Asian Journal of Plant Sciences

ISSN 1682-3974

science alert

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Asian Journal of Plant Sciences 5 (5): 838-846, 2006
ISSN 1682-3974

Field Evaluation of Screening Procedures for Thrips Resistance in Peanut

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Abstract: Selection of an efficient, simple and accurate screening method is important in a varietal evaluation program. The objective of this study was to evaluate reactions of peanut lines to natural thrips infestation using thrips number parameters and thrips damage parameters to identify which parameters were consistent and most suitable in separating the difference of peanut lines. Another objective was to evaluate appropriate assessment times. A randomized complete block design with six replications was used at three environments. Data were recorded for adult thrips number. Juvenile thrips number, total thrips number, Percentage of damaged plants, percentage of damaged leaves and thrips damage rating at 30, 40, 50, 60 and 70 Days After Planting (DAP). Sticky traps were also used to monitor thrips abundance in environment 3 and found that *Scirtothrips dorsalis* was the most abundant species accounting for 48.7% of total adult thrips number. Differences among cultivars for adult thrips number and total thrips number were observed at 40, 50, 60 and 70 DAP, but not at 30 DAP. Differences among cultivars for juvenile thrips number were observed at 60 and 70 DAP. The differences among cultivars for thrips number were less consistent across evaluation dates. The most appropriate assessment times for thrips number would be between 50 to 70 DAP. It would be difficult to identify thrips resistant lines by using thrips number as selection criterion. Differences among cultivars for percentage of damaged plants were observed at 30, 40, 50 and 60 DAP, but not at 70 DAP. Appropriate assessment times would be at 30 to 50 DAP. Differences among cultivars for percentage of damaged leaves and thrips damage rating were quite similar and observed at 30 to 70 DAP. Appropriate assessment times would be at later evaluation dates (50 to 70 DAP). Plant damage parameters are more useful than thrips number in identifying differences among peanut cultivars. These parameters are more consistent across evaluation dates and years and should be promising for use as selection criteria for thrips resistance in peanut. Among tested cultivars, IC 10 showed the lowest thrips number and plant damage.

Key words: Thrips resistance, assessment time, thrip number parameters, plant damage parameters

INTRODUCTION

Thrips (Thysanoptera: Thripidae) are important pests of a number of crops worldwide. Nine thrips species have been reported to infest peanut in ago-ecosystems in Thailand (Wongkaew, 1993) and are important as disease vectors rather than as damaging pests (Mound, 1996; Ghewande and Nandagopal, 1997). However, early season moisture stress intensifies peanut yield and quality losses associated with combined injury from thrips and post-emergence herbicides (Funderburk *et al*., 1998). Thrips control programmes on peanut involve mostly pesticides and only very rarely do farmers use alternative cultural, physical or biological methods. A number of parasites, predators and pathogens are reported but they have not been used for biological control under field conditions (Ghewande and Nandagopal, 1997). Additionally, several thrips species are capable to develop insecticide resistance (Daughtrey *et al*., 1997; Immaraju *et al*., 1992). This can have negative impact on integrated pest management programmes with chemical control as one of the components (Jensen, 2000).

Resistant varieties impeded thrips population development and also provided protection to *Tomato spotted wilt virus* (TSWV) infection in pepper (Maris *et al*., 2003). Reduced spread of *Groundnut bud necrosis virus* (GBNV) was found in peanut accession Robut 33-1, which was attributed to fewer thrips on the

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plants of this accession than on thrips susceptible accessions (Amin, 1985). However, change in thrips feeding behavior leaded to the increased spread of tospovirus in thrips resistant cultivars of chrysanthemum (Van de Wetering, 1999). 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 be easily integrated with other control measures. Host plant resistance offers a primary strategy for thrips management and also be an important component of integrated pest management control. Significant efforts have been invested in screening peanut accessions for thrips resistance. As a result, various resistant accessions have been identified and used as germplasm sources for thrips resistance breeding programs.

Since Painter (1951), three mechanisms of the basis of insect resistance have been proposed. Non-preference refers to the groups of plant traits and insect responses that lead to or away from the use of particular plant or variety, for oviposition, for food, for shelter or for combinations of the three. Antibiosis exhibits those adverse effects on the insect life history when the insect uses resistant plant for food. Tolerance denotes the ability of plant to grow and reproduce itself or to repair injury in spite of the supporting thrips population similar to that damaging (Painter, 1951). Later on, 'antixenosis' was proposed to describe more accurately the term of non-preference of insects for a resistant plant (Kogan and Ortman, 1978).

