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# MECHANISMS AND DIVERSITY OF RESISTANCE TO THE SORGHUM MIDGE, CONTARINIA SORGHICOLA COQ.

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## ABSTRACT

Cultivar non-preference to adults, less oviposition, and antibiosis are the major components of resistance to the sorghum midge, Contarinia sorghicola Coq. Short floral parts, faster rates of ovary development, and high tannin content of grain are apparently associated with resistance to sorghum midge. However, cultivars either having high tannin content or short floral parts may not always be resistant, and that lines having low tannin content (e.g. DJ 6514) are also known to be resistant. Different genotypes seem to have different combinations of the factors apparently associated with resistance to sorghum midge. Glume length G2, lodicule length and breadth, rate of ovary development based on grain size, and tannin content of mature grain have the correlation and path coefficients (direct effects) in the same direction, and these characters may be useful in selecting for resistance to sorghum midge. Glume length G1, lema length L1, anther length, and palea length were positively correlated with susceptibility to midge, but had negative direct effects. Ovary growth rate, based upon fresh weight of grains was negatively associated with midge damage but showed positive direct effects. Sources of resistance to sorghum midge having different mechanisms were placed in separate groups based upon canonical-variate analysis. There is a distinct possibility of increasing the levels and broadening the basis of resistance to sorghum midge.


## INTRODUCTION

Sorghum midge, Contarinia sorghicola Coq. is the most destructive pest of grain sorghum all over the world (Harris, 1976). Resistant cultivars could be an important means of minimizing midge damage to sorghum (Sharma, 1984). The nature of resistance to sorghum midge is variable amongst different cultivars. Factors such as short glumes (Ball and Hastings, 1912), cliestogamous glume character (long glumes)(Bowden and Neve, 1953), and nature of glume coupling (Geering,

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1953; Berguist _et al._, 1974; Rossetto _et al._, 1975) have been reported to be associated with midge resistance. Murty and Subramaniam (1978) reported that glume length, rachis length, and the presence of awns were not associated with midge resistance.

At the ICRISAT center, studies were initiated to investigate the role of morphological characteristics of the florets, rate of ovary development, and the tannin content of sorghum grain in resistance to sorghum midge.

## MATERIALS AND METHODS

The studies were conducted using four resistant DJ 6514 (Shyamsunder _et al._, 1975), TAM 2566 (Johnson _et al._, 1973), AF 28 (Rossetto _et al._, 1975), and IS 15107 (Sharma, 1984) and two susceptible (CSH 1 and Swarna) cultivars over four cropping seasons between 1982 to 1984. Cultivar non-preference to adults was recorded for two seasons only. The cultivars were planted in a randomized complete block design with three replications. Each plot was 4x3 m. The crop was planted on ridges 75 cm apart. The plants were thinned to 10 cm spacing within the row 15 days after emergence.

### Insect/Host-Plant Relationship

Cultivar non-preference to adults was recorded during 1981 rainy season and 1982-83 postrainy season as the number of midges attracted to the panicles of different genotypes during flowering under free choice field conditions. The number of adult midges on five randomly selected panicles was recorded at top-anthesis in each plot for three consecutive days between 0900 to 1000h. The number of eggs and larvae, and adult emergence were recorded over four seasons under no-choice conditions by artificially infesting the sorghum panicles with 60 female midge flies per panicle at top-anthesis stage using a headcage (Sharma, 1984). The panicles were covered with muslin cloth bags at panicle emergence to avoid oviposition by the natural midge population. Nine randomly selected panicles were caged in each plot, of which three panicles each were utilized to record data on each parameter (egg number, larval number, and adult emergence). The number of chaffy florets (florets without grain due to damage by midge larvae) was recorded in panicles used for recording larval numbers. Eggs in florets were counted two days after caging midges on the sorghum panicles. Three primary branches were taken from the top, middle, and lower portion of the infested panicles, and the primary branches were then split into smaller secondary branches. From these secondary branches, 250 florets were picked up randomly to record the number of florets with eggs and the total number of eggs. The number of florets with midge larvae, and the total number of larvae per 300 florets were recorded 10 days after infestation in the same manner as the egg numbers were recorded. Fifteen days after infestation, the number of florets with midge larvae and the number of chaffy florets were recorded from a sample of 500 florets. The adult emergence in each panicle was recorded between 15 and 30 days after infestation. Midge emergence in the headcages was recorded daily. The midges were collected with an aspirator and counted.

