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Generation Means Analysis for Thrips (Thysanoptera: Thripidae) Number and Leaf Damage by Thrips Feeding in Peanut

[1]K. Niyomsil, [1]S. Jogloy, [2]M. Keerati-kasikorn, [1]C. Akkasaeng, [1]T. Kesmala and [1]A. Patanothai
[1]Department of Agronomy,
[2]Department of Entomology, Faculty of Agriculture, Khon Kaen University,
Khon Kaen 40002, Thailand

Abstract: As disease vectors and damaging pests, several thrips species are important for peanut production. Development of resistant cultivars is economical and sustainable mean to combat the problem. To achieve this goal, a better understanding of genetic control of thrips resistance is of paramount importance to the success of breeding programs. The objective of this study was to estimate relative importance of genetic parameters for total thrips number, number of adult thrips, number of larval thrips and leaf damage by thrips feeding, which might be indicative of thrips resistance in the three crosses of peanut, using generation means analysis. The experiment was conducted in a farmer's field after rice harvest in Kalasin province in the Northeast of Thailand during dry season in 2002. Seven generations of three crosses were evaluated in a randomized complete block design with six replications under natural infestation of thrips population. Data of 50 days after planting (DAP) were reported for thrips number and data of 60, 70 and 80 DAP were reported for leaf damage. Dominance gene effect was significant in the cross ICGV 86388 x IC 10 for number of adult thrips and number of total thrips and in the cross ICGV 86388 x Khon Kaen 60-1 all genetic parameters estimated were not significant expect for dominance by dominance of adult thrip number. Additive gene effect was found in the cross IC 10 x Khon Kaen 60-1 for total thrips number. Additive x dominance epistatic gene effect was also found in the cross IC 10 x Khon Kaen 60-1 for total thrips number and larval thrips number, while dominance x dominance was expressed for adult thrips number. Additive genetic parameter for thrips damage was not significant for three sampling dates. Dominance and epistatic gene effects were significant in the cross IC 10 x Khon Kaen 60-1. Improvement of thrips resistance may be possible in the cross IC 10 x Khon Kaen 60-1 because of significant additive gene effect.

Key words: Genetic parameter, gene effect, relative importance, thrips resistance

INTRODUCTION

Several species of thrips (Thysanoptera: Thripidae) have been reported to infest peanut (Wongkaew, 1993) and they are important as disease vectors rather than as damaging pests (Mound, 1996). Both nymps and adults feed on tender parts of peanut plants, causing scars and deformed leaves (Ghewande and Nandagopal, 1997). Funderburk *et al.* (1998) reported that heavy infestation at early growth stages could result in losses of biomass and kernel yield and the effects of thrips infestation on yield become greater when associated with drought stress, extreme temperature, herbicide toxicity and viral diseases. Control of thrips is relied heavily on the application of insecticides, in which frequent chemical sprays are needed to achieve the effective control. However, this is not sustainable manner against thrips when considering its capacity of developing resistance to insecticides (Daughtrey *et al.*, 1997; Immaraju *et al.*, 1992). The use of peanut cultivars with resistance to thrips is one of the most promising alternative control measures since it is economically and environmentally safe and can easily be integrated with other control measures.

Painter (1968) described classical mechanisms of plant resistance to insect pests; non-preference, antibiosis and tolerance. Later on, 'antixenosis' has been proposed as a new and more suitable term for non-preference (Kogan and Ortman, 1978). Antixenosis mechanism of thrips resistance has been reported to be present in peanut accession Robut 33-1 (Amin, 1985). Resistance to thrips in ICGV 86031, a Spanish type peanut, was associated with its hairy and dark green leaves and thrips were attracted more to yellow than dark green (Dwivedi *et al.*, 1993). The accession IC 10 was a thrips resistant line in previous

Corresponding Author: S. Jogloy, Department of Agronomy, Faculty of Agriculture, Khon Kaen University, Khon Kaen 40002, Thailand Tel: 66-43364637

insect screening in Thailand (Keerati-kasikorn and Singha, 1987; Chuapong, 1997). ICGV 86388 was also identified as a *Peanut bud necrosis virus* (PBNV) resistant cultivar under low concentration of PBNV inoculum and had moderate resistance to its vector, *Thrips palmi* Karny (Dwivedi *et al*., 1996).