Although resistant germplasm lines are available and mechanisms underlying thrips resistance are well understood, effective and reliable screening procedures, which are in accordance with resistance mechanisms, are also important in developing new resistant cultivars. Screening method for cabbage has been based on either the extent of the injury observed on leaves (Penzes *et al*., 1996), or on both the extent of injury and the number of thrips collected (Shelton *et al*., 1988). Kumar *et al*. (1996) found that rating for thrips damage was more reliable and efficient than estimating thrips number in screening pepper accessions. The parameters should be user-friendly in terms of less time, small attempt, low cost of research and available resources. Moreover, environment variation, population dynamic of thrips species and components of thrips population might affect the reactions of host plants to insect pests and thus the appropriate access times for evaluation for target areas should be determined.

The relative usefulness of the characters based on injury by thrips and thrips number are still questionable for practical breeding programs and appropriate evaluation times have to be determined. The main objective was to evaluate the reactions of peanut lines to natural thrips infestation, using thrips number parameters and thrips damage parameters to identify which parameters were consistent and most suitable in separating the difference of peanut lines. Another objective was to evaluate appropriate assessment times.

MATERIALS AND METHODS

Eight peanut lines (IC 10, IC 34, ICGV 86031, ICGV 86388, KK 60-3, KKU 72-1 KKU 72-2 and Luhua 11) were evaluated for their reactions to thrips infestation under field conditions. IC 10 and IC 34 are the lines that showed low thrips infestation in test at Khon Kaen, Thailand (Chuapong, 1997). IC 10 was derived from the cross Robut 33-1×NC Ac 2214 and IC 34 was derived from the cross [NC Ac 1107×(NC Ac 2232×NC Ac 2214)] (Chuapong, 1997). Robut 33-1 had low thrips infestation in field test in India (Amin, 1985). NC Ac 2214 is resistant to thrips but has low yield potential and other undesirable traits (Dwivedi *et al*., 1993). NC Ac 2232 has been identified as an accession with consistently low symptoms of bud necrosis at ICRISAT (Isleib *et al*., 1994). ICGV 86031 is a selection from a cross between F334A-B-14 and NC Ac 2214. It is a high-yielding improved germplasm line with multiple resistance to and/or tolerance of insect pests. ICGV 86388 is a selection from the cross [(Dh 3-20×US 20)×NC Ac 2232. It is a high-yielding, sequentially branched, improved germplasm line with moderate resistance to thrips (*Thrips palmi* Karny) and jassids (*Empoasca kerri*). KK 60-3 is Virginia-type released cultivar in Thailand. KKU 72-1 and KKU 72-2 are sister lines from the cross NC Ac 17090×B1 and has been released in Thailand. Luhua 11 is a germplasm line from China. All released cultivars and Luhua 11 have not been tested for reaction to thrips infestation.

Field evaluation of these lines was conducted in 2003 at Khon Kaen University Agronomy Farm and the experiment was repeated in 2004 and 2005 at a peanut growing area in Kalasin in Northeast Thailand. All tests were conducted in the dry season during January to April. The similar experimental procedures were used for all years. The trial was conducted in a randomized complete block design with 6 replications. A single-row plot, 3.0 m long and spaced 0.5 m apart with 12 plants, was used. Neither fungicide nor insecticide was applied to the crop and other cultural practices were in accordance with the recommendations for irrigated peanut. The test at Khon Kaen was drip-irrigated. The tests at Kalasin were furrow-irrigated in which seeds were sowed on raised beds in rice fields after rice harvest.

Data were recorded for total thrips number, number of adult thrips and number of larval thrips at 30, 40, 50, 60 and 70 Days After Planting (DAP). Five 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 (12 × magnificence) and then total thrips number, number of adult thrips and number of larval thrips were determined.

Plant damage by thrips feeding based on 10 plants in each plot were recorded as percent damaged plants (plants having thrips feeding scars) and percent damaged leaves (leaves on main stems showing thrips feeding damage) at 30, 40, 50, 60 and 70 DAP. Percentage of damaged leaves was recorded based on percentage of leaves showing visible scars on main stems of 10 plants in each plot. In each leaf, a single leaflet or more in a petiole having scars of thrips feeding was considered damaged.

Thrips damage ratings of 1-9 were given to 10 individual plants in each plot, with 1 = no damage to damage 10%, 3 = damage 11-30%, 5 = damage 31-50%, 7 = damage 51-70% and 9= damage 71-100% (Keeratikasikorn and Singha, 1987).

In the test in 2005, thrips population dynamic was also monitored two times at 60 and 67 DAP. Twelve blue sticky traps with the size of A4 paper were randomly placed near the top of peanut canopy in six replications of the test and thus there would be twelve replications totally. The traps were left in the field for 7 days before collecting for thrips count. Five thrips species were identified and the rest was regarded as unidentified species.

