Genetic Resources and Crop Evolution **50:** 817–824, 2003.

Wild relatives of pigeonpea as a source of resistance to the pod fly (*Melanagromyza obtusa* Malloch) and pod wasp (*Tanaostigmodes cajaninae* La Salle)

H.C. Sharma*, G. Pampapathy and L.J. Reddy
*International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India; *Author for correspondence (e-mail: h.sharma@cgiar.org)*

Received 30 October 2001; accepted in revised form 31 May 2002

Key words: Pigeonpea, Plant resistance, Pod fly, Pod wasp, Resistance mechanisms, Wild relatives

Abstract

Pigeonpea [*Cajanus cajan* (L.) Millsp.] is an important legume crop in South Asia, East and southern Africa, and the Caribbean. Pod fly (*Melanagromyza obtusa* Malloch) and pod wasp (*Tanaostigmodes cajaninae* La Salle) are important constraints to increase the production and productivity of pigeonpea under subsistence farming conditions. Host plant-resistance can be used as an important component for the management of these pests, and therefore, we evaluated 28 accessions of wild relatives of pigeonpea for resistance to these pests. There were significant inter- and intra-species differences in the relative susceptibility to pod fly and pod wasp damage. Accessions belonging to *Cajanus scarabaeoides* (L.) Thouars, *C. sericeus* (Benth. ex Bak.) van der Maesen, *Rhynchosia bracteata* Benth. ex Bak., *C. acutifolius* (F.v. Muell.) van der Maesen, *C. lineatus* (W. & A.) van der Maesen, and *C. albicans* (W. & A.) van der Maesen showed resistance to pod fly damage, while those from *C. platycarpus* (Benth.) van der Maesen, *C. cajanifolius* (Haines) van der Maesen and *R. aurea* DC. were susceptible. For the pod wasp, some of the accessions from *C. scarabaeoides*, *C. albicans*, *Flemingia stricta* Roxb., and *R. bracteata* (Roxb.) Wight showed a resistant reaction, while ICPW 83 belonging to *C. scarabaeoides* showed a susceptible reaction. ICPW 141, ICPW 278, and ICPW 280 (*C. scarabaeoides*), ICPW 214 (*R. bracteata*), ICPW 14 (*C. albicans*), and ICPW 202 (*F. stricta*) showed resistance to both pod fly and pod wasp damage. There was considerable variation in accessions belonging to different species for their susceptibility to pod fly and pod wasp, which can be exploited to breed for resistance to these pests. There was a negative association between pod wasp and pod borer damage, and therefore, it is important to keep track of the relative susceptibility of pigeonpea genotypes to pod wasp, while breeding for resistance to pod borers.

Introduction

Pigeonpea (*Cajanus cajan* (L.) Millsp.) is one of the major grain legumes (pulses) in the semi-arid tropics (SAT) (Nene and Sheila 1990). It is grown in 50 countries in Asia, Africa, and the Caribbean for food, fodder, fuel wood, rearing lac insects, hedges, windbreaks, soil conservation, green manuring, and roofing. Pigeonpea yields have remained stagnant for the past 3 to 4 decades, largely due to insect pest damage. More than 200 species of insects feed on this crop, of which pod fly, *Melanagromyza obtusa* Malloch (Agromyzidae: Diptera) and pod wasp, *Tanaostigmodes cajaninae* La Salle (Tanaostigmatidae: Hymenoptera) are important pests, in addition to the ubiquitous pest, *Helicoverpa armigera* (Hub.) (Reed and Lateef 1990; Shanower et al. 1999). Losses due to pod fly damage have been estimated to be US$ 256 million annually (1992).

Identification and utilization of cultivars resistant/tolerant to pod fly, *M. obtusa* and pod wasp, *T. cajaninae* would have a number of advantages, particularly for a relatively low value crop such as pigeonpea. Resistant or less susceptible cultivars would provide an equitable and environmentally sound tool for sustainable pest management. Earlier studies have shown that early-maturing genotypes suffer low pod fly damage in comparison to the late maturing ones (Bhosale and Nawale 1985; Lal et al. 1988) and the determinate types are less susceptible than the indeterminate types (Lal et al. 1986; Gupta et al. 1991). More than 10,000 germplasm accessions have been screened for pod fly resistance (Lateef and Pimbert 1990). However, Singh and Singh (1990) reported that no definite conclusions could be drawn about the relative susceptibility of pigeonpea genotypes to pod fly damage because of staggered flowering and variation in pod fly abundance over time. There are no specific studies on genetic resistance to pod wasp, *T. cajaninae*. Since levels of resistance to these pests in the cultivated pigeonpeas are low to moderate, it is important to identify wild relatives of pigeonpea with high levels of resistance for use in crop improvement.