Although resistance mechanisms are understood and resistant germplasm lines are now available, a better understanding of the relative importance of gene effects affecting the genetic variation of thrips resistance will help peanut breeders to formulate effective breeding programs. However, this information is not well-documented in the literature especially for peanut. In onion, Hamilton *et al.* (1999) found very low heritability estimates for thrips number, indicating low additive genetic variance. Loges *et al*. (2004) also found low, heritability estimates for thrips resistance and its associated parameters.

The study was conducted to explore the possibility of improving peanut cultivars with resistance to thrips under natural field infestation of thrips population. Difference in thrips number among generations was assumed to be caused by genetic difference for morphological and physiological processes that supports or inhibits leaf feeding, oviposition, hatching, growth and development of thrips in peanut. Percentage of damaged leaves was assumed to be a function of thrips feeding and probing (exploring for suitable host plants). Therefore, thrips number and percentage of damaged leaves might be useful criteria to measure susceptibility in peanut.

The objective of this study was to estimate the relative importance of genetic parameters explaining the genetic variation of generation means for total thrips number, number of adult thrips, number of larval thrips and percentage of damaged leaves in the seven generations of three crosses involved the two resistant lines and a well-adapted high yielding cultivar.

MATERIALS AND METHODS

Plant materials: Three peanut genotypes, IC 10, ICGV 86388 and Khon Kaen 60-1, were selected for this study. IC 10 is a thrips resistant line selected from a cross, involved Robut 33-1 and NC Ac 2214 as parents (Keerati-kasikorn and Singha, 1987). ICGV 86388 is an elite Spanish germplasm line derived from the cross (Dh 3-20/USA20//NC Ac 2232) (Dwivedi *et al*., 1996). Therefore, IC 10 should receive resistant genes from both Robut 33-1 (Amin, 1985) and NC Ac 2214 (Amin *et al*., 1985) and ICGV 86388 also has NC Ac 2232, a thrips-resistant line, as a resistant parent (Amin *et al*., 1985). Khon Kaen 60-1 is a high yielding Spanish cultivar widely grown in Thailand. The parental lines were selected because of their difference in resistance to thrips and diverse origins.

IC 10, ICGV 86388 and Khon Kaen 60-1 were crossed in all possible combinations without reciprocal in an open air crossing block in 1999. Each of the resulting three F_1 hybrids was crossed to both parents to generate six backcross populations (BC_{11} and BC_{12}) and self-pollinated to produce three F_2 populations and further selfed again to generate six BCS_1 and three F_3 populations. The three F_2 populations with ample seed were kept in seed store until use. The parents were crossed again to produce the new F_1's with seed health similar to other generations. The six backcross populations were not reproduced. Therefore, the seven generations of each cross consisting of P_1, P_2, F_1 F_2, F_3, $BC_{11}S_1$ and $BC_{12}S_1$ were available for generation means analysis.

The experiment was planted in a farmer's field after rice harvest in Kalasin province in the Northeast of Thailand, where natural occurrence of thrips infestation was abundant during January to April 2002. The seven generations of the three crosses were arranged in a randomized complete block design with six replications. The entries were planted in the raised beds with 7.5 m long, each of which accommodated two single-row plots with spacing of 30 cm between plants within row and 50 cm between rows. Seeds were over-planted and the seedlings were then thinned to obtain one plant per hill at 20 days after planting. Other cultural practices were followed according to the recommendations for irrigated peanut in Thailand, including gypsum and fertilizer application and weed control. Neither insecticide nor pesticide was sprayed during crop growth to promote high infestation of natural thrips population.

Data were recorded for total thrips number, number of adult thrips and number of larval thrips at 20, 30, 40, 50 and 60 days after planting (DAP). Twelve plants in each plot were randomly chosen as a sample unit. Four folded leaflets in the same petiole on the main stem of each plant were harvested and immediately put in a small plastic vial containing 70% ethyl alcohol. Thrips count was conducted in laboratory under light microscope (12X magnificence) and then total thrips number, number of adult thrips and number of larval thrips were determined.