Thrips numbers from sticky traps across two sampling dates were subjected to combined analysis of variance according to a randomized complete block design using original data. Five thrips species and unidentified mixed species were regarded as treatments. Percentage of each species was calculated and Duncan's multiple rang test was used to compare means.

Data of total thrips number, juvenile thrips number and adult thrips number were analyzed statistically after being transformed by square root (sqrt(x+0.5)). Traits other than thrips number were also analyzed statistically, using original data. Combined analysis of variance across three environments was also performed for thrips and plant damage parameters. Replications within environment means of squares were used to test the significances of environment differences and pooled errors were used to test the significances of variety differences and variety×location interactions. Duncan's multiple range test was used to compare means.

RESULTS AND DISCUSSION

Monitor of thrips population dynamic: The objective of monitoring thrips population dynamic was to understand which species are significant in agro-ecosystems of peanut production in Thailand and to identify target species.

Five species (*Scirtothrips dorsalis* Hood, *Megalurothrips usitatus* Bagnall, *Caliothrips indicus* Bagnall, *Frankliniella schultzei* Trybom, *Thrips palmi* Karny and unidentified species were significantly different for two sampling dates and combined analysis. *S. dorsalis* was the most abundant species accounting for 43.9% in sampling date 1 and 52.8% in sampling date 2 with average of 48.7% for two sampling dates. *M. usitatus* was the second abundant species with average number of 18.7% similar to unidentified species (18.6%). *C. indicus* was the third abundant species accounting for 12.8% of thrips population. *F. schultzei* and *T. palmi* were very rare, accounting for 0.1 and 0.9%, respectively (Table 1).

The results were quite similar to previous studies conducted in different years and regions in Thailand. All studies were conducted in the dry seasons during January to March because thrips is not a severe problem for peanut in the wet season. In the central of Thailand, Chuapong (1997) found that *S. dorsalis* was the most abundant species, but *T. palmi* was rarely detected in peanut. In the northeast, Buddasimma (2004) also found that 55.7% of adult thrips in peanut was *S. dorsalis* followed by *C. indicus*, *M. usitatus*, *F. schultzei* and *T. palmi* with the percentages of 16.7, 10.6, 3.9 and 2.7%, respectively.

Reactions of peanut genotypes to thrips infestation for thrips number and thrips damage parameters under field conditions across environments and sampling dates may be altered by different components of thrips species due to differences in thrips behavior. Wightman *et al.* (1995) reported that *S. dorsalis* was found mostly in young folded leaves before blooming, whereas *F. schultzei* was found mostly in flowers and *T. palmi* was

Table 1: Means of original data for thrips number of two sampling dates collected from test site in Kalasin during February and March 2005

Thrips species	Combined		60 days after planting		67 days after planting	
	Mean	(%)	Mean	(%)	Mean	(%)
S. dorsalis	117.8a	48.7	97.6a	43.9	138.1a	52.8
M. usitatus	45.2b	18.7	54.2b	24.4	36.4b	13.9
C. indicus	31.0c	12.8	31.0c	13.9	31.0b	11.8
F. schultzei	0.3d	0.1	0.3d	0.1	0.3c	0.1
T. palmi	2.2d	0.9	1.0d	0.4	3.5c	1.3
unidentified	45.0b	18.6	38.0b	17.1	52.1b	19.9
CV	51.7		43.6		56.6	
F-ratio	101.6**		61.1**		50.1**	

Significant at 0.01 probability level

found both in young folded leaves and flowers. According to findings of Wightman *et al.* (1995), sampling of young terminal leaves was considered appropriate because *S. dorsalis*, the major component, did not attract to flowers.

Wongkaew (1993) reported that nine thrips species (*Thrips tabaci*, *T. palmi*., *T. setosus*, *S. dorsalis*, *F. schultzei*, *F. occidentalis*, *F. fusca*, *C. indicus* and *M. usitatus*) were found in peanut production areas in Thailand of which *Frankliniella* sp. *C. indicus* and *S. dorsalis* were the most damaging species (Keeratikasikorn *et al.*, 1990). Seven species are the vectors of tospoviruses including peanut bud necrosis virus which is vectored by *T. palmi* and two species, *C. indicus* and *M. usitatus* are not important as virus vectors (Wongkaew, 1993). Wongkaew (1995) also reported that four thrips species (*S. dorsalis*, *T. palmi*, *C. indicus* and *Haplothrips gowdeyi*) were found in peanut production areas in Thailand. In this survey, *S. dorsalis* was the most abundant species and *T. palmi* was very rare.

