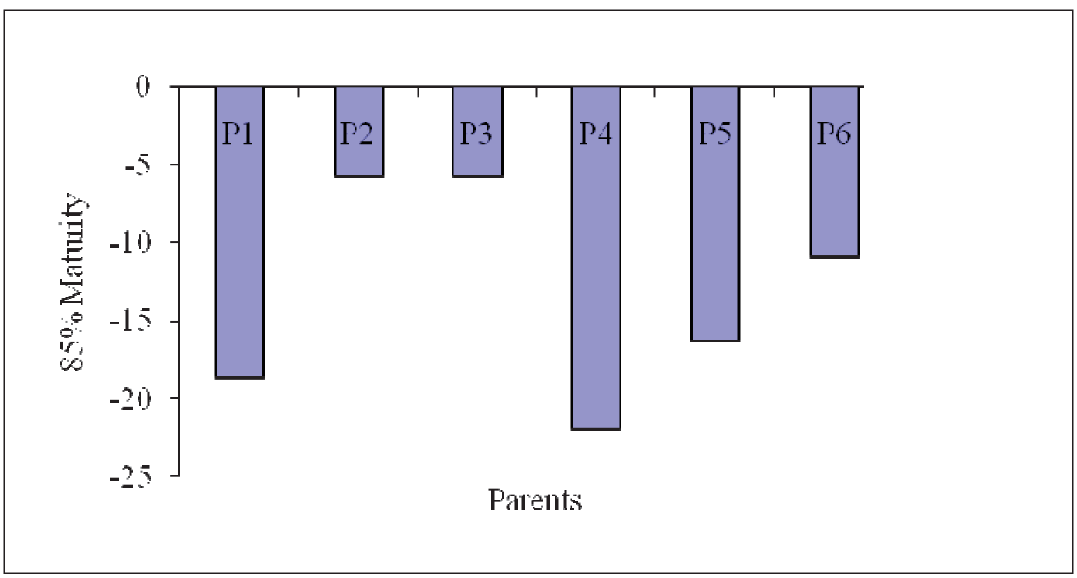

Figure 2: Relative GCA effects for days to 85% maturity

General combining ability showed significant difference ($p \leq 0.001$) on plant height for all six parents used in this study. Out of these six parents

P2 showed highest and significant plant height compared with other parents (Table 2a and Figure 3**)**

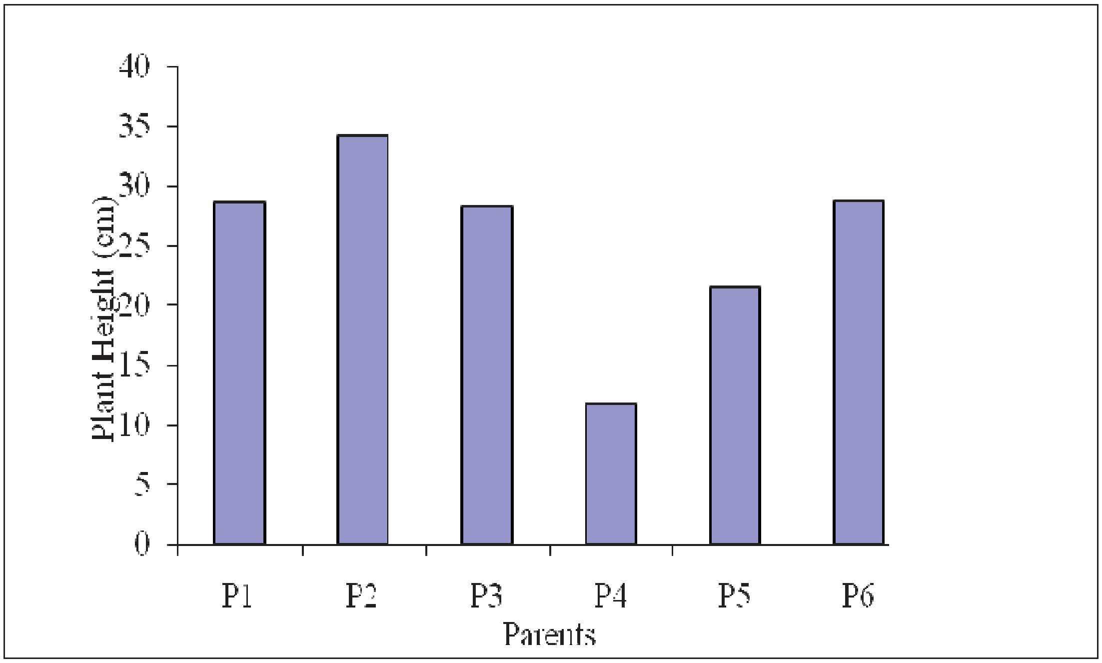

Figure 3: Relative GCA effects for plant height (cm)

Number of branches per plant was significant in GCA for all parents ($p \leq 0.05$), ($p \leq 0.01$), ($p \leq 0.001$) except for P4 while among these six parents P6 showed many number of branches per plant , positive and significant (Table 2a and Fig. 4).