Plant damages by thrips feeding based on 20-25 plants in each plot avoiding end plants were recorded as percent damaged plants (plants having thrips feeding scars) and percent damaged leaves (leaves on main stems showing thrips feeding damage) at 45, 50, 60, 70 and 80 days after planting. As almost all the plants were infested by thrips, percent of damaged plants was not used for generation means analysis. Percentage of

damaged leaves was recorded based on percentage of leaves showing visible scars on main stems of 20-25 plants in each plot. In each leaf, a single leaflet or more in a petiole having scars of thrips feeding was considered damaged. Percentages of damaged leaves at 60, 70 and 80 days after planting were reported.

Data analysis: Test for independence of variances on means was carried out for thrips number and thrips damage. On this basis, transformation of data was carried out using different options: arc sin, logarithmic, square root and 1/X transformation methods. Data resulting from square-root transformation (Sqrt (X±0.5) was found to be normal and more efficient than those obtained from all other methods and was used for further analysis. The transformed data were subjected to analysis of variance followed a randomized complete block design (Gomez and Gomez, 1984) to select the best evaluation dates for generation means analysis based on low C.V. value and high F-ratio. Data of 50 DAP for thrips number and 60, 70 and 80 DAP for percentage of damaged leaves were used for generation means analysis.

Means of the F_1's and their corresponding mid-parent values were compared to detect the presence of dominance expression in the three crosses for all traits and evaluation dates using t-test (Gomez and Gomez, 1984).

A generation mean analysis was separately performed for each cross to determine additive, dominance and epistatic gene effects using model described by Hayman (1958) and the various gene effects were designated using Gamble's notations (Gamble, 1962), which are m = mean using F_2 as reference, a = sum of additive gene effects, d = sum of dominance gene effects, aa = sum of additive x additive gene effects, ad = sum of additive x dominance gene effects and dd = sum of dominance x dominance gene effects. Generation means were weighted with the respective inverses (1/Vx) of their variances to reduce variance heterogeneity among various generation means (Nigam *et al*., 2001). The regression analysis was used to find the best fit models as suggested by Torres *et al*. (1993). A stepwise procedure was employed for generation mean analysis. Weighted generation means were regressed sequentially on the variable subsets m, a, d, aa, ad and dd. Any non-significant effect at 0.05 probability level was removed from the model. Only those significant parameters were retained and fitted by weighted least square method as suggested by Rowe and Alexander (1980). The Chi square test proposed by Mather and Jink (Mather and Jink, 1977) was not used as pointed out by Nigam *et al*. (2001) that the inclusion of F_2 and other generations will inflate the Chi square values making the validity of the test questionable.

RESULTS

Thrips number: Data for total thrips number, adult thrips number and larval thrips number at 50 Days After Planting (DAP) were selected for generation means analysis because of their low CV values and high F-ratios from analysis of variance. Means of F_1 were significantly higher than those of their corresponding mid-parents for total thrips number, adult thrips number and larval thrips number in the cross ICGV 86388 × IC 10, indicating some degree of dominance gene effect in this cross (Table 1). Means of F_2, F_3, $BC_{11}S_1$ and $BC_{12}S_1$ were lower than means of F_1 but they were in the range of the two parents for total thrips number, adult thrips number and larval thrips number. Means of the two parents seemed to be extreme in this cross.

In the cross ICGV 86388 x Khon Kaen 60-1, the differences between means of F_1 and mid-parents were not significant for total thrips number, adult thrips number and larval thrips number. However, means of the two parents were quite similar. Means of F_2, F_3, $BC_{11}S_1$ and

Table 1: Means±SE of different generations for total thrips number, adult thrips number and number of larval thrips of peanut