The results of this study and earlier studies provided firm conclusion that *S. dorsalis* was a major component of thrips population in our study and its number was more than two times higher than other species. *S. dorsalis* was the target species for thrips resistance under field condition in our study. The components of thrips species changed slightly across years and *S. dorsalis* is always the most abundant species. This information is useful for thrips management in peanut and peanut breeders to formulate effective breeding methods.

Thrips number parameters: Combined analysis of variance showed highly significant differences ($p \leq 0.01$) between environments for adult thrips number at 40, 50, 60 and 70 DAP (Table 2). Differences between cultivars were also significant ($p \leq 0.01$) at these evaluation dates. However, variety×environment (V×E) interactions were significant ($p \leq 0.01$) at 50 DAP only. Differences between peanut genotypes for adult thrips number were not significant at 30 DAP, but the differences were observed at the successive evaluations. This was possibly due to the lower infestation of thrips population at early evaluation dates and the thrips population was more abundant at later evaluations.

Number of thrips adults on host plants reflects the preference of thrips species, while number of immature thrips involves both preference and antibiotic effects. Therefore, Reactions of peanut lines to thrips infestation under field conditions were evaluated, using number of thrips adults and immature thrips as thrips resistance parameters and peanut lines with lower number of thrips are preferable.

Buddasimma (2004) observed the peak time of thrips infestation in peanut at 7 weeks after planting and thrips number declined in successive observations. In this study, thrips adults slightly increased after 50 days after planting. The discrepancy of the results was possibly due to differences in environmental conditions. However, ranks of these genotypes were not consistent at early evaluation dates, but more consistent at late evaluation dates as indicated by similarity in ranks of peanut genotypes evaluated at 60 and 70 DAP (Table 3). For example, IC 10 showed low thrips number at 40 DAP, but thrips number was increased at 50 DAP and then decreased again at 60 and 70 DAP (Table 3). It seemed that peanut genotypes responded differently to thrips infestation at different evaluation dates in relation to levels of thrips abundance.

Differences of peanut lines for thrips numbers were low and inconsistent. The inability of adult thrips number to identify genotype differences might be caused by low figures of thrips in each plot because of relatively low number of samples taken from each plot. Thrips numbers are also affected by sampling methods. According to Buddasimma (2004), correlation between thrips number by trap count and whole plant sampling ($r = 0.93$) was high and correlation between trap count and indirect sampling from other plant parts ($r \leq 0.52$) was moderate. Whole plant sampling is the most accurate method to evaluate thrips population. In our study, we gained very low number of thrips adults on four unfolded terminal leaves. Culbreath *et al.* (1997) also reported low number of fewer

Table 2: Combined analysis of variance for adult thrips number and juvenile thrips number at three environments evaluated at 30, 40, 50, 60 and 70 Days After Planting (DAP)

Source of variation	Degree of freedom	Adult thrips No.					Juvenile thrips No.				
		30 DAP	40 DAP	50 DAP	60 DAP	70 DAP	30 DAP	40 DAP	50 DAP	60 DAP	70 DAP
Environment (E)	2	1.170	4.602**	4.958**	10.741**	12.313**	0.037	2.749*	11.656**	18.812**	42.819**
Rep. within E	15	0.429	0.324	0.389	0.367	0.743	0.452	0.434	0.614	2.395	1.386
Variety (V)	7	0.286	0.560**	1.405**	1.779**	4.107**	0.280	0.337	0.261	1.518*	0.921*
V×E	14	0.269	0.120	0.641**	0.483	0.837	0.146	0.111	0.366	2.178**	0.903**
Pooled error	105	0.215	0.189	0.245	0.359	0.532	0.179	0.229	0.307	0.595	0.375

*,** significant at 0.05 and 0.01 probability levels, respectively

Table 3: Means of square root-transformed data across three environments for adult thrips number and juvenile thrips number evaluated at 30, 40, 50, 60 and 70 Days After Planting (DAP)

	Adult thrips No.					Juvenile thrips No.				
Variety	30 DAP	40 DAP	50 DAP	60 DAP	70 DAP	30 DAP	40 DAP	50 DAP	60 DAP	70 DAP
IC 10	1.06	0.86c	1.86ab	1.78b	1.56b	0.95	1.13	1.35	1.92bc	1.69b
IC 34	1.05	1.26ab	1.61bcd	1.67b	1.84b	1.01	0.95	1.49	1.40ab	2.15a
ICGV86031	0.21	1.50a	1.78bc	2.33a	2.41a	1.09	1.27	1.60	2.65a	2.37a
ICGV86388	1.44	1.14bc	2.14a	2.34a	2.86a	0.95	1.09	1.50	2.08abc	2.22a
KK 60-3	1.21	1.26ab	1.35d	1.69b	1.71b	1.01	1.06	1.63	1.78c	2.02ab
KKU 72-1	1.11	1.26 ab	1.33d	1.76b	1.67b	1.24	1.12	1.37	2.45a-c	2.21a
KKU 72-2	1.25	1.19ab	1.45cd	1.48b	1.47b	1.00	1.28	1.59	2.17a-c	2.02ab
LUHUA 11	1.15	1.22ab	1.58bcd	1.74b	1.78b	1.26	1.36	1.68	2.48ab	2.39a
F-ratio	1.33	2.97**	5.73**	4.95**	7.72**	1.56	1.47	0.85	2.55*	2.45*
CV (%)	39.09	35.75	30.16	32.65	38.04	39.72	41.21	36.19	34.81	28.72