Materials and methods

To evaluate the relative susceptibility of wild relatives of pigeonpea towards pod fly (*M. obtusa*) and pod wasp (*T. cajaninae*), 18 accessions of wild relatives of pigeonpea were tested during the 1998 rainy season at the International Crops Research Institute for the Semi-Arid Tropics, Patancheru, Andhra Pradesh, India. Of these, 13 accessions belonged to *Cajanus scarabaeoides* (L.) Thours, 1 to *C. platycarpus* (Benth.) van der Maesen, 1 to *C. cajanifolius* (Haines) van der Maesen, 1 to *C. sericeus* (Benth. ex Bak.) van der Maesen, 1 to *Rhynchosia bracteata* Benth. ex Bak., and 1 to *C. albicans* (W. & A.) van der Maesen. Five pigeonpea [*Cajanus cajan* (L.) Millsp.] cultivars (ICPL 332, ICPL 187-1, ICPL 84060, ICP 7203-1, and ICPL 87) were included as a control. Passport data of the entries used in this study can be accessed from ICRISAT Gene Bank database at: www.ICRISAT.org.

Each entry was sown in a 3-row plot, 2-m long. The trial was planted on ridges 75-cm apart on deep black Vertisol soils. The seeds were sown in hills at a spacing of 30-cm between the hills. Three seeds were sown in each hole at a depth of 5-cm below the soil surface. There were three replications in a randomized complete block design. The trial was sown twice (first sowing on 12th Jun 1998, and the second on 6th Aug 1998) so that late flowering lines from the first sowing, and early flowering lines from the second sowing flower at the same time, and are exposed to maximum abundance of these pests under multi-choice conditions in the field. The testa of the seeds of the wild relatives was cut at one end with a sharp knife, and the seeds were soaked in water overnight before sowing for faster germination.

Only one seedling was retained per hill 30 days after crop germination. Normal agronomic practices were followed for raising the crop (basal fertilizer, and top dressing with urea @ 50 kg ha^{-1} 40 days after germination N:P:K- 100:60:40. Interculture and weeding operations were carried out as needed. The crop was raised under rainfed conditions between July to October. Since there was complete cessation of rains after 15 Oct, the crop was irrigated three times between Nov–Feb at an interval of one month. Because of heavy rainfall during the 1998 rainy season (1180 mm compared to a mean of 700 mm), there was a high incidence of *Fusarium* wilt; and therefore a spray of Metalaxyl (@ 1 kg ai ha^{-1}) was applied at 70 days after sowing. Cypermethrin was sprayed at one month after seedling emergence to protect the seedlings from ground beetles (*Gonocephalum* spp.), and with methomyl on 21st Dec to control the pod-sucking bugs (*Clavigralla* spp.) on pigeonpea cultivars. Wooden pegs (1.5 m) were provided as a support for accessions belonging to *C. scarabaeoides* and *C. platycarpus*, which have a creeping growth habit.