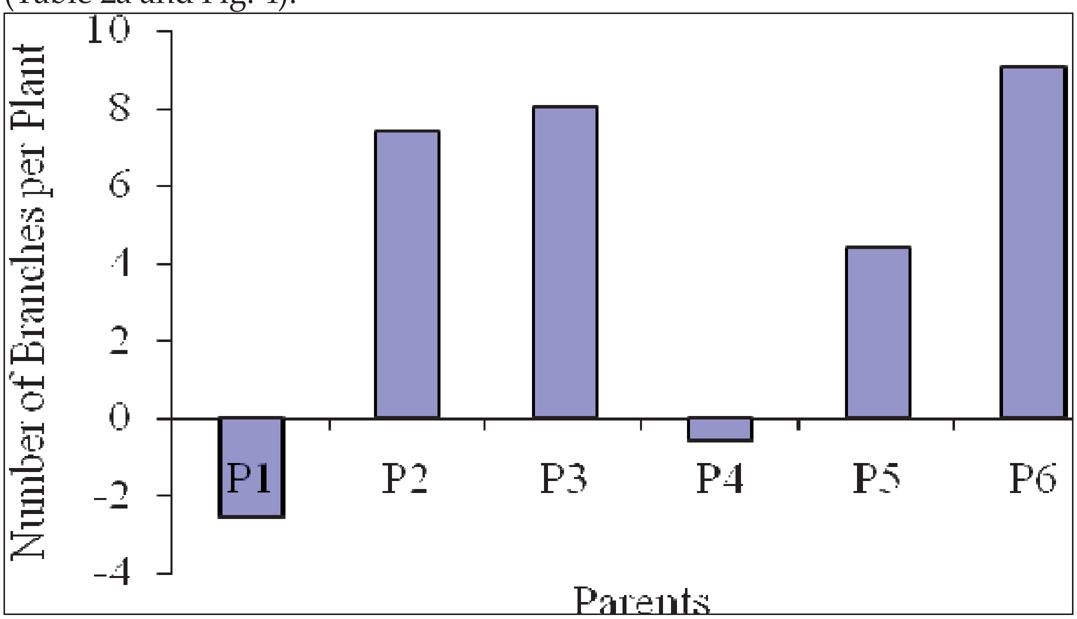

Figure 4: Relative GCA effects for number of branches per plant

All parents except P5 showed significant effects on number of on number of pods per plant. Among all parents assessed the P6 scored the highest, positive and significant number of pods per plant followed by P4 while P3, P2 and P1 revealed negative GCA (Table 2b and Fig. 5).

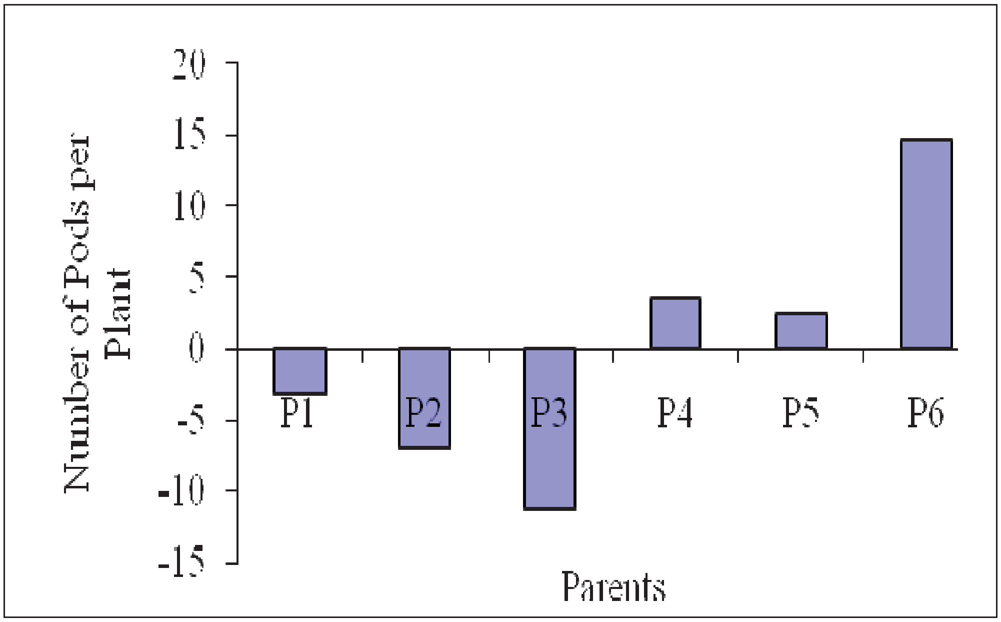

Figure 5: Relative GCA effects for number of pods per plant

Significant effect was observed for all parents except P5 in number of seeds per pod. P2 scored many and significant number of seeds per pod (Table 2b and Fig. 6).

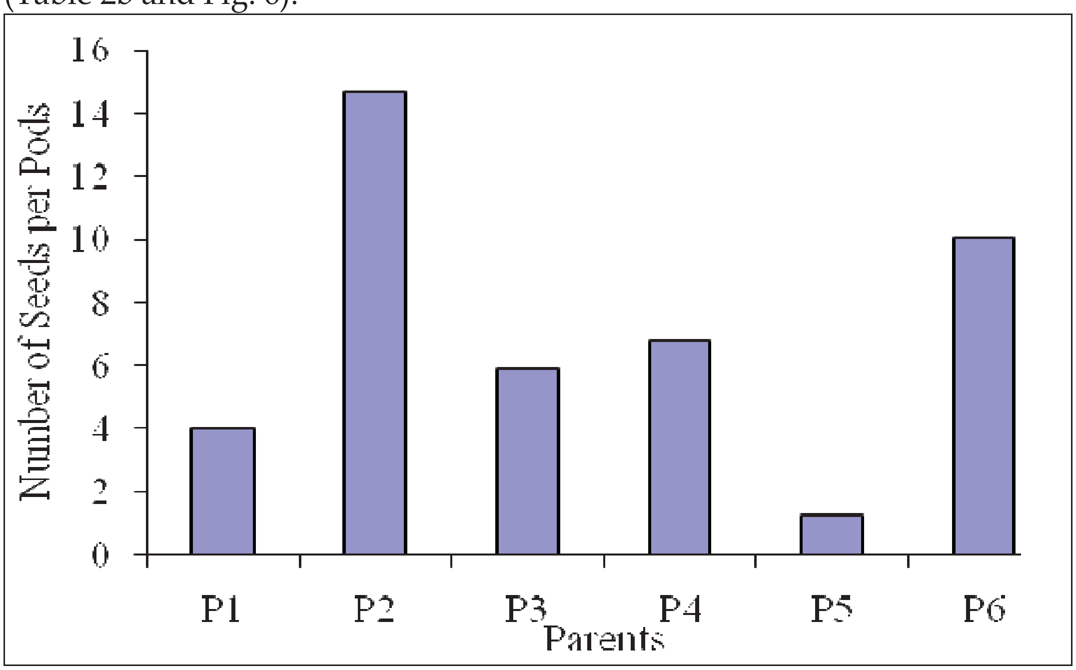

Figure 6: Relative GCA effects for number seeds per pods

All parents used in this study showed significant difference ($p \le 0.01$) on 100 seeds weight. Among these parents P6 revealed positive and highest seeds weight while P4 and P1 scored negative GCA (Table 2b and Figure 7).