Means in the same column with the same letter(s) are not statistically different by DMRT at 0.05 probability level. *,** significant at 0.05 and 0.01 probability levels, respectively

than 4 *F. occitalis* adults per 10 whole plants, leaves or peanut flowers. Increase sampling size or different sampling methods may not increase accuracy, if thrips population is low. This is possibly due the fact that thrips population is clumped rather than random distribution. Thrips are not randomly distributed throughout the field and therefore any particular plant may have few thrips due to genetic resistance or simply by chance (Hamilton *et al*., 1999). Cumulative values of thrips numbers and other non- destructive methods might be useful parameters and should be explored in future investigations.

Thrips is also highly moveable species compared to other insect pests such as aphid. It is interesting to note that ICGV 86031 and ICGV 86388, which were reported to have low number of thrips in India, had the highest thrips number in this study. KK 60-3, KKU 72-1, KKU 72-2 and Luhua 11 had low thrips number similar to those of IC 10 and IC 34, which were tested for thrips resistance in Thailand. These released cultivars adapt to growing regions in Thailand. The differences in reactions to thrips infestation are possibly due to the difference in components of thrips species in India and Thailand. Chuapong (1997) found predominance of *S. dorsalis* and very low number of *Thrip palmi* in the test in Thailand, while *F. schultzei* was more abundant in the test in India (Amin, 1985).

KK 60-3, KKU 72-1, KKU 72-2 and Luhua 11 were different from ICGV 86031 and ICGV 86388 in two aspects; 1) KK 60-3, KKU 72-1, KKU 72-2 and Luhua 11 are Virginia type with spreading growth habit (semi-spreading for Luhau 11) and they are shorter than ICGV 86031 and ICGV 86388 and 2) KK 60-3, KKU 72-1, KKU 72-2 and Luhua 11 have dark green leaves, while ICGV 86031 and ICGV 86388 are Spanish type and have more yellowish leaves. Amin (1985) also observed lower thrips adults in the accession Robut 33-1 (Virginia type and dark green leaves) compared with TMV 2 (Spanish type and yellowish leaves).

The appropriate times to assess adult thrips number were between 50 to 70 DAP when low Coefficient of Variations (CV) and high F-ratios were considered. Assessments at 30 and 40 days after planting may be too early to obtain reasonably reliable results because thrips number was too low. Assessment at 50 DAP was lesser suitable than at 60 and 70 DAP because of high V×E interaction. V×E interactions are common in evaluations of host plants to insect pests, suggesting that environments are important for the reactions of peanut genotypes to insect stress and multi-location testing is required.

Numbers of juvenile thrips were significantly different ($p \leq 0.05$) between environments at 40, 50, 60 and 70 DAP, but variety differences ($p \leq 0.05$) and V×E interactions ($p \leq 0.05$) were significant at 60 and 70 DAP (Table 2). This is possibly because number of juvenile thrips was too low at 30, 40 and 50 DAP. IC 10 showed to have consistently low juvenile thrips number across evaluation dates (Table 2).

Buddasimma (2004) reported that thrips numbers in peanut plants increased after six weeks after planting but the number declined after seven weeks after planting. He also found that the numbers of *S. dorsalis* and *C. indicus* still increased after 7 weeks after planting indicating that peanut was the most appropriate host for these species.

Assessments at 60 and 70 DAP gave better results than at 30 to 50 DAP. Assessments at 30 to 50 DAP may be too early to separate the differences in juvenile thrips number among peanut genotypes. The results showed that appropriate assessment times for juvenile thrips number were somewhat later than those of adult thrips number and total thrips number. However, this parameter may not be appropriate because of the significance of V×E interactions at 60 and 70 DAP and low variation of juvenile thrips number between peanut varieties. Variation in juvenile thrips number was lower than that of adult thrips number as indicated by lower F-ratios and

identification of genotypes with low juvenile thrips number is more difficult because the presence of high V×E interaction. This parameter is less useful than adult thrips number to be used as selection criterion for thrips resistance.