## Floral Morphology

The linear measurements (length and/or breadth) of different floral parts (glume G1 and G2, lema L1 and L2, palea, lodicule, anther, ovary, stigma and style) were made on 10 florets at anthesis under a microscope with an ocular micrometer. The samples were drawn from three panicles of each cultivar.

## Rate of Ovary Growth

The rate of ovary growth was measured in terms of the size(width), fresh weight, and dry weight of the developing grain. Random samples of 300 grains were taken on the third and seventh day after anthesis from the mid portion of three panicles to record fresh and dry weights in each replication. Grains were dried at 80 C to a constant weight in an oven. Grain size was measured with a specially designed grain size meter (Sharma, 1984) on third and seventh day after anthesis. The rates of ovary growth were determined between third and seventh day after anthesis as explained in Table 2.

## Tannin Content of Grain

The tannin content of 10-day-old and mature grain was determined by the method of Mertin _et al_. (1978). The grains were dried completely at 80 C in an oven.

Data were statistically analysed to determine the differences between cultivars in the parameters measured. Correlation coefficients between six dependent (number of eggs/100 florets, % florets with eggs, number of larvae/100 florets, % florets with larvae, % chaffy florets, and adult emergence) and 14 independent variables (glume length G1 and G2, lema length L1 and L2, palea length, lodicule and anther length and breadth, ovary growth rates (g1, g2 and g3), and tannin content of 10-day-old and mature grain) were calculated. The data were also subjected to cononical (Rao, 1952) and path coefficient (Dewey and Lu, 1959) analysis in an attempt to determine the diversity in the sources of resistance and the direct and indirect contribution of various factors associated with midge resistance.

## RESULTS AND DISCUSSION

The results on the various parameters measuring insect/host-plant interaction are given in Table 1. Susceptible cultivars (CSH 1 and Swarna) were generally more attractive to the midge flies than TAM 2566 and IS 15107. Cultivar non-preference is one of the mechanisms of resistance to sorghum midge (Wiseman and McMillian, 1968; Sharma, 1984). However, cultivar non-preference may have limited value when the same cultivar is planted over a large area in farmers' fields. Number of eggs/100 florets and % florets with eggs were higher in CSH 1 and Swarna. AF 28 and TAM 2566 had lower percentage of florets with eggs, followed by DJ 6514 and IS 15107. The closed spikelet character of AF 28 has been suggested to make oviposition apparently difficult (Rossetto et al., 1975). The number of florets with midge larvae and the number of larvae/100 florets were lowest in DJ 6514 followed by TAM 2566, AF 28, and IS 15107. Adult emergence was very low in resistant cultivars (15 to 71 midges/panicle) compared to the susceptible ones (318 to 404 midges/panicle). The number of chaffy florets was least in DJ 6514, closely followed by AF 28, TAM 2566, and IS 15107. Grain damage in the susceptible cultivars CSH 1 and Swarna was much higher (>81%) than in the resistant ones (<39%).

There were significant differences amongst the cultivars in the linear measurements of the floral parts, rates of grain development, and the tannin content of the grain (Table 2). The correlation coefficients between the dependent and independent variables are given in Table 3. The rate of grain development was generally higher in the resistant cultivars than in the susceptibles, and were negatively associated with susceptibility to sorghum mige. Long glume G1 and G2, lema L1 and L2, palea, lodicule, anther, style, and stigma and lodicule breadth were positively associated with susceptibility to sorghum midge. Ovary and anther breadth showed negative correlation with susceptibility to sorghum midge. Tannin content of grain was also negatively correlated with susceptibility to mige, although there were distinct exceptions e.g. DJ 6514 is highly resistant but has a low tannin content.

The direct and indirect effects of 14 floret characters associated with midge resistance are given in Table 4. Glume length G2 showed positive direct effects, and the indirect effects were also positive through lodicule length and breadth, and ovary growth rate based upon grain size. Lodicule length and breadth showed positive direct effects as also the indirect effects through glume length G2. The direct effects of ovary growth rate based on grain size were negative as were also the indirect effects of this factor through glume length G2 and lodicule length. Tannin content of mature grain showed negative direct effects as well as an association with midge damage. The correlation coefficients and direct effects of glume length G2, lodicule length and breadth, ovary growth rate based upon grain size, and the tannin content of mature grain were in the same direction, and hence, these characters might be useful in selecting for resistance to sorghum midge.