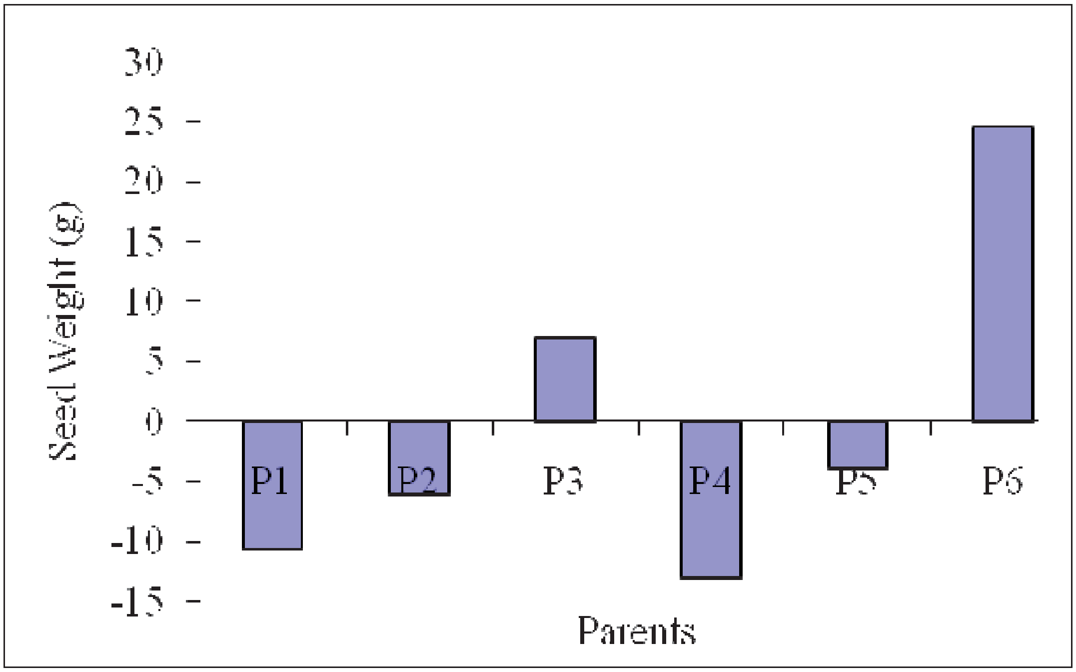

Figure 7: Relative GCA effects for 100 seeds weight (Kg)

Significant effects on yield for GCA were observed in pigeon pea yield for all parents ($p \le 0.001$) except P1 and P5 (Table 2b and Figure 8)

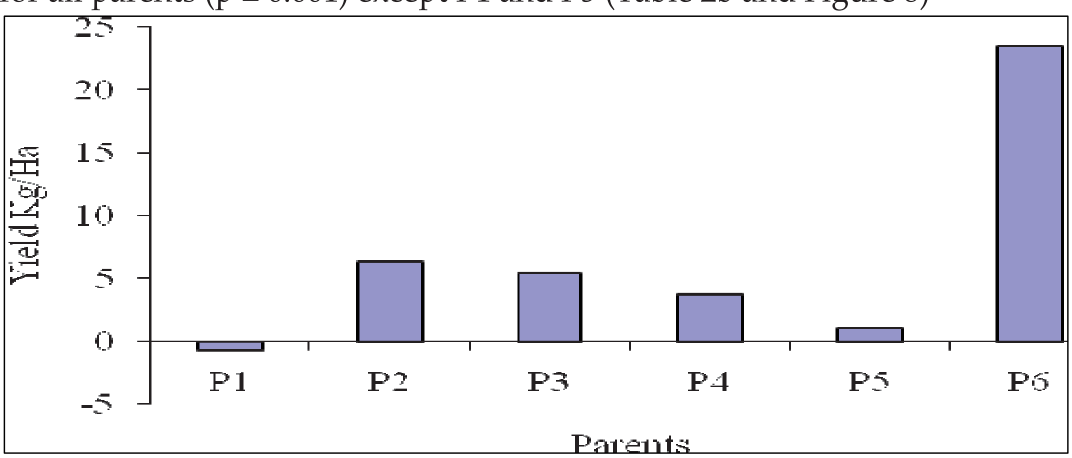

Figure 8: Relative GCA effects for yield (Kg)

P3, P4, and P6 revealed significant effects in GCA in Fusarium wilt reaction, among these P6 showed the lowest disease reaction and significant (Table 2b and Figure 9)

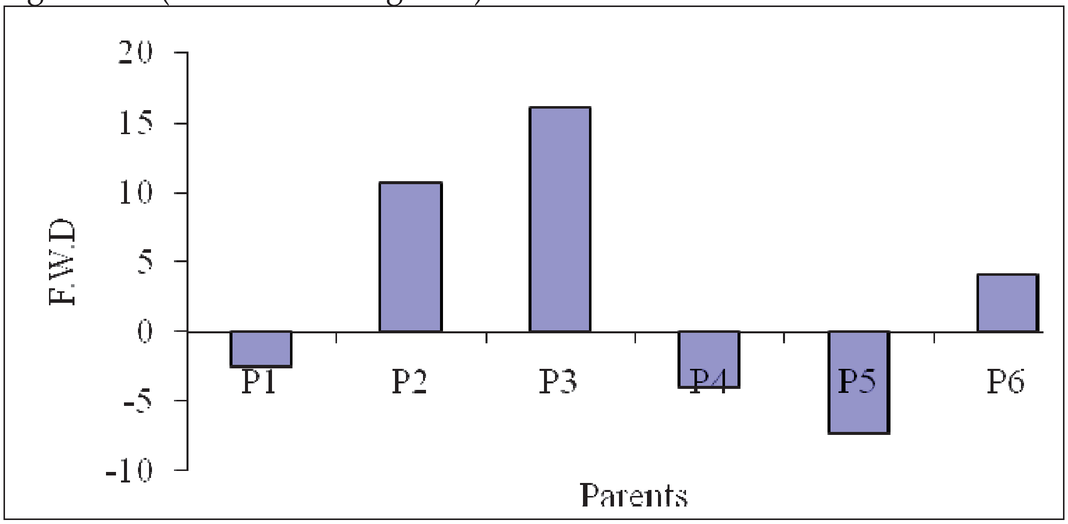

Figure 9: Relative GCA effects for Fusarium wilt resistance

Table 2a: General Cmbining ability effects in Pigeon Peas Yield

Parents	Number of days to **50 % Flowering**	Number of days to 85% maturity	Plant height (cm)	Number of branches/plant
P1	-21.7916***	-18.6887***	28.67814***	-2.60479*
P2	-8.86271***	-5.81088***	34.14458***	7.371257***
P3	2.389484	-5.81088***	28.26391***	8.041916***
P4	2.389484	-21.9431***	11.72146***	-0.61078
P5	-27.6339***	-16.3649***	21.45898***	4.377246**
P6	-15.4625***	-10.9715***	28.77395***	9.035928****