Highly significant differences ($p \leq 0.01$) between locations were observed for total thrips number at 40, 50, 60 and 70 DAP. Significant differences ($p \leq 0.05$) between peanut lines were observed at 40, 50, 60 and 70 DAP, but V×E interactions ($p \leq 0.01$) were significant at 60 and 70 DAP (Table 4). Number of juvenile thrips had a large contribution to V×E interaction for total thrips number and precluded its use as a selection criterion for thrips resistance. Differences between peanut genotypes for total thrips number was not significant at 30 DAP, but significant at 40, 50, 60 and 70 DAP (Table 5). However, the best genotypes having the lowest total thrips number was still unresolved when all evaluation dates were considered. This is possibly because of the environmental noise or difference in mechanisms of resistance. Environmental factors may have large effect on this parameter; non preference and antibiotic resistance mechanisms might occur in this population. Antagonistic or synergetic effect between the two mechanisms might operate in some genotypes. Peanut genotypes with lower thrips adults may not always have low number of immature thrips and vice versa. Therefore, total thrips number is not good parameter for thrips resistance assessment because of low differentiating ability of this parameter to separate peanut genotypes. Further studies on antixenosis and antibiosis in these germplasm are required.

The appropriate assessment times for total thrips number were between 50 to 70 days after planting and quite similar to those of adult thrips number. IC 10 showed to have more consistently lower total thrips number than other cultivar evaluated, whereas ICGV 876031 and ICGV 86388 had relatively higher total thrips number across evaluation dates (Table 5).

In general, our findings support those of previous studies. Our results were subjected two limitations. One is the difficulty to obtain uniform distribution of thrips population. Landscape management of test field might improve uniformity of thrips distribution. Another is the difficulty of interpretation of the results because of temporal and spatial fluctuation of thrips population. Moreover, laborious work in both field for collecting thrips and many hours of thrips count in laboratory do not support evaluation of large samples. Based on the results, IC 10 was identifies as thrips resistant line because of lower thrips adults and we also identified appropriate times to get access to the field for evaluation.

Plant damage parameters: Differences between environments for percentage of damaged plants were not significant for all evaluation dates. Significant differences ($p \leq 0.01$) among varieties were observed at 30, 40, 50 and 60 DAP, but not at 70 DAP. V×E interactions were significant ($p \leq 0.05$) at 40 and 50 DAP (Table 6). The interaction mean squares were relatively low compared

Table 4: Combined analysis of variance for total thrips number at three environments evaluated at 30, 40, 50, 60 and 70 Days After Planting (DAP)

Source of variation	Degree of freedom	Total thrips No.				
		30 DAP	40 DAP	50 DAP	60 DAP	70 DAP
Environment (E)	2	0.625	10.446**	17.938**	32.842**	54.518**
Rep. within E	15	0.974	0.678	0.510	1.687	0.923
Variety (V)	7	0.296	0.605*	0.946*	2.136**	3.916**
V×E	14	0.302	0.227	0.430	1.709**	1.097*
Pooled error	105	0.260	0.244	0.368	0.556	0.550

*,** significant at 0.05 and 0.01 probability levels, respectively

Table 5: Means of square root-transformed data across three environments for total thrips number evaluated at 30, 40, 50, 60 and 70 Days After Planting (DAP)

Variety	Total thrips No.				
	30 DAP	40 DAP	50 DAP	60 DAP	70 DAP
IC10	1.27	1.26c	2.26ab	2.62bc	2.23e
IC34	1.32	1.44bc	2.17bc	2.87bc	2.82cd
ICGV 86031	1.48	1.85a	2.37ab	3.54a	3.46ab
ICGV 86388	1.59	1.47bc	2.58a	3.11ab	3.60a
KK 60-3	1.39	1.54a-c	2.02bc	2.41c	2.62cde
KKU 72-1	1.56	1.54a-c	1.83c	2.82bc	2.75cd
KKU 72-2	1.49	1.64ab	2.05bc	2.71bc	2.49de
LUHUA 11	1.63	1.73ab	2.26ab	3.03b	2.99bc
F-ratio	1.14	2.48*	2.57*	3.84**	7.11**
CV (%)	34.69	31.68	27.68	25.81	25.84

Means in the same column with the same letter(s) are not statistically different by DMRT at 0.05 probability level, *,** significant at 0.05 and 0.01 probability levels, respectively

with the corresponding mean squares of variety effects. IC 10 showed consistently the lowest percentage of damaged plants across three evaluation dates at 30, 40 and 50 DAP, but the ranks were not consistent at 60 DAP (Table 7).

Plant damage parameters measure the reactions of peanut genotypes to thrips feeding. Thrips is piecing-sucking species. Both mature and immature thrips feed on unfolded young peanut leaves, making scared and deformed leaves. Plant damage parameters may be resulted from both preference and antibiotic mechanisms.