During the 1999 and 2001 rainy seasons, 28 accessions of wild relatives and five cultivated pigeonpea genotypes were tested for their relative resistance/susceptibility to pod fly and pod wasp. Of the 28 accessions tested, 12 accessions belonged to *Cajanus scarabaeoides* (L.) Thours, 1 to *C. platycarpus* (Benth.) van der Maesen, 2 to *C. sericeus* (Benth. ex Bak.) van der Maesen, 1 to *Rhynchosia bracteata* Benth. ex Bak. 1 to *R. aurea* DC., 2 to *C. cajanifolius* (Haines) van der Maesen, 1 to *Dunbaria ferruginea* W. & A., 1 to *C. acutifolius* (F.v. Muell.) van der Maesen, 2 to *C. albicans* (W. & A.) van der Maesen, 2 to *C. lineatus* (W. & A.) van der Maesen, 1 to *Flemingia stricta* Roxb., 1 to *Paracalyx scariosa* (Roxb.) Ali, and 1 to *F. bracteata* (Roxb.) Wight. Five pigeonpea cultivars (ICPL 332, ICPL 187-1, ICPL 84060, ICP 7203-1, and ICPL 87) were included as a control. The material was grouped into three experiments based on days to 50% flowering (early <60 days, medium 60 to 120 days, and late >120 days). There were three replications for each experiment in a randomized complete block design. Each experiment was planted twice, at an interval of one month so that material is exposed to peak insect abundance either in the first or in the second sowing. Normal agronomic practices were followed for raising the crop. The crop was sprayed with Benlate to minimize the incidence of *Fusarium* wilt. No insecticide was applied during the reproductive stage of the crop.

Data were recorded on percentage pods damaged by pod fly, *M. obtusa*, and the pod wasp, *T. cajaninae*. Inflorescences (30–40 cm long) of different genotypes flowering at the same time were marked with ribbons, and observations were recorded on the number of pods, and the pods damaged by pod fly and pod wasp. Pod samples (nearly 200 pods) were also collected at random from each plot at maturity, and the numbers of pods damaged by different insects were recorded as described earlier. Data on plant/pod/seed characteristics was obtained from the ICRISAT gene bank for correlation and regression analysis with pod fly and pod wasp damage.

Data were subjected to analysis of variance. Significance of differences between treatments was judged by F-test, while the differences between treatment means were compared by least significant difference (LSD) at P 0.05. Data on pod fly and pod wasp damage and plant morphological characteristics were subjected to correlation and stepwise regression analysis to identify plant morphological characteristics contributing to insect resistance in wild relatives of pigeonpea. Data on pod fly and pod wasp damage in two plantings in the 1998 rainy season, and pod fly and pod wasp damage along with plant morphological characteristics in the 1999/2000 rainy seasons was subjected to principal component analysis based on correlation matrix to assess the diversity in resistance to these insects in accessions of wild relatives of pigeonpea (GENSTAT 5).

Results

Relative susceptibility to pod fly, Melanagromyza obtusa

During the 1998 rainy season, pod fly damage ranged from 0.00 in ICPW 159, and ICPW 90 to 31.39% in ICPW 68 in pod samples collected from the tagged inflorescences, and 0.92 in ICPL 84060 to 29.52% in ICPL 332 in samples collected at random (Table 1). Accessions ICPW 83, ICPW 90, ICPW 94, ICPW 141, ICPW 278, and ICPW 281 (*C. scarabaeoides*), ICPW 28 (*C. cajanifolius*), ICPW 159 (*C . sericeus*), ICPW 214 (*R. bracteata*), and ICPW 13 (*C. albicans*) suffered <6.16% pod fly damage, both in samples collected from the tagged inflorescences as well as in the pod samples taken at random compared to 31.39% damage in the tagged inflorescences in ICPW 68 (*C. platycarpus*). There was considerable variation (0.00 in ICPW 90 to 10.29% in ICPW 152) in the susceptibility of different accessions of *C. scarabaeoides* to pod fly damage. Among the cultivated genotypes, pod fly damage was greater in ICPL 332 and ICPL 187-1, possibly because of greater pod retention (due to less susceptibility to pod borer) than in ICPL 84060 and ICPL 87. The estimates of pod fly damage, in general, were greater in pods collected from tagged inflorescences than in samples collected at random.