Table 2b: General Combining ability effects in Pigeon Peas Yield

Parents	Number of pods per plant	Number of seeds per pod	Seed weight (g)	Yield (Kg/ha)	F.W.D incidence (%)
P1	-3.15825*	4.008333**	-10.6364***	-0.6643	-2.47222
P2	-6.87176****	14.65833***	-6.09091***	6.357788***	10.80556***
P3	-11.2299***	5.866667***	7***	5.44063***	16.19444***
P4	3.549795**	6.791667***	-12.9924***	3.722815**	-4.00000
P5	2.412688	1.233333	-3.81818**	1.064706	-7.25000
P6	14.691***	10.03333***	24.67424***	23.49466***	4.13889**

P1 = KAT60, P2 = ICP7035, P3 = ICEAP00557, P4 = ICPL96061, P5 = ICPL20108 and P6 = ICEAP00540

Estimates of Specific Combining Ability effects

The specific Combining Ability (SCA) effect on days to 50% flowering showed significant effects ($p \leq 0.01$) in P1×P4, P1 ×P5, P4 ×P5 and P5 × P6 crosses where by P5 ×P6 showed highest positive effects (10.037) while P3 × P6 and P3 × P4 showed negative score on days to 50% flowering -2.546 and -1.991 (Table 3 and Figure 10).

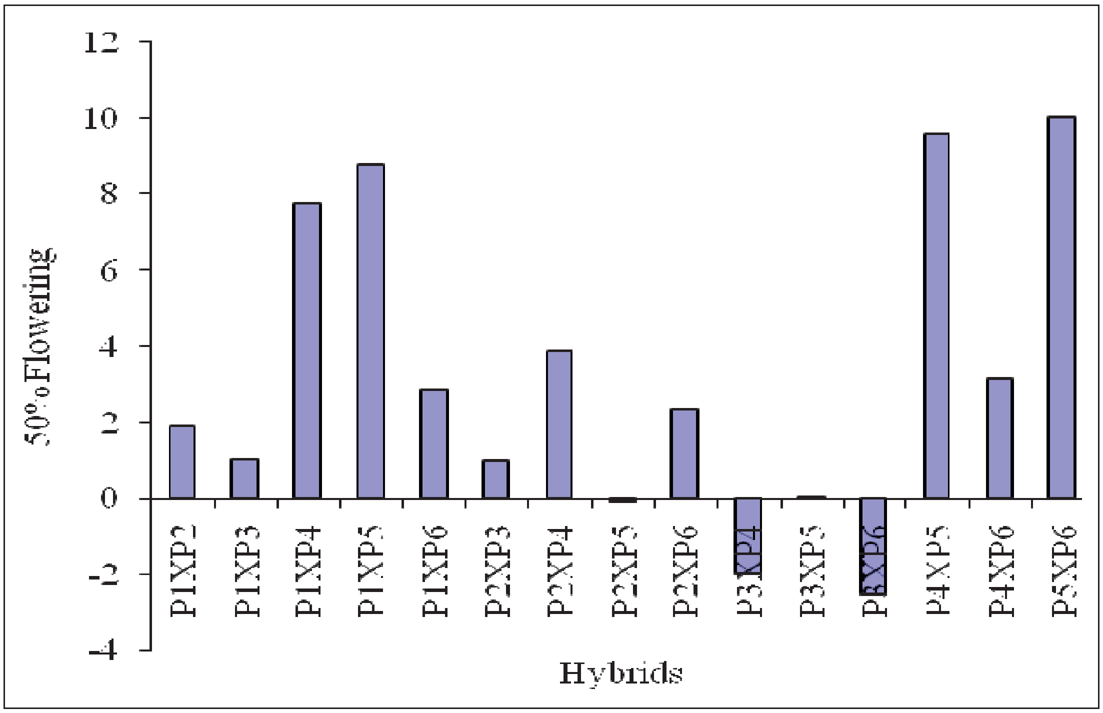

Figure 10: Relative SCA effects for days to 50% flowering

The SCA effects revealed significant effects on days to 85% maturity for the crosses P1 × P4, P4 × P5 ($p \leq 0.01$), P1 × P5 ($p \leq 0.05$). Out of these P1 × P5 showed little number of days to 85% maturity (Table 3 and Fig. 11).

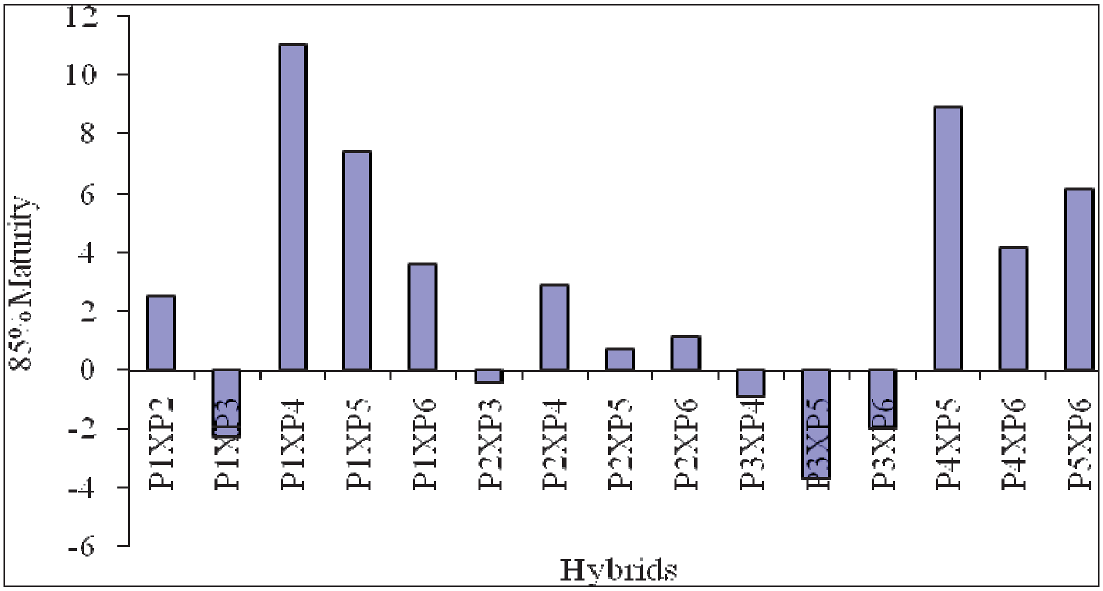

Figure 11: Relative SCA effects for days to 85% Maturity.