There was no clear cut reaction in the ranks of the rest of varieties when all evaluation dates were considered. The severity of percentage of damaged plant become much greater at the later evaluation dates and at 60 and 70 DAP the severity of percentage of damaged plants was too high to obtain reliable results as some of plots reached nearly 100% of damaged plants. Lower percentage of damaged plants reflects non-preference of thrips to probe or browse on peanut genotypes, leaving fewer plants having visual damage on leaves. This was true at early evaluations, but most plants were browsed by thrips at late evaluations.

The most appropriate assessment times were between 40 and 50 DAP. Assessments at 30 DAP were too early, whereas assessments after 70 DAP were too late and plants suffered severe infestation of thrips population. Levels of insect pressure have to be considered when assesses percentage of damaged plants. Furthermore, percentage of damaged plants might be affected by plant maturity and growth stages. Peanut genotypes with more rapid growth seemed to have more percentage of damaged plant than did genotypes with slower growth.

Differences between environments for percentage of leaf damage were not significant for all evaluation dates. Differences ($p \leq 0.01$) among varieties were significant for all evaluation dates indicating uniformity of environments for this traits, but V×E interactions were significant ($p \leq 0.05$) at 30 and 70 days after planting (Table 6). The interaction means of squares were relatively low compared with their corresponding variety effects, indicating that there were slightly changes in ranks or magnitude for percentage of leaf damage. The results supported general knowledge that V×E interactions are common in evaluations for insect resistance (Painter, 1951). It seemed that extreme damages (both low and high) might affects ranks of peanut genotypes for percentage of leaf damage. Therefore, the insect pressure should not extremely high or low for accurate evaluation. IC 10 had the lowest leaf damage across five evaluation dates, but the reactions of other cultivars were not consistent (Table 7). IC 10 showed to be useful source of thrips resistance because of its lower percentage of damaged leaves.

Appropriate assessment times for percentage of leaf damage were relatively wide from 40 to 70 days after planting. Assessments at later stages were more accurate

Table 6: Combined analysis of variance for percentage of damaged plants and percentage of damaged leaves at three environments evaluated at 30, 40, 50, 60, and 70 Days After Planting (DAP)

		Percentage of damaged plants					Percentage of damaged leaves				
Source of variation	Degree of freedom	30 DAP	40 DAP	50 DAP	60 DAP	70 DAP	30 DAP	40 DAP	50 DAP	60 DAP	70 DAP
Environment (E)	2	1444.9	8964.9	4415.0	6009.7	6168.7	332.7	1997.9	454.5	183.6	665.6
Rep. within E	15	2032.5	2719.9	1290.5	2837.2	1796.4	173.1	868.1	602.5	1059.2	825.3
Variety (V)	7	876.3**	1887.9**	2825.7**	621.6**	109.7	103.6**	213.2**	431.1**	321.4**	418.4**
V×E	14	280.8	527.8*	577.3*	207.1	133.1	46.6*	82.3	121.4	124.7	181.5**
Pooled error	105	177.5	272.9	267.8	178.2	69.5	26.0	49.4	72.1	96.0	77.3

*,** significant at 0.05 and 0.01 probability levels, respectively

Table 7: Means of original data across three environments for percentage of damaged plants and percentage of damaged leaves evaluated at 30, 40, 50, 60 and 70 Days After Planting (DAP)

	Percentage of damaged plants					Percentage of damaged leaves				
Variety	30 DAP	40 DAP	50 DAP	60 DAP	70 DAP	30 DAP	40 DAP	50 DAP	60 DAP	70 DAP
IC 10	13.13e	26.26c	40.10d	74.14a-c	87.17	3.31c	7.97c	10.24c	18.63b	24.31c
IC 34	16.67de	34.34bc	58.18c	67.68c	90.71	4.77bc	10.93bc	18.45b	19.54b	26.60c
ICGV 86031	20.20cde	37.88b	55.86c	72.63bc	88.28	5.67bc	14.24ab	21.00ab	30.45a	37.35a
ICGV 86388	22.73bcd	39.90b	65.15bc	72.73bc	94.44	7.33ab	14.99ab	22.83ab	25.24ab	37.57a
KK 60-3	30.81ab	45.96ab	70.40ab	83.84a	91.82	9.53a	16.11a	22.71ab	26.64a	30.71bc
KKU 72-1	32.83a	55.05a	77.98a	80.41ab	91.01	9.75a	17.83a	23.89ab	27.77a	28.11bc
KKU 72-2	27.78abc	56.57a	74.95ab	82.53ab	89.09	9.42a	17.95a	25.72a	25.01ab	29.62bc
LUHUA 11	27.78abc	45.45ab	72.43ab	81.52ab	93.23	7.29ab	15.76ab	23.95ab	28.90a	33.22ab
F-ratio	4.94**	6.91**	10.55**	3.49**	1.58	3.99**	4.32**	5.98**	3.35**	5.41**
CV (%)	55.53	38.71	25.42	17.53	9.19	71.45	48.55	40.26	38.78	28.42