		Thrips number		
Cross	Generation[a]	Total	Adult	Larval
ICGV86388 x IC 10	P_1	10.33±0.95	3.83±0.77	6.50±0.79
	P_2	3.50±0.33	1.67±0.41	1.83±0.49
	F_1	12.83±0.70	4.33±0.28	8.50±0.90
	F_2	9.50±0.74	4.33±0.47	5.17±0.93
	F_3	5.50±1.05	2.17±0.56	3.33±0.92
	$BC_{11}S_1$	6.67±0.64	2.83±0.59	3.83±0.55
	$BC_{12}S_1$	7.71±0.91	3.00±0.40	4.17±0.92
	MP	6.92*	2.75*	4.17*
ICGV 86388 x	P_1	10.33±0.95	3.83±0.77	6.50±0.79
Khon Kaen 60-1	P_2	10.33±0.68	4.50±0.74	5.83±0.64
	F_1	11.17±0.87	3.83±0.82	7.33±0.88
	F_2	7.83±0.74	3.33±0.72	4.50±0.55
	F_3	8.67±0.54	4.33±0.39	4.33±0.78
	$BC_{11}S_1$	9.50±1.09	3.83±0.89	5.67±0.72
	$BC_{12}S_1$	10.50±0.95	4.17±0.56	6.33±0.85
	MP	10.33ns	4.17ns	6.17ns
IC 10 x Khon	P_1	3.50±0.33	1.67±0.41	1.83±0.49
Kaen 60-1	P_2	10.33±0.68	4.50±0.74	5.83±0.64
	F_1	7.67±0.67	4.83±0.53	2.83±0.76
	F_2	8.50±0.28	4.00±0.64	4.50±0.61
	F_3	7.83±0.66	4.17±0.77	3.67±0.40
	$BC_{11}S_1$	7.00±0.69	3.83±0.39	3.17±0.83
	$BC_{12}S_1$	8.17±0.59	2.50±0.31	5.67±0.61
	MP	6.92ns	3.09*	3.83ns

[a]P_1 = Parental line 1, P_2 = Parental line 2, F_1 = First filial generation of crosses, F_2 = Second filial generation of crosses, F_3 = Third filial generation of crosses, $BC_{11}S_1$ = Selfed-generation of the first back-cross generation with parental line 1, $BC_{12}S_1$ = Selfed-generation of the first back-cross generation with parental line 2. ns,* Difference between F_1 value and mid-parent value was non-significant and significant at 0.05 probability levels, respectively

$BC_{12}S_1$ were lower than means of F_1 but they were in the range of the two parents. No clue for dominance gene effect was indicated in the comparison of generation means.

In the cross IC 10 x Khon Kaen 60-1, means of F_1 and mid-parents were not significantly different for total thrips number and larval thrips number, but significantly different for adult thrips number. For adult thrips number, means of F_2, F_3, $BC_{11}S_1$ and $BC_{12}S_1$ were in range of their parents and lower than that of F_1. For number of total thrips and larval thrips number, means of F_2, F_3 and $BC_{12}S_1$ were somewhat higher than that of F_1.

The results of generation means analysis were generally consistent with the comparisons between F_1 and mid-parent values. In the cross ICGV 86388 x IC 10, means of both parents were extremely different for total thrips number, adult thrips number and immature thrips number. The results found that additive gene effects were not important for total thrips number, adult thrips number and larval thrips number (Table 2). However, dominance gene effect was important for total thrips number and adult thrips number and the results were consistent with the comparison of means of F_1 and their mid-parents. For juvenile thrips number, all genetic parameters estimated were not significant. Dominance gene effect was more pronounced in this cross for total thrips number and adult thrips number. Positive sign showed enhancing effect of the genetic parameter.

In the cross ICGV 86388 x Khon Kaen 60-1, means of parental lines were similar for total thrips number, adult thrips number and immature thrips number. All genetic parameters were not significant in this cross for total thrips number and juvenile thrips number. However, significant and positive dominance effect was found for adult thrips number, showing an increasing effect on generation means. Dominance x dominance epistatic effect was also significant and negative, indicating a decreasing effect on generation means. In the cross IC 10 x Khon Kaen 60-1, additive gene effect was significant for total thrips number and additive x dominance was also significant for total thrips number, adult thrips number and larval thrips number. Sign difference in additive x dominance genetic effect merely indicated whether high parent was assigned as P_1 or P_2. Dominance x dominance epistatic gene effect was significant and positive for adult thrips number, indicating an increasing effect on generation means.