During the 1999/2000 rainy seasons, the early duration accessions belonging to *C. scarabaeoides* (ICPW 94, ICPW 130, ICPW 137, and ICPW 152) suffered 2.05 to 6.10% damage by the pod fly compared to 11.45 to 12.65% pod damage in *C. platycarpus* (ICPW 68), 6.55 to 18.55% damage in *R. aurea* (ICPW 210), and 1.90 to 7.35% damage in *C. cajan* (ICPL 87) (Table 2). In the medium maturity group, pod fly damage ranged from 0.00 to 14.85% in the samples collected from tagged inflorescences and 1.31 to 14.15% in the samples collected at random (Table 3). Eight accessions (ICPW 83, ICPW 90, ICPW 116, ICPW 125, ICPW 141, ICPW 278, ICPW 280, and ICPW 281) of *C. scarabaeoides* and two (ICPW 159 and ICPW 160) of *C. sericeus* in the medium maturity group showed 0.00 to 5.15% pod damage compared to 12.85 to 14.85% pod damage in *C. cajanifolius* and 2.10 to 9.00% damage in *C. cajan* genotypes. In the long duration group, accessions belonging to *C. acutifolius* (ICPW 1 and ICPW 2), *C. albicans* (ICPW 14), and *C. lineatus* (ICPW 40) suffered low (<5.85%) pod damage compared to 14.45 to 35.55% pod damage in ICPW 41 (*C. lineatus*), and 2.54 to 8.61% damage in ICPL 87 (Table 4). *Flemingia bracteata* (ICPW 192), *F. stricta* (ICPW 202), *P. scariosa* (ICPW 207), and *R. bracteata* (ICPW 214) showed moderate susceptibility to pod fly damage.

Relative susceptibility to pod wasp, Tanaostigmodes cajaninae

Pod wasp damage ranged from 0.00% in ICPW 159 to 30.61% in ICPW 83 in pods collected from the tagged inflorescences, and 1.43% in ICPL 332 to 24.56% in ICP 7203-1 (Table 1). Accessions ICPW 141, ICPW 278, and ICPW 280 (*C. scarabaeoides*), and ICPW

Table 1. Pod fly and pod wasp damage in pigeonpea (*Cajanus cajan*) and its wild relatives under field conditions (ICRISAT, Patancheru, 1998 rainy season).

Species	Accession number	Pod damage (%)*			
		Samples from tagged inflorescences		Samples taken at random	
		Pod fly	Pod wasp	Pod fly	Pod wasp
Cajanus. platycarpus	ICPW 68	31.39	4.03	7.51	12.29
C. scarabaeoides	ICPW 83	2.12	30.61	5.41	6.94
C. scarabaeoides	ICPW 90	0.00	1.99	2.61	18.84
C. scarabaeoides	ICPW 94	2.19	12.96	0.48	0.00
C. scarabaeoides	ICPW 116	3.54	7.83	7.18	13.33
C. scarabaeoides	ICPW 125	2.17	8.05	9.75	23.73
C. scarabaeoides	ICPW 130	2.61	8.99	16.10	14.38
C. scarabaeoides	ICPW 137	3.85	21.88	5.38	9.05
C. scarabaeoides	ICPW 141	3.85	8.34	3.05	4.18
C. scarabaeoides	ICPW 152	10.29	19.54	1.98	6.38
C. scarabaeoides	ICPW 278	0.83	3.13	2.51	9.68
C. scarabaeoides	ICPW 280	2.16	9.11	3.01	9.70
C. scarabaeoides	ICPW 281	0.65	7.73	3.35	14.11
C. cajanifolius	ICPW 28	4.26	5.60	1.15	11.30
C. sericeus	ICPW 159	0.00	0.00	6.16	22.12
Rhynchosia bracteata	ICPW 214	3.30	7.71	2.73	5.34
C. albicans	ICPW 13	4.24	11.97	2.54	6.19
C. cajan	ICPL 332	10.11	13.36	29.52	1.43
C. cajan	ICP 7203-1	7.81	17.70	0.98	24.56
C. cajan	ICPL 84060	6.50	11.93	0.92	9.52
C. cajan	ICPL 187-1	11.38	28.67	1.76	4.07
C. cajan	ICPL 87	5.89	5.57	3.20	6.14
Mean	5.42	11.21	5.33	10.60	
SE	±2.24	±4.87	±2.88	±3.94	

* Means of two sowings during the 1998 rainy season

Table 2. Pod fly and pod wasp damage in seven accessions of short-duration wild relatives of pigeonpea (ICRISAT, Patancheru, 1999 and 2000 rainy seasons).