The hybrids P1 × P2, P1 × P4, P1 ×P6 revealed significant effects ($p \leq 0.01$), P2 × P3, P2 × P6 ($P \leq 0.001$) while crosses P2 × P5, P3 × P5 and P5 × P6 showed significant effects ($p \leq 0.05$) on plant height. On the other hand, highest negative significant SCA effects were observed in P3 × P5 (-3.694). The significant and lowest negative was revealed by P5 × P6 (Table 3 and Figure12)

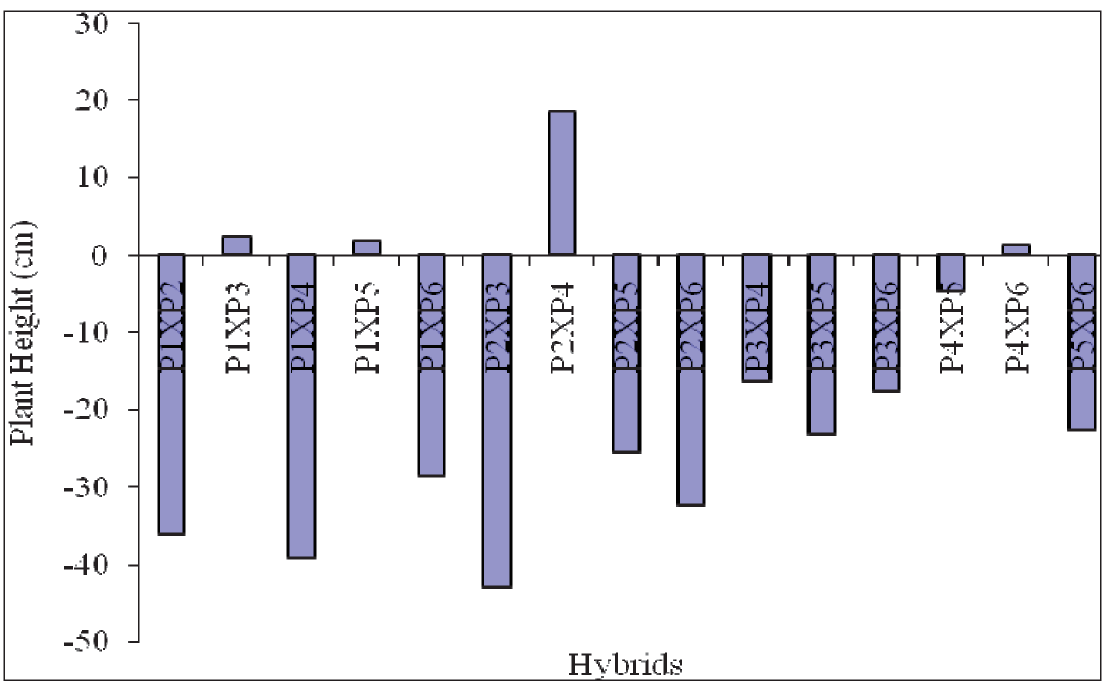

Figure 12: Relative SCA effects for Plant Height

Statistically the following crosses revealed significant effects P1 × P4, P3 × P5 and P4 × P5 ($p \leq 0.05$), P2 × P3 ($p \leq 0.01$) on their number of branches. The hybrids P4 × P5 showed the lowest, negative and significant on their number of branches (Table 3 and Figure 13).