The correlation coefficients and direct effects of glume length G1, lema length L1, and ovary growth rate based on fresh weight of grain were in opposite directions. The positive association of glume length G1 and Lema length L1 with susceptibility to midge was through glume length G2, lodicule length and breadth, and ovary growth rate based upon grain size.

Short glumes (Ball and Hastings, 1912) and other floral parts thus seem to be associated with resistance to sorghum midge. Less oviposition, apparently because of glume coupling (Rossetto et al., 1975) is another factor associated with resistance to midge. Antibiosis (larval/pupal mortality) is also a component of resistance to midge e.g. the least number of larvae and adults were recorded on DJ 6514, although it had the maximum number of eggs amongst the resistant cultivars. This contrasts with AF 28, which had least eggs, but ranked 2nd and 3rd in larval and adult numbers respectively.

The canonical clusters based on different parametes are shown in Fig.1. The cultivars were placed in separate groups based on different parameters measuring susceptibility to sorghum midge. DJ 6514 and TAM 2566 were generally grouped together (except the groups based on number of larvae/100 florets). AF 28 was always placed independently as was Swarna (except in groups based on number of eggs/100 florets). These results suggest that the sources of midge resistance are diverse and have different mechanisms of resistance which can be utilized in increasing the levels and diversity of resistance.

## CONCLUSIONS

Resistance to sorghum midge is mainly comprised of cultivar non-preference to adults, less oviposition, and antibiosis. Short floral parts, faster rate of ovary growth, and high tannin content of grain are apparently associated with resistance. However, there may be distinct exceptions to this trend, and cultivars having either of these characters may not always be resistant and vice-versa. Glume length G2, lodicule length and breadth, ovary growth rate based on grain size and tannin content of mature grain may be useful in breeding for midge resistance, and need to be evaluated in a diverse array of germplasm and breeding materials. Sorghum midge resistant cultivars are diverse, and there is a distinct possibility of increasing resistance levels and broadening the basis of resistance by hybridization amongst the diverse sources.

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Table 1

Cultivar preference under free choice conditions and oviposition, larval numbers, adult emergence, and midge damage in six sorghum cultivars under no-choice conditions in four seasons

| Cultivar | No. of midge flies/ 5 heads | | % of florets with eggs | No. of eggs/ 100 florets | % of florets with larvae (10 days after infestation) | No. of larvae/ 100 florets | % of florets with larvae (15 days after infestation) | No. of adults emerged/ head | Midge damage (% chaffy florets) |
|---|---|---|---|---|---|---|---|---|---|
| | 1980R* | 1982-83P* | | | | | | | |
| DJ 6514 | 7 | 20 | 23 (28)[a] | 37 (6)[b] | 7 (14)[a] | 8 (2)[b] | 2 (8)[a] | 15 (3)[b] | 15 (22)[a] |
| AF 28 | 11 | 8 | 17 (23) | 21 (4) | 43 (40) | 56 (7) | 8 (16) | 24 (4) | 33 (34) |
| TAM 2566 | 5 | 15 | 18 (24) | 37 (5) | 31 (34) | 41 (6) | 13 (20) | 33 (6) | 30 (33) |
| IS 15107 | 5 | 13 | 23 (27) | 38 (6) | 47 (42) | 59 (7) | 18 (24) | 71 (8) | 39 (38) |
| CSH 1 (S) | 12 | 33 | 54 (47) | 153 (12) | 81 (65) | 142 (12) | 74 (60) | 404 (19) | 81 (65) |
| Swarna (S) | 10 | 36 | 50 (44) | 141 (11) | 74 (60) | 127 (11) | 72 (58) | 318 (18) | 83 (66 |
| SE | ±0.9 | ±2.4 | ±(2.9) | ±(0.9) | ±(3.2) | ±(1.2) | ±(4.6) | ±(1.1) | ±(4.1) |
| LSD (0.05) | 2.48 | 6.62 | 8.01 | 2.48 | 8.83 | 3.31 | 12.69 | 3.04 | 11.32 |
| CV (%) | 19.7 | 20.3 | (19.8) | (27.6) | (16.2) | (14.6) | (19.8) | (24.2) | (20.9) |

1 = Mean of 4 seasons
*R = Rainy season
*P = Postrainy season
a = Figures in parentheses are Arcsin $\sqrt{\%}$ transformed values
b = $\sqrt{N}$ Transformed values
(S)= Susceptible check