Species	Accession number	Pod damage (%)*			
		Samples taken from tagged inflorescences		Samples taken at random	
		Pod fly	Pod wasp	Pod fly	Pod wasp
Cajanus platycarpus	ICPW 68	12.65	5.75	11.45	5.75
Cajanus scarabaeoides	ICPW 94	2.70	6.30	2.10	12.35
Cajanus scarabaeoides	ICPW 130	2.05	12.65	6.10	13.25
Cajanus scarabaeoides	ICPW 137	3.35	13.55	5.10	16.60
Cajanus scarabaeoides	ICPW 152	2.85	12.50	5.25	3.15
Rhynchosia aurea	ICPW 210	6.55	2.40	18.55	3.90
Cajanus cajan-check	ICPL 87	7.35	1.00	1.90	5.10
Mean		5.36	7.70	7.21	8.60
SE		±1.8	±3.88	±1.64	±4.37

* Means of 1999 and 2000 rainy seasons

214 (*R. bracteata*) suffered <9.70% pod wasp damage compared to 30.61% damage in ICPW 83 (*C. scarabaeoides*). There was considerable variation in the susceptibility of different accessions of *C. scarabaeoides* to pod wasp damage. ICPW 83, ICPW 125, ICPW 137, ICPW 159, ICP 7203-1, and ICPL

Table 3. Pod fly and pod wasp damage in 12 accessions of medium-duration wild relatives, and five genotypes of pigeonpea (ICRISAT, Patancheru, 1999 and 2000 rainy seasons)

Species	Accession number	Pod damage (%)*			
		Samples taken from tagged inflorescences		Samples taken at random	
		Pod fly	Pod wasp	Pod fly	Pod wasp
C. cajanifolius	ICPW 28	14.85	12.25	14.15	16.84
C. cajanifolius	ICPW 29	12.85	10.95	1.75	6.14
C. scarabaeoides	ICPW 83	3.05	26.00	4.29	25.61
C. scarabaeoides	ICPW 90	5.15	32.70	1.47	31.16
C. scarabaeoides	ICPW 116	3.90	20.70	3.20	27.52
C. scarabaeoides	ICPW 125	1.30	22.25	2.65	18.86
C. scarabaeoides	ICPW 141	0.60	13.05	1.31	10.87
C. sericeus	ICPW 159	0.00	1.30	2.20	1.07
C. sericeus	ICPW 160	0.00	3.95	1.70	2.37
C. scarabaeoides	ICPW 278	3.65	10.00	3.50	8.75
C. scarabaeoides	ICPW 280	3.10	15.35	2.86	8.84
C. scarabaeoides	ICPW 281	2.20	10.65	3.99	11.92
C. cajan	ICPL 332	3.90	9.85	4.11	6.07
C. cajan	ICP 7203-1	2.10	3.20	2.43	2.24
C. cajan	ICPL 84060	6.40	7.10	3.89	4.87
C. cajan	ICPL 187-1	9.00	7.15	5.05	4.24
C. cajan	ICPL 87	3.00	2.05	7.92	2.37
Mean		4.42	12.3	3.7	11.2
SE		±2.23	±7.35	±1.45	±6.39

* Mean of 1999 and 2000 rainy seasons

Table 4. Pod fly and pod wasp damage in 11 accessions of long-duration wild relatives of pigeonpea (ICRISAT, Patancheru, 1999 and 2000 rainy seasons).

Species	Accession number	Pod damage (%)*			
		Samples taken from tagged inflorescences		Samples taken at random	
		Pod fly	Pod wasp	Pod fly	Pod wasp
C. acutifolius	ICPW 1	2.45	34.50	1.55	25.90
C. acutifolius	ICPW 2	0.00	40.15	0.25	31.95
C. albicans	ICPW 13	9.10	26.80	2.65	19.45
C. albicans	ICPW 14	5.85	14.00	3.45	12.45
C. lineatus	ICPW 40	1.70	32.25	2.90	20.90
C. lineatus	ICPW 41	14.45	26.35	35.55	60.30
Flemingia bracteata	ICPW 192	8.05	30.05	1.85	24.05
Flemingia stricta	ICPW 202	1.09	17.71	8.36	9.58
Paracalyx scariosa	ICPW 207	8.70	42.20	5.65	31.55
Rhynchosia bracteata	ICPW 214	14.95	19.55	0.00	38.20
C. cajan	ICPL 87	8.61	−0.21	2.54	1.22
Mean		6.80	25.80	5.90	25.10
SE		±5.93	±13.59	±11.59	±23.45

* Mean of 1999 and 2000 rainy seasons

187-1 suffered >20% pod wasp damage in one or both the sampling methods. The estimates of pod wasp damage differed between the two sampling methods. ICPW 141, ICPW 278, and ICPW 280 (*C. scarabaeoides*) and ICPW 214 (*R. bracteata*) showed resistance to both pod fly and pod wasp damage.