Means in the same column with the same letter(s) are not statistically different by DMRT at 0.05 probability level. *,** significant at 0.05 and 0.01 probability levels, respectively

Table 8: Combined analysis of variance for thrips damage rating at three environments evaluated at 30, 40, 50, 60 and 70 Days After Planting (DAP)

Source of variation	Degree of freedom	Thrips damage rating				
		30 DAP	40 DAP	50 DAP	60 DAP	70 DAP
Environment (E)	2	3.361	24.250	3.250	3.000	7.583
Rep. within E	15	2.517	10.717	5.700	12.950	9.256
Variety (V)	7	1.837**	4.123**	4.873**	4.028**	4.111**
V×E	14	0.885	1.075	1.694	1.379	2.409**
Pooled error	105	0.536	1.053	1.154	1.280	1.052

*,**significant at 0.05 and 0.01 probability levels, respectively

Table 9: Means of original data across three environments for thrips damage rating evaluated at 30, 40, 50, 60 and 70 Days After Planting (DAP)

Variety	Thrips damage rating (1-9)[1/]				
	30 DAP	40 DAP	50 DAP	60 DAP	70 DAP
IC 10	1.11b	1.56c	2.00b	2.78b	3.44d
IC 34	1.22b	1.78c	2.78a	2.78b	3.67cd
ICGV 86031	1.22b	2.00bc	3.00a	3.89a	4.89a
ICGV 86388	1.56ab	2.22abc	3.00a	3.44ab	4.56ab
KK 60-3	1.89a	2.56ab	3.44a	3.67a	3.89b-d
KKU 72-1	1.56ab	2.89a	3.44a	3.78a	3.89b-d
KKU 72-2	2.00a	2.67ab	3.56a	3.33ab	4.00b-d
LUHUA 11	1.56ab	2.67ab	3.44a	4.00a	4.33a-c
F-ratio	3.43**	3.92**	4.22**	3.15**	5.20**
C.V. (%)	48.36	44.78	34.84	32.72	18.50

Means in the same column with the same letter(s) are not statistically different by DMRT at probability level, *,** significant at 0.05 and 0.01 probability levels, respectively, [1/] 1 = no damage to damage 10% , 3 = damage 11-30% , 5 = damage 31-50% , 7 = damage 51-70% and 9 = damage 71-100%

than at early stages because CV values were getting lower and F-ratios were getting higher.

Differences between environments for thrips damage rating were not significant for all evaluation dates, but variety differences were significant ($p \leq 0.01$) for all evaluation dates. V×E interactions were significant ($p \leq 0.01$) at 70 DAP (Table 8). V×E interaction did not affect the line IC 10 as it showed the lowest leaf damage rating for all evaluation dates (Table 9). Although it was possible to assess thrips damage rating as early as 30 days after planting, CV value was still high. The CV values were getting lower at later evaluations. Therefore, appropriate assessment times were between 40 to 70 DAP.

Although peanut genotypes with low thrips number could be identified for most evaluation dates, the results were less consistent across evaluation dates. However, evaluations at the most appropriate assessment times might give more reliable results. Assessments at 50 to 70 DAP seemed to be the most appropriate to identify peanut lines with low thrips number when high F-ratios and low CV values were considered.

For plant damage parameters, percentage of damaged plants could be evaluated at early growing season, but not at late growing season because of severe infestation of thrips population. In contrast, percentage of leaf damage and thrips damage rating could be evaluated more accurately at later growth season.

The results demonstrate that plant damage parameters such as percentage of damaged plants, percentage of damaged leaves and leaf damage rating are more useful than thrips number parameters in identifying thrips resistant peanut lines. Percentage of damaged plants should be good criterion if damaged plants are not too high and evaluations should be carried out at early growth stages. Percentage of leaf damage and thrips damage rating are more promising criteria in identifying thrips resistant peanut lines and the appropriate assessment times are wide from 40-70 DAS. Among tested genotypes, IC 10 showed consistently the lowest thrips number and plant damage and might be used as a source of thrips resistance in peanut.

ACKNOWLEDGMENTS

This study was funded by the Senior Research Scholar Project of Prof. Dr. Aran Patanothai under the Thailand Research Fund and also supported by the Peanut Improvement Project, Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand.

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