Table 2. Linear measurements of floral parts, ovary growth rates, and tannin content in six cultivars (4 season means)

| Cultivar | Glume G1 length | Glume G2 length | Lemma L1 length | Lemma L2 length | Lodicule length | Lodicule bredth | Anther length | Anther bredth | Palea length | Growth rate $g_1$ | Growth rate $g_2$ | Growth rate $g_3$ | Tannins in 10 days | Tannins in matured grain |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DJ 6514 | 139 | 142 | 128 | 70 | 55 | 25 | 83 | 34 | 95 | 0.77 | 1.47 | 0.47 | 0.063 | 0.027 |
| AF 28 | 137 | 139 | 130 | 110 | 51 | 23 | 90 | 32 | 99 | 0.75 | 1.87 | 0.97 | 13.8 | 7.0 |
| TAM 2566 | 122 | 125 | 115 | 98 | 59 | 26 | 83 | 32 | 84 | 0.67 | 1.03 | 0.83 | 10.7 | 1.0 |
| IS 15107 | 154 | 151 | 136 | 107 | 55 | 30 | 99 | 29 | 91 | 1.03 | 1.52 | 0.94 | 10.25 | 3.0 |
| CSH 1 | 181 | 180 | 149 | 123 | 71 | 27 | 120 | 34 | 103 | 0.47 | 0.93 | 0.31 | 0.24 | 0.03 |
| Swarna | 188 | 192 | 163 | 137 | 59 | 32 | 108 | 30 | 105 | 0.47 | 0.85 | 0.55 | 5.93 | 0.03 |
| SE | ±2.49 | ±2.64 | ±2.09 | ±1.99 | ±1.24 | ±0.68 | ±1.31 | ±0.73 | ±3.37 | ±0.09 | ±0.09 | ±0.12 | ±2.7 | ±0.15 |
| LSD (0.05) | 6.87 | 7.28 | 5.77 | 5.49 | 3.42 | 1.87 | 3.61 | 2.01 | 9.30 | 0.25 | 0.25 | 0.33 | 7.45 | 0.41 |
| CV(%) | 3.56 | 3.73 | 3.34 | 4.05 | 4.64 | 5.46 | 2.96 | 5.04 | 7.67 | 2.9 | 3.3 | 3.7 | 8.8 | 18 |

[a] Lenear measurements are in occular scale units (40 occular scale units = 1 mm)

[b] Ovary growth rate ($g_1$, $g_2$ and $g_3$) = Size/wt. of the ovary on 7th day after anthesis - Szie/wt. of the ovary on 3rd day after anthesis / Mean size/wt. of the ovary during the observation period x Duration of the observation period

$g_1$ Growth rate 1 (between 3rd and 7th day) based upon grain size.

$g_2$ Growth rate 2 (between 3rd and 7th day) based upon fresh weight of the grain.

$g_3$ Growth rate 3 (between 3rd and 7th day) based upon dry weight of the grain.

Table 3

Correlation coefficients between the parameters measuring midge resistance and ovary growth rates, linear measurements of floral parts and tannin content of grain (Sharma, 1984)

| Floral Parameter | % florets with midge larvae | % chaffy florets | % florets with eggs | eggs/100 florets | Larvae/100 florets | Adult emergence/ head |
|---|---|---|---|---|---|---|
| Ovary growth rate g1 | -0.35 | -0.36 | -0.20 | -0.21 | -0.12 | -0.25 |
| Ovary growth rate g2 | -0.50** | -0.49* | -0.36 | -0.54** | -0.33 | -0.41* |
| Ovary growth rate g3 | -0.37 | -0.24 | -0.49* | -0.53** | -0.17 | -0.31 |
| Glume length - G1 | 0.87** | 0.79** | 0.73** | 0.69** | 0.75** | 0.81** |
| Glume length - G2 | 0.89** | 0.80** | 0.77** | 0.73** | 0.74** | 0.81** |
| Lema length - L1 | 0.82** | 0.74** | 0.67** | 0.70** | 0.71** | 0.78** |
| Lema length - L2 | 0.78** | 0.79** | 0.59** | 0.60** | 0.88** | 0.85** |
| Palea length | 0.56** | 0.49** | 0.56** | 0.56** | 0.63** | 0.67** |
| Lodicule length | 0.68** | 0.59** | 0.58** | 0.51** | 0.50* | 0.60** |
| Lodicule breadth | 0.49* | 0.43* | 0.35 | 0.49* | 0.36 | 0.38 |
| Ovary length | 0.32 | 0.33 | 0.21 | 0.19 | 0.35 | 0.38 |
| Ovary breadth | -0.16 | -0.18 | -0.15 | -0.21 | -0.13 | -0.16 |
| Anther length[a] | 0.89** | 0.82** | 0.72** | 0.65** | 0.84** | 0.89** |
| Anther breadth | -0.16 | 0.17 | -0.06 | -0.14 | -0.42* | -0.29 |
| Style length | 0.80** | 0.63** | 0.68** | 0.68** | 0.50* | 0.59** |
| Stigma length | 0.26 | 0.24 | 0.32 | 0.26 | 0.25 | 0.31 |
| Tannins 10 day grains | -0.51** | -0.32 | -0.62** | -0.52** | -0.33 | -0.52** |
| Tannins in mature grains | -0.47 | -0.32 | -0.47* | -0.45* | -0.23 | -0.45* |