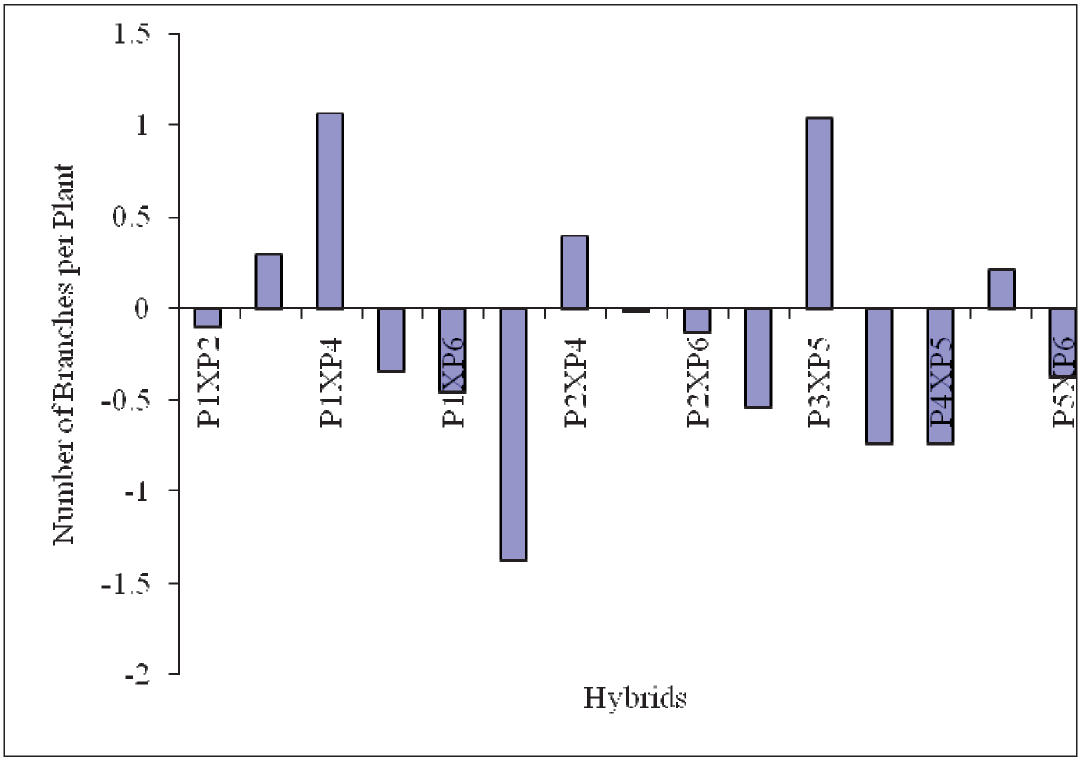

Figure 13: Relative SCA effects for number of Branches Per Plant

Cross P1 × P2 showed significant ($p \leq 0.01$), P2 × P5 ($P \leq 0.001$), P2 × P3, P2 × P4 and P2 × P6, revealed significant effect ($p \leq 0.01$) on number of pods per plant while cross between P2 × P3 showed the highest positive SCA effect (25.231) (Table 3 and Figure 14).

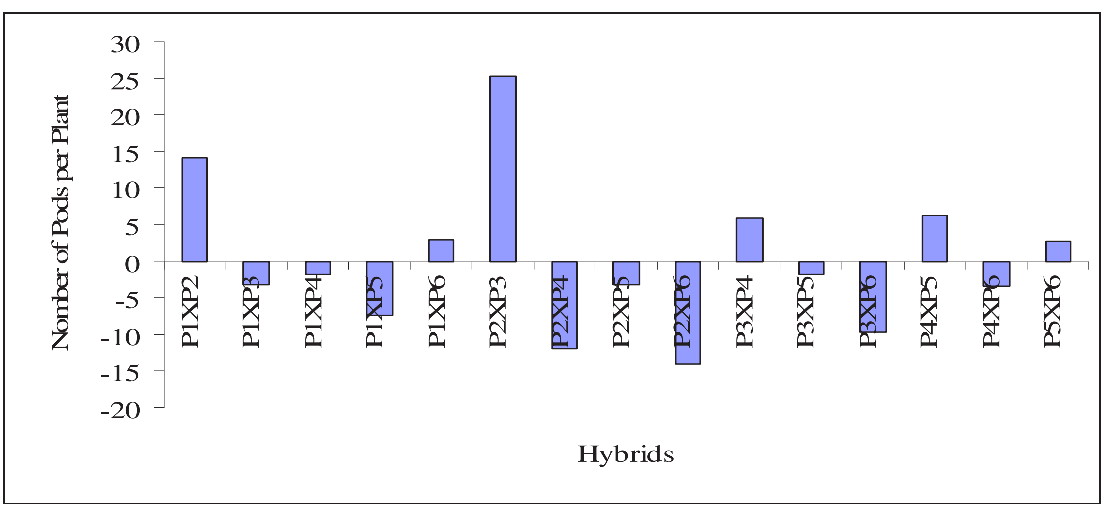

Figure 14: Relative SCA effects for number of pods per plant

The SCA effects showed significant effects at different levels P1 × P6 and P2 × P4, revealed significant effect ($p \leq 0.05$), whereby P2 × P3 and P2 × P6 ($p \leq 0.01$). Out of all crosses hybrids P2 × P4 showed positive and highest number of seeds per pod the rest showed positive but low while most of the crosses were responded negatively (Table 3 and Figure 15)

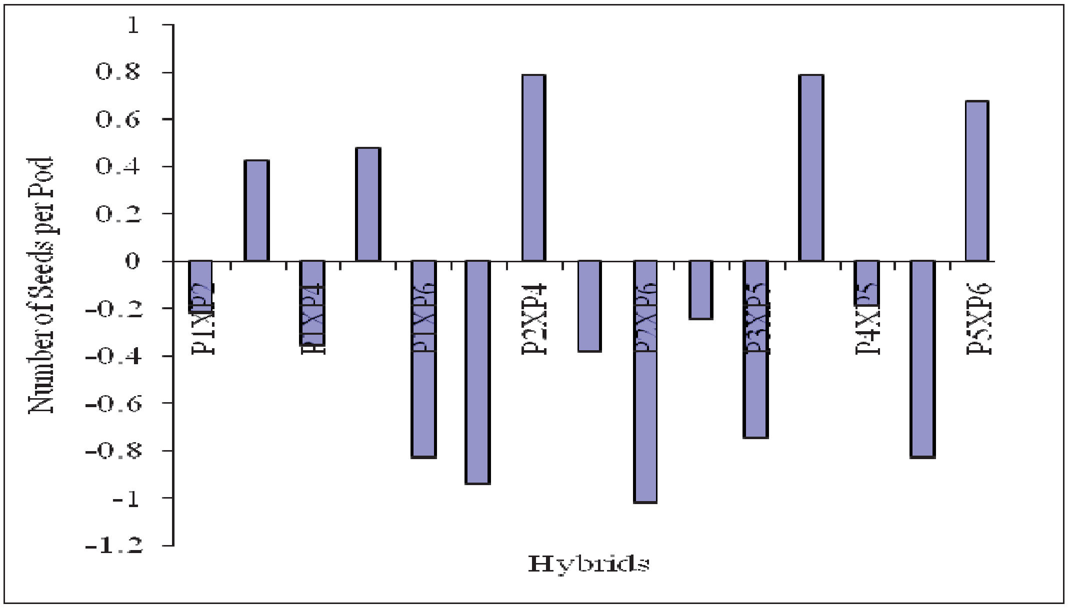

Figure 15: Relative SCA effects for seeds per pod

The SCA effects were statistically significant for 100 seed weight for the hybrid lines developed from the crosses of P1 × P2, P1×P6, P2 × P6 ($p \leq 0.01$), P4 × P6 ($p \leq 0.05$) .The hybrid P1 × P2 was the one indicated the highest, positive and significant 100 seed weight (Table 3 and 16)