During the 1999/2000 rainy seasons, ICPW 68 (*C. platycarpus*) and ICPW 210 (*R. aurea*), which were susceptible to the pod fly damage, were least susceptible to pod wasp damage among the early maturing accessions. Among the *C. scarabaeoides* accessions tested, the pod wasp damage ranged from 3.15 to 16.60%. Pod wasp damage was also low in the cultivated genotype, ICPL 87, possibly because of its high susceptibility to pod borers. None of these accessions showed cross-resistance to pod fly and pod wasp. In the medium maturity group, accessions belonging to C. *scarabaeoides* and *C. cajanifolius* suffered greater pod wasp damage than the accessions belonging to *C. sericeus* (Table 3). Among the cultivated pigeonpea genotypes tested, the pod wasp damage ranged from 2.05 to 9.85%, and there was no trend in susceptibility to pod wasp across the two sampling methods. *Cajanus albicans* (ICPW 14) and ICPW 202 (*F. stricta*) showed less susceptibility to pod wasp (9.58 to 17.71% pod damage) compared to 26.80 to 60.30% damage in *C. acutifolius* (ICPW 1 and ICPW 2), *C. albicans* (ICPW 13), *C. lineatus* (ICPW 40 and ICPW 41), *F. bracteata* (ICPW 192), *P. scariosa* (ICPW 207), and *R. bracteata* (ICPW 214) (Table 4). ICPW 14 (*C. albicans*) and ICPW 202 (*F. stricta*) showed resistance to both pod fly and pod wasp damage. Pod fly damage was positively associated with egg and larval numbers and pod damage by *H. armigera* (R = 0.63** to 0.66**), while pod wasp damage showed a negative association (r = −0.31 to −0.36). However, there was no association between pod fly and pod wasp damage (r = −0.04). Therefore, while developing pigeonpea cultivars with resistance to pod borers, care should be taken that such cultivars are not highly susceptible to the pod wasp, in the absence of competition from other insect species.

Table 5. Association of morphological characteristics of 25 accessions of wild relatives of pigeonpea with pod fly and pod wasp damage (ICRISAT, Patancheru 1999 and 2000 rainy seasons)

	Pod damage (%)	
	Pod wasp	Pod fly
Days to flowering (days)	0.62**	0.10
Days to maturity (days)	0.60**	0.12
Growth habit	0.11	−0.18
Leaf length	0.13	0.25
Leaf width	0.24	0.17
Pod width	0.26	0.10
Pod length	0.11	0.23
Protein content	−0.29	−0.09
Seeds/pod	−0.28	−0.23
Seed weight	0.28	0.26
Flower streak colour	−0.04	0.35*
Streak density on flowers	−0.01	0.33

Flower streak color (1 = red, 2 = no streaks). Streak density on flowers (1 = few streaks, 2 = dense streaks, 3 = medium streaks, and 4 = no streaks). Growth habit (1 = erect, and 2 = creeper) *, ** = Correlation coefficients are significant at P = 0.05 and 0.01, respectively

Association of plant morphological characteristics with resistance to pod fly and pod wasp damage

Days to flowering and maturity showed a significant and positive association with pod wasp damage (r = 0.60** to 0.62**), but there was no association of these characteristics with pod fly damage (Table 5). Leaf length and width, pod length and width, and seed weight showed a positive correlation with pod fly and pod wasp damage (r = 0.10 to 0.28). Protein content and seeds per pod were negatively associated with the pod wasp damage, while flower streak color and streak density showed positive association with pod fly damage (r = 0.33 to 0.35*). However, some of the correlation coefficients were non-significant. Stepwise regression analysis indicated that days to maturity (DM), leaf length (LL), and leaf width (LW) explained 51.7% of the variation in pod wasp (Pwp) damage [Pwp (Y) = −4.88 + 0.19DM** − 4.02LL* + 4.05LW (R^2 = 51.7%).