Percentage of damaged leaves: Percentage damaged leaves was recorded on main stems showing thrips feeding scars at 60, 70 and 80 days after planting. At 60 days after planting, in the cross ICGV 86388 x IC 10, ICGV 86388 x Khon Kaen 60-1 and IC 10 x Khon Kaen 60-1, the F_1 means of these crosses were higher than their respective mid-parent means and exceeded the range of their parents. However, associated errors were large and means of other generations were not consistent e.g. F_2 and F_3 means were larger than F_1 mean in the cross ICGV 86388 x Khon Kaen 60-1. At 70 days after planting, IC 10 was the most susceptible parent having 97.6% of damaged leaves followed by ICGV 86388 (95.04%), whereas Khon Kaen 60-1 was the least (81.97%). F_1 means of the three crosses were somewhat larger than their respective mid-parent means. At 80 days after planting, generation means are in similar pattern of those at 70 days after planting. IC 10 was the most susceptible (93.42%) followed by ICGV 86388 (88.69%) and Khon Kaen 60-1 (70.75%), respectively. F_1 means were larger than their respective mid-parent means (Table 3).

Table 2: Estimates of gene effects with their associated standard errors for total thrips number, adult thrips number and larval thrips number in the three crosses of peanut

		Thrips number		
Cross	Gene effect	Total	Adult	Juvenile
ICGV86388 x IC 10	m	2.91±0.17	2.91±0.17	2.22±0.30
	a	NS	NS	NS
	d	1.56±0.41	1.56±0.41	NS
	aa	NS	NS	NS
	ad	NS	NS	NS
	dd	NS	NS	NS
ICGV 86388 x Khon Kaen 60-1	m	2.85±0.10	3.08±0.09	2.24±0.16
	a	NS	NS	NS
	d	NS	0.01±0.25	NS
	aa	NS	NS	NS
	ad	NS	NS	NS
	dd	NS	-2.98±0.21*	NS
IC 10 x Khon Kaen 60-1	m	2.93±0.04	1.91±0.20	2.04±0.10
	a	-0.31±0.07*	NS	NS
	d	NS	NS	NS
	aa	NS	NS	NS
	ad	0.64±0.06*	-2.71±1.26	0.48±0.18*
	dd	NS	-0.48±1.26	NS

m = Mean, a = Sum of additive effects, d = Sum of dominance effects, aa = Sum of additive x additive epistatic effects, ad = Sum of additive x dominance epistatic effects, dd = sum of dominance x dominance epistatic effects, *Significant at 0.05 probability level, NS: Non Significant

Generation means analysis demonstrated that no significant parameter was detected for percentage of damaged leaves in the cross ICGV 86388 x IC 10 at 60, 70 and 80 days after planting. In the cross ICGV 86388 x Khon Kaen 60-1, additive x dominance genetic parameter was significant at 80 days after planting, but other parameters were not significant at any evaluation dates. Negative sign indicated that low parent was assigned as P_1, but it has no genetic consequence. In the cross IC 10 x Khon Kaen 60-1, significant dominance and additive x additive genetic effects were detected at 70 days after planting. The significant parameters were not persisted at

Table 3: Means±SE of different generations of peanut for percentage of leaf damage by thrips at 60, 70 and 80 Days After Planting (DAP)

	Percentage of damage leaves		
Generation	60 DAP	70 DAP	80 DAP
ICGV 86388 x IC 10			
P_1	83.30±13.80	95.04±6.09	88.69±7.78
P_2	84.21±13.32	97.64±3.54	93.42±7.15
F_1	89.32±5.77	97.7±3.94	92.45±6.42
F_2	85.74±9.69	96.56±4.09	92.05±5.71
F_3	82.49±13.49	94.55±4.82	93.46±4.11
$BC_{11}S_1$	84.46±11.52	98.19±2.02	90.09±14.30
$BC_{12}S_1$	85.55±12.07	94.76±3.44	92.89±6.34
MP	83.76*	96.34*	91.06*
ICGV 86388 x KK 60-1			
P_1	83.30±13.80	95.04±6.09	88.69±7.78
P_2	75.68±18.50	81.97±15.17	70.75±9.52
F_1	83.46±9.40	89.94±7.67	89.38±9.76
F_2	87.54±11.04	95.36±4.86	89.97±5.96
F_3	88.45±9.01	93.92±7.13	90.48±9.33
$BC_{11}S_1$	84.75±10.52	92.92±4.35	87.00±7.81
$BC_{12}S_1$	77.84±16.76	81.4±13.21	73.58±12.57
MP	79.49*	88.51*	79.72*
IC 10 x KK 60-1			
P_1	84.21±13.32	97.64±3.54	93.42±7.15
P_2	75.68±18.50	81.97±15.17	70.75±9.52
F_1	88.62±7.38	97.42±2.02	94.7±6.33
F_2	85.88±10.66	93.1±6.70	89.6±4.17
F_3	84.21±7.83	91.18±6.77	87.68±3.43
$BC_{11}S_1$	86.92±8.33	93.05±5.04	89.68±5.59
$BC_{12}S_1$	78.89±14.30	81.05±13.18	75.31±9.95
MP	79.95*	89.81*	82.09*