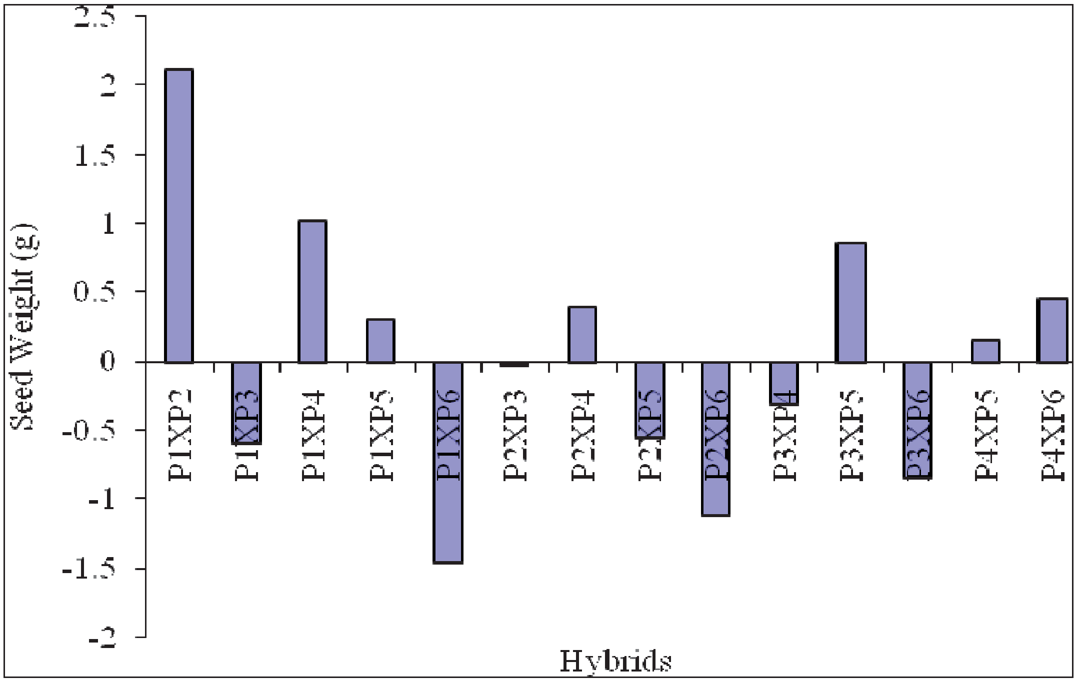

Figure 16: Relative SCA effects for seed weight (*g*)

The SCA effects of these crosses P1 × P2, P1 × P3, P1 × P6, P2 × P4, P2 × P5 ($p \leq 0.001$) P3 × P4 ($p \leq 0.05$) and the cross P3 × P5, showed significant effect ($p \leq 0.01$) on pigeon pea yield per ha (Table 3 and Figure17).

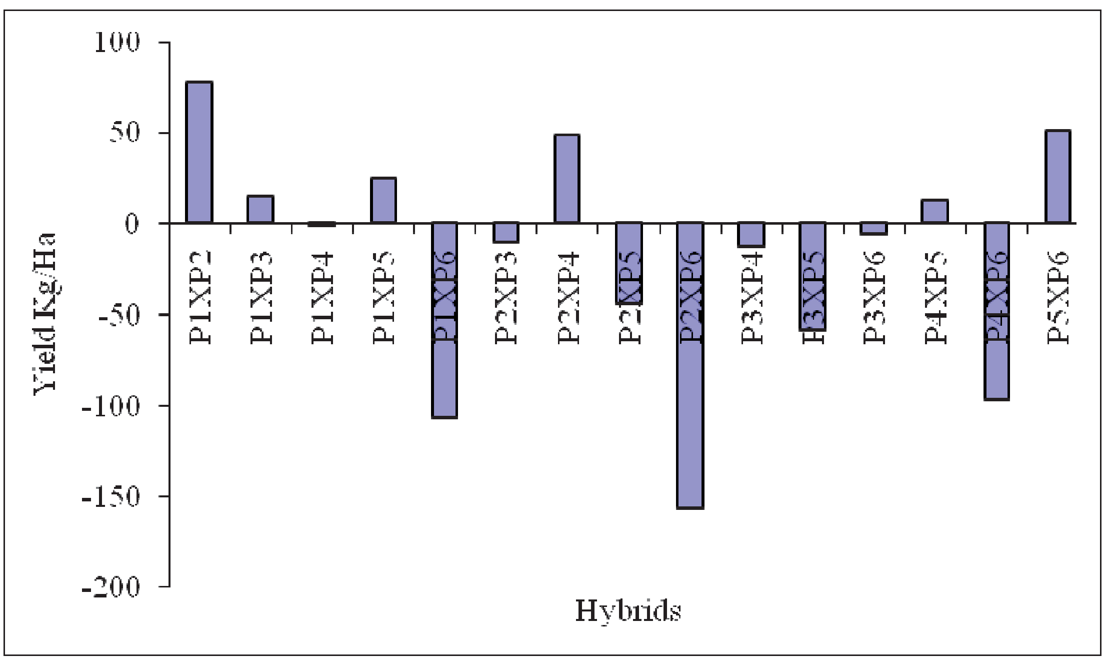

Figure 17: Relative SCA effects for yield in Kg/Ha

The estimate of SCA effects for Fusarium wilts disease resistance showed significant difference ($p \leq 0.001$) for crosses P1 × P2, P1 × P4, P1× P5, P1 × P6, P2 × P4, P2 × P5 while cross P3 × P4 revealed the lowest and significant value for fusarium wilt ($p \leq 0.05$) (Table 3 and Figure 18).