Principal component analysis

Principle component analysis of pod fly and pod wasp damage and the morphological characteristics indicated that there is considerable diversity in accessions of wild relatives of pigeonpea. The test genotypes were placed into four groups [1 = ICPW 68 (*C. platycarpus*), ICPW 94, ICPW 125, ICPW 130, ICPW 137, ICPW 141, ICPW 152, and ICPW 281 (*C. scarabaeoides*), and ICPW 210 (*R. aurea*); II = ICPW 83, ICPW 90, ICPW 116, and ICPW 280 (*C. scarabaeoides*), ICPW 159 and ICPW 160 (*C. sericeus*), ICPW 13 and ICPW 14 (*C. albicans*); III = ICPW 28 and ICPW 29 (*C. cajanifolius*) and ICPL 332 and ICPL 87 (*C. cajan*); IV = ICPW 1 and ICPW 2 (*C. acutifolius*), ICPW 40 and ICPW 41 (*C. lineatus*), ICPW 192 (*F. bracteata*), ICPW 202 (*F. stricta*), ICPW 207 (*P. scariosa*), and ICPW 214 (*R. bracteata*)] (Figure 1).

Discussion

Early-flowering genotypes suffer low pod fly damage

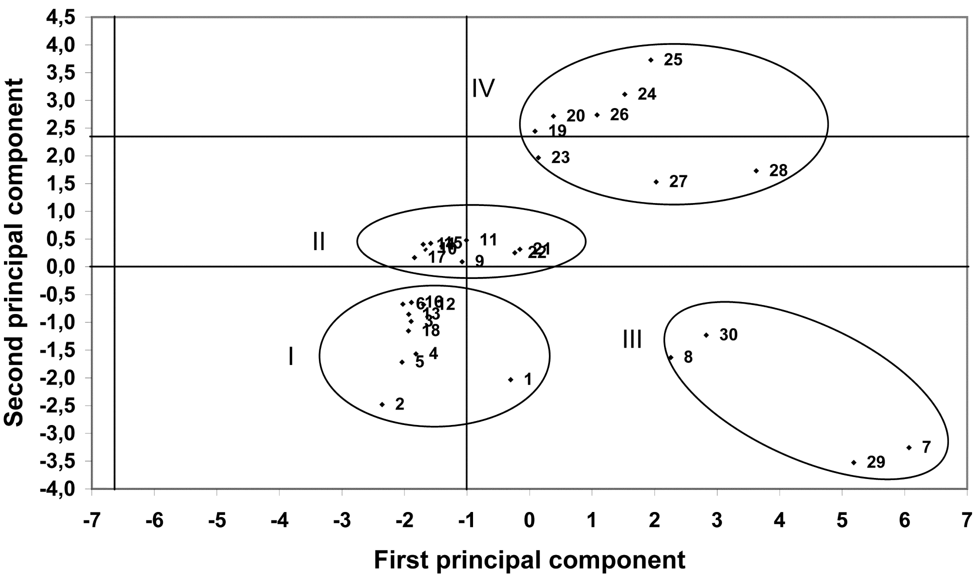

Figure 1. Principal component analysis of 30 accessions of wild relatives of pigeonpea based on pod fly and pod wasp damage and plant traits listed in Table 5 (1 = ICPW 68, 2 = ICPW 94, 3 = ICPW 130, 4 = ICPW 137, 5 = ICPW 152, 6 = ICPW 210, 7 = ICPW 28, 8 = ICPW 29, 9 = ICPW 83, 10 = ICPW 90, 11 = ICPW 116, 12 = ICPW 125, 13 = ICPW 141, 14 = ICPW 159, 15 = ICPW 160, 16 = ICPW 278, 17 = ICPW 280, 18 = ICPW 281, 19 =ICPW 1, 20 = ICPW 2, 21 = ICPW 13, 22 = ICPW 14, 23 = ICPW 40, 24 = ICPW 41, 25 = ICPW 192, 26 = ICPW 202, 27 = ICPW 207, 28 = ICPW 214, 29 = ICPL 87, and 30 = ICPL 332).