*Indicates difference between F_1 value and mid-parent value was significant at 0.10 probability level

Table 4: Estimates of gene effects and their associated standard errors for percentage of leaf damage by thrips in the three crosses of peanut at 60, 70 and 80 Days After Planting (DAP)

		Percentage of leaf damage by thrips		
Cross	Gene effect	60 DAP	70 DAP	80 DAP
ICGV 86388 x IC 10				
	m	9.28±0.05	9.92±0.09	9.61±0.03
	a	NS	NS	NS
	d	NS	NS	NS
	aa	NS	NS	NS
	ad	NS	NS	NS
	dd	NS	NS	NS
ICGV 86388 x KK 60-1				
	m	9.27±0.19	9.70±0.20	9.27±0.14
	a	NS	NS	NS
	d	NS	NS	NS
	aa	NS	NS	NS
	ad	NS	NS	-0.35±0.27
	dd	NS	NS	NS
IC 10 x KK 60-1				
	m	9.29±0.01	9.65±0.11	9.40±0.16
	a	NS	NS	NS
	d	NS	0.55±0.23	NS
	aa	NS	0.46±0.25	NS
	ad	NS	NS	-0.43±0.33
	dd	NS	NS	0.02±1.26

m = Mean, a = Sum of additive effects, d = Sum of dominance effects, aa = Sum of additive x additive epistatic effects, ad = Sum of additive x dominance epistatic effects, dd = Sum of dominance x dominance epistatic effects, *Significant at 0.05 probability level, NS: Significant

80 days after planting, but additive x dominance and dominance x dominance gene effects were significant (Table 4).

DISCUSSION

Thrips number: Low figures of thrips number obtained might be caused by sampling procedures, in which unfolded leaflets from a single petiole on the main stem of 12 plants were harvested in each plot. Low figures of thrips number were also obtained by using similar sampling procedures (Chuapong, 1997) and higher figures were recorded using three youngest leaves of 10 randomly selected plants (Amin, 1985). However, heavy sample taking was highly destructive and did not allow the successive evaluations and regeneration of segregating material. This method is not practical for breeding. Thrips adults were found in peanut plants as soon as they emerged from the soils (Amin, 1985). Destructive sampling at early growth stages for thrips count at early growth stages was not possible. Therefore, plants were allowed to grow for several weeks before sampling to reduce effects of destructive sampling on plant growth.

Gene effects varied from cross to cross. Dominance gene effect was detected in the cross ICGV 86388 x IC 10 and ICGV 86388 x Khon Kaen 60-1. The positive sign associated with this effect indicated increasing values of generation means by the gene effect. The results indicated that susceptibility for thrips infestation was dominant over resistance. Based on the results, there was limited possibility to improve peanut lines with reduced total thrips number, adult thrips number and larval thrips number in these crosses because the most gene effects present in the cross were non-fixable.

Differences between means of the two parents of each cross are the main source of additive variation in the generation means analysis. It is particularly true when dominance gene effect is small and environmental variation is low. However, Additive gene effect was important in the cross IC 10 x Khon Kaen 60-1 for total thrips number. Improvement of peanut lines with reduced total thrips number seemed to be possible in this cross because of additive gene effect. The presence of significant additive x dominance gene effect (non-fixable) in the cross can hinder the progress of breeding program. High standard errors of homogeneous genotypes (P_1, P_2 and F_1) indicated that spatial distribution of thrips population was not random throughout the experiment and also suggested the need for effective field plot techniques and sampling procedures.