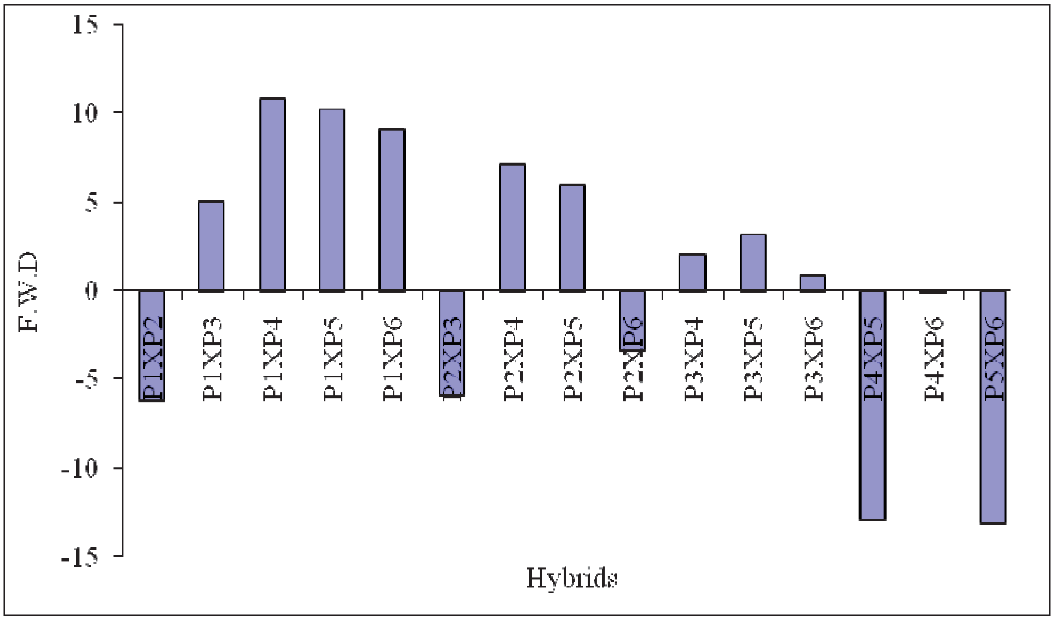

Figure 18: Relative SCA effects for Fusarium Wilt Resistance

Table 3: Estimate of Specific combining ability effects in eight Characters and fusarium wilt in 6x6 F_1 Diallel Crosses

Hybrids	Number of days to 50% flowering	Number of days to 85% maturity	Plant height	Number of branches	Number of pods per plant	Number of seeds per pod	Seed weight (g)	Yield (kg/ha)	F.W.D Incidence (%)
P1×P2	1.926	2.528	-36.167**	-0.102	14.148**	-0.213	2.113***	77.477**	-6.17
P1×P3	1.037	-2.25	2.25	0.287	-3.213	0.426	-0.59	14.582	5.04***
P1×P4	7.759**	11.056**	-39.25**	1.065*	-1.88	-0.352	1.024**	-1.493	10.79***
P1×P5	8.787**	7.389*	1.722	-0.352	-7.38	0.481	0.313	24.566	10.26***
P1×P6	2.87	3.611	-28.528**	-0.463	2.954	-0.824*	-1.456**	-106.232**	9.10***
P2×P3	1.009	-0.389	-43.222***	-1.38**	25.231***	-0.935**	-0.023	-10.41	-5.92
P2×P4	3.898	2.917	18.444	0.398	-11.935**	0.787*	0.391	48.402	7.15***
P2×P5	-0.074	0.75	-25.583*	-0.019	-3.269	-0.38	-0.554	-44.19	5.96***
P2×P6	2.343	1.139	-32.5**	-0.13	-14.102**	-1.019**	-1.123**	-156.47**	-3.37
P3×P4	-1.991	-0.861	-16.472	-0.546	5.87	-0.241	-0.312	-12.81	2.04*
P3×P5	0.037	-3.694	-23.333*	1.037*	-1.796	-0.741*	0.86*	-58.08	3.18**
P3×P6	-2.546	-1.972	-17.75	-0.741	-9.63	0.787*	-0.859*	-6.182	0.85

P4×P5	9.593**	8.944**	-4.833	-1.019*	6.204	-0.185	0.157	12.691	-12.89
P4×P6	3.176	4.167	1.25	0.204	-3.463	-0.824*	0.455	-96.673*	-0.06
P5×P6	10.037**	6.167	-22.778*	-0.38	2.704	0.676*	-0.273	50.752	-13.09

** Significant (p≤0.1), *Significant (p ≤0.5), *** Significant (p≤0.01),PH- plant height, PP- Pods per plant, SW- 100 seed weight, SP- seeds per pod, F- Days to 50% flowering

Discussion

Estimate of General and Specific Combining Ability

The significant effects due to GCA and SCA were observed in this study. The obtained results could be due to influence of additive and non-additive type of gene action (Hassan *et al.*, 2010; Sharma *et al.*, 2013). Greater magnitude of GCA for character like days to 50% flowering, days to 85% maturity, pods per plant, 100 seed weight and yield in Kg per ha in this could probably be due to additive genetic control on these characters while the number of branches per plant and seed per pod were influenced by non additive genetic control. Similarly, Borah (2009) and Hassan *et al.* (2010) reported dominance of both additive and non-additive gene action of pea (*Pisum sativum* L). The ratio of GCA/SCA obtained was more than one for plant height, number of branches per plant and seed per pod which meant greater role of additive gene action in the inheritance of these traits (Ercan and Mehmet, 2005; Bayoumi and El-Bramawy, 2007; Vaghela *et al*. 2009; Hassan *et al*., 2010).

GCA and SCA showed the highest negative value in P5 and P1 × P4 for days to 50%. Similar results were also reported by Sharma *et al.* (2013) in pigeon pea. Negative GCA effect is preferable for days to flowering because it indicates the capacity of early parent to transmit its character to progenies in cross combination with other parents. Thus, P5 and the cross P1× P4 could be the best general and specific for early flowering in pigeon pea. The GCA and SCA for days to 85% maturity showed negative and significant for P4 andcross P1 × P5. Positive GCA and SCA effects for days to 85% maturity would reflect combining ability for late harvest where by negative effects mean good combining ability for early harvest. Therefore, P4 and P1 × P5 was good combiner for both GCA and SCA (Hassan *et al*., 2010).

Positive, significant and the highest GCA as well as its SCA effects are preferable for plant height, the number of branches per plant, the number of pods per plant, the number of seeds per pod, seeds weight and yield in general (Ojo, 2003; Bayoumi and Bramawy, 2007). On the other hand GCA and SCA performance for parents and crosses scored the lowest disease reaction would be worth to be considered in future breeding programs. From the individual analysis of parents the P2, P5 and P6 with crosses P1 × P2, P1 × P4, P1 × P5, P2 × P3, P2 × P4, P5 × P6 were the good general and specific combiners for yield and yield components including fusarium wilt.

Conclusion and Recommendation

With regards to combining ability it was concluded that, P2, P5 and P6 with crosses P1 × P2, P1 × P4, P1 × P5, P2 × P3, P2 × P4, P5 × P6 were the good general and specific combiners for yield and yield components including fusarium wilt. Hence could be used by breeders as source of composite and hybrid materials.

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