in comparison to the late-maturing cultivars (Bhosale and Nawale 1985; Lal et al. 1988; Shanower et al. 1998), and the indeterminate types are more susceptible than the determinate types because of availability of green pods for a longer period (Lal et al. 1986; Gupta et al. 1991). However, there was no relationship between pod fly damage and days to flowering and maturity under conditions in southern India. More than 10,000 germplasm accessions have been evaluated for pod fly resistance (Lateef and Pimbert 1990), and 10 lines (ICRISAT 16, 166-2-1, ICP 7946-1-3-3, ICP 127, SL 12-3-1, 41-3-3, PDA 88-2E, 3-1, ICP 3401, ICP 7950, and ICP12304) have been identified to be promising for resistance to pod fly. These lines have been tested across locations in India. Borad et al. (1991) reported ICPL 7035, GAUT 85-K, ICPL 87075 and ICPL 151 to be less susceptible to pod fly. Durairaj and Ganapathy (1997) reported that PDA 92-2E was less susceptible to pod fly. However, Singh and Singh (1990) observed that no definite conclusions could be drawn about the relative susceptibility of pigeonpea genotypes to pod fly damage because of staggered flowering, and fluctuations in pod fly density during the crop-growing season. There are no specific studies on genotypic resistance to the pod wasp, *T. cajaninae*. Lateef et al. (1985) reported 1.5 to 12.6% pod wasp damage in the 16 genotypes of pigeonpea, of which ICPL 7537, ICPL 4185-1, ICPL 7041, and PPE-3821 suffered $<2\%$ pod damage compared to 12.6% damage in PPE 35-1.

In the present studies, we observed significant inter- and intra-species differences in the relative susceptibility to pod fly and pod wasp damage. Accessions belonging to *C. scarabaeoides*, *C. cajanifolius*, *C. sericeus*, *R. bracteata*, *C. acutifolius*, *C. lineatus* and *C. albicans* showed resistance to pod fly damage, while those belonging to *C. platycarpus*, *C. cajanifolius*, and *R. aurea* showed a susceptible reaction. *Flemingia bracteata*, *F. stricta*, *P. scariosa*, and *R. bracteata* showed moderate susceptibility to pod fly damage. There was considerable variation in pod fly damage among the *C. scarabaeoides* accessions tested.

Accessions ICPW 141, ICPW 278, and ICPW 280 (*C. scarabaeoides*), and ICPW 214 (*R. bracteata*) showed a resistant reaction to pod wasp, while ICPW 83 (*C. scarabaeoides*) showed a susceptible reaction. ICPW 141, ICPW 278, and ICPW 280 (*C. scarabaeoides*), ICPW 14 (*C. albicans*), *F. stricta* (ICPW 202) and ICPW 214 (*R. bracteata*) showed resistance to both pod fly and pod wasp damage. Accessions belonging to C. *scarabaeoides* and *C. cajanifolius* suffered greater pod wasp damage than the accessions belonging to *C. sericeus*. Accessions belonging to *Cajanus albicans* and *F. stricta* were resistant to pod wasp damage. Accessions belonging to *C. acutifolius*, *C. lineatus*, *F. bracteata*, *P. scariosa*, *R. bracteata*, and *C. platycarpus* and *R. aurea*, which were susceptible to pod fly damage, were less susceptible to pod wasp damage during the 1999/2000 rainy seasons. Pod fly and pod wasp damage was also low in the cultivated pigeonpea genotypes possibly because of their high susceptibility to the pod borers. There was considerable variation in pod damage estimates in samples collected from the inflorescences flowering at the same time and in the pod samples collected at maturity. Therefore, it is essential to record pod damage in samples collected from branches flowering at the same time, or compare the damage levels among the genotype with similar maturity. There is considerable diversity in accessions of wild relatives of pigeonpea, which can be exploited to breed for resistance to these pests. Resistance to pod borers and pod fly can be combined in the same genetic background. However, there is a negative association between pod wasp and pod borer damage. Therefore, it is important to keep track of the relative susceptibility of pigeonpea genotypes to pod wasp, while breeding for resistance to pod borers.

Acknowledgements

We thank Mr. Madhusudan Reddy, Mr V V Rao, and Mr Raja Rao for help in the field experiments, and Mr Harikrishna for advise on statistical analysis.

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