Percentage of damaged leaves: Thrips population emigrated to experiment field soon after peanut emergence (two weeks after planting) and leaf feeding scars were clearly visible few weeks later. However, early evaluations (45-50 days after planting) showed extremely high C.V. values and low F ratios and did not differentiated among genotypes. It seems that peanut genotypes showed differences in rates of recovery from thrips damage after thrips feeding declined, resulting in low yield reduction at harvest. This tolerant mechanism of resistance may be useful for farmers. However, yield losses in this study were not determined. Thrips damage evaluated by our method may be meaningful if evaluations were extended to more than 80 days after planting as indicated by more significant genetic parameters were detected at later sampling dates. Percentage of damaged leaves was relatively high and normally only leaves on the tops of main stems were not damaged by thrips. Therefore, the differences between parent means of each cross were generally narrow.

Two parents (ICGV 86388 and IC 10) were previously identified as thrips-resistant germplasm. ICGV 86388 is resistant to sap-inoculation of peanut bud necrosis virus (PBNV) and moderately resistant to its vector (*Thrips palmi* Karny). The pedigree of ICGV 86388 is (Dh 3-20/USA20//NC Ac 2232) F_2-B_1-B_1-B_1-B_1 (Dwivedi *et al*., 1996) and has NC Ac 2232 having resistance to thips in its pedigree. IC 10 is derived from the cross Robut 33-1 x NC Ac 2214 and it has been selected because of resistance to thrips in Thailand (Keerati kasikorn *et al*., 1990). Robut 33-1 is the first released cultivar in India with resistance to PBNV and thrips (Amin, 1985) and NC Ac 2214 is thrips-resistant germplasm line (Amin *et al*., 1985). Resistance to PBNV in Robut 33-1 is caused by lower thrips infestation under field conditions (Amin, 985). Similar results were reported in other virus-host-vector systems. Low incidence of tomato spotted wilt caused by tomato spotted wilt virus (TSWV), a related virus species to PBNV, was observed in thrips-resistant pepper cultivars (Maris *et al*., 2003).

The results were not unexpected because of narrow differences of parental means, high environmental variation and percentage of damaged leaves were relatively high. High insect pressure may mask the expression of genetic parameters. Although ICGV 86388 and IC 10 were previously identified as thrips-resistant lines as indicated by lowering thrips number in this genotypes, showing antixenosis mechanism of resistance. The resistance, however, may not associate with lower damaged leaves as antixenosis mechanism may stimulate thrips mobility and increase feeding and probing (exploring) for more favorable plants, leaving high leaf scars on infested plants. Another possible cause is that ICGV 86388 and IC 10 had retarded growth rate when compared with Khon Kaen 60-1, which could maintain higher undamaged leaf number on the top of main stems. The severity of thrips damage to peanut is related to the number of thrips feeding and the growth rate of peanut seedlings (Funderburk *et al*., 1998). Also severity is greater when associated with drought and herbicide stresses. The most severe thrips damage occurs in the earliest plantings and the damage usually declines as the growing season progress.

There was difficulty to select lines with reduced total thrips number, adult thrips number and larval thrips number in the crosses ICGV 86388 x IC 10 and ICGV 86388 x Khon Kaen 60-1 because the lack of additive gene effect. There would be possibility to improve total thrips number in the cross IC 10 x Khon Kaen 60-1. However, the improvement would be difficult, although additive gene effect was significant, because of the presence of additive x dominance epistatic (a non-fixable) gene effect and selection in later generations was suggested.

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REFERENCES

Amin, P.W., 1985. Apparent resistance of groundnut cultivar Robut 33-1 to bud necrosis disease. Plant Dis., 69: 718-719.

Amin, P.W., K.N. Singh, S.L. Dwivedi and V.R. Rao, 1985. Sources of resistance to the jassid (*Empoasca kerri* Pruthi), thrips (*Frankliniella schultzei* [Trybom]) and termites (*Odontotermes* sp.) in groundnut (*Arachis hypogaea* L.). Peanut Sci., 12: 58-60.

Chuapong, J., 1997. Screening of peanut cultivars resistant to bud necrosis disease caused by peanut bud necrosis virus. M.Sc. Thesis. Khon Kaen University, Thailand (In Thai with English summary).

Daughtrey, M.L., R.K. Jones, J.W. Moyer, M.E. Daub and J.R. Baker, 1997. Tospovirus strike the greenhouse industry: INSV has becomes a major pathogen on flower crops. Plant Dis., 81: 1220-1230.

Dwivedi, S.L., D.V.R. Reddy, S.N. Nigam, G.V. Ranga Rao, J.A. Wightman, P.W. Amin, G.V.S. Nagabhushanam, A.S. Reddy, E. Scholberg and V.M. Ramraj, 1993. Regisration of ICGV 86031 peanut germplasm. Crop Sci., 33: 220.

Dwivedi, S.L., S.N. Nigam, D.V.R. Reddy and G.V. Ranga Roa, 1996. Registration of ICGV 86388 peanut germplasm. Crop Sci., 36: 1423.

Funderburk, J.E., D.W. Gorbet, I.D. Teare and J. Stavisky, 1998. Thrips injury can reduce peanut yield and quality under conditions of multiple stress. Agron. J., 90: 563-565.

Gamble, E.E., 1962. Gene effects in corn (*Zea mays* L.) I. Separation and relative importance of gene effects for yield. Can. J. Plant Sci., 42: 339-348.

Ghewande, M.P. and V. Nandagopal, 1997. Integrated pest management in groundnut (*Arachis hypogaea* L.) in India. Integrated Pest Manage. Rev., 2: 1-15.

Gomez, K.A. and A.A. Gomez, 1984. Statistical Procedures for Agricultural Research. 2nd Edn., John Wiley and Sons Inc., Singapore.

Hayman, B.I., 1958. The separation of epistatic from additive and dominance variation in generation means. Heredity, 12: 371-390.

Hamilton, B.K. and L.M. Pike, A.N. Sparks, D.A. Bender and R.W. Jones, 1999. Heritability of thrips resistance in the IP-3 onion cultivar in South Texas. Euphytica, 109: 117-122.

Immaraju, J.A., T.D. Paine, J.A. Bethke, K.L. Robb and J.P. Newman, 1992. Western flower thrips (Thysanoptera: Thripidae) resistance to insecticides in costal California greenhouses. J. Econ. Entomol., 83: 9-14.

Keerati-Kasikorn, M. and P. Singha, 1987. Evaluation of groundnut lines for insect resistance. Proceedings of 6th Thailand National Groundnut Meeting. Prince of Songkla University, Songkla and the Talebun National park, Satul. March 18-20, 1987 (In Thai with English summary), pp: 313-317.

Keerati-Kasikorn, M., T. Sattayavirutama, S. Sirisingha and S. Pitak, 1990. Peanut insect pest research in Thailand to the year 1989. In the 9th Proceedings of the National Peanut Research Meeting. Khon Kaen University. May 7-11, (In Thai with English summary), pp: 155-169.

Kogan, M. and E.E. Ortman, 1978. Antixenosis-a new term proposed to replace Painter's non-preference modality of resistance. Bull. Entomol. Soc. Am., 24: 175.

Loges, V., M.A. Lemos, L.V. Resende, D. Menezes, J.A. Candeia and V.F. dos Santos, 2004. Caracteres de produção da cebola associados? resistência a tripes. Hortic. Bras., 22: 771-774.

Maris, P.C., N.N. Joosten, R.W. Goldbach and D. Peters, 2003. Restricted spread of tomato spotted wilt virus in thrips resistant pepper. Phytopathology, 93: 1223-1227.

Mather, K. and J.L. Jinks, 1977. Introduction to biometrical genetics. Chapman and Hall London.

Mound, L.A., 1996. The Thysanoptera vector species of tospoviruses. Acta Hortic., 431: 298-309.

Nigam, S.N., H.D. Upadhyaya, S. Chandra, R.C. Nageswara Rao, G.C. Wright and A.G.S. Reddy, 2001. Gene effects for specific leaf area and harvest index in three crosses of groundnut (*A. hypogaea*). Ann. Applied Biol., 139: 3301-306.

Painter, R.H., 1968. Insect resistance in crop plants. The University Press of Kansas, Lawrence.

Rowe, K.E. and W.I. Alexander, 1980. Computations for estimating the genetic parameters in Joint-scaling tests. Crop Sci., 20: 109-111.

Torres, A.M., M.T. Moreno and J.I. Gubero, 1993. Genetic of six components of autofertility *in Vicia faba*. Plant Breed., 115: 220-228.

Wongkaew, S., 1993. Peanut virus disease in Thailand. Department of Agricultural Extension, Ministry of Agriculture and Co-operatives (In Thai).