*Significant at P0.05

**Significant at P0.01

Table 4

Direct and indirect effects of 14 characters on midge damage (% chaffy florets)

| Character | Glume G1 length | Glume G2 length | Lemma L1 length | Lemma L2 length | Lodicule length | Lodicule breadth | Anther length | Anther breadth | Palea length | Growth rate 1 | Growth rate 2 | Growth rate 3 | Tannins in 10 days | Tannins in matured grain | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Glume G1 | -1.15$^{P}$ | 2.21 | -1.32 | 0.11 | 0.98 | 0.55 | -0.23 | 0.19 | -0.13 | 0.78 | -1.48 | 0.16 | -0.06 | 0.20 | 0.75 |
| Glume G2 | -1.5 | 2.2$^{P}$ | -1.3 | 0.11 | 0.94 | 0.56 | -0.22 | 0.18 | -0.13 | 0.88 | -1.5 | 0.16 | -0.07 | 0.21 | 0.80 |
| Lemma L1 | -1.4 | 2.2 | -1.3$^{P}$ | 0.12 | 0.69 | 0.57 | -0.21 | 0.32 | -0.14 | 0.75 | -1.3 | 0.13 | -0.05 | 0.16 | 0.74 |
| Lemma L2 | -1.14 | 1.68 | -1.03 | 0.15$^{P}$ | 0.67 | 0.46 | -0.20 | 0.49 | -0.09 | 0.75 | -1.2 | 0.02 | 0.02 | -0.01 | 0.79 |
| Lodicule length LL | -0.85 | 1.21 | -0.54 | 0.06 | 1.7$^{P}$ | 0.19 | -0.18 | -0.51 | -0.05 | 0.94 | -2.1 | 0.20 | -0.09 | 0.33 | 0.59 |
| Lodicule breadth LB | -0.96 | 1.4 | -0.89 | 0.08 | 0.39 | 0.87$^{P}$ | -0.12 | 0.73 | -0.03 | 0.19 | -1.6 | 0.04 | -0.01 | 0.26 | 0.43 |
| Anther length AL | -1.4 | 1.9 | -1.14 | 0.12 | 1.26 | 0.42 | -0.25$^{P}$ | 0.07 | -0.11 | 0.72 | -1.4 | 0.14 | -0.05 | 0.14 | 0.82 |
| Anther breadth AB | 0.26 | -0.36 | 0.38 | -0.06 | 0.78 | -0.56 | 0.01 | -1.14$^{P}$ | -0.01 | 0.57 | -0.26 | 0.17 | -0.09 | 0.15 | 0.17 |
| Palea length PL | -1.24 | 1.86 | -1.15 | 0.09 | 0.52 | 0.15 | -0.18 | -0.07 | -0.16$^{P}$ | 0.86 | -0.52 | 0.14 | -0.05 | 0.03 | 0.49 |
| Growth rate 1 | 0.82 | -1.36 | 0.70 | -0.08 | -1.13 | -0.11 | 0.13 | 0.45 | 0.09 | -1.4$^{P}$ | 1.99 | -0.19 | 0.06 | -0.24 | -0.36 |
| Growth rate 2 | 0.82 | -1.3 | 0.64 | -0.07 | -1.3 | -0.53 | 0.13 | 0.11 | 0.03 | -1.05 | 2.74$^{P}$ | -0.17 | 0.06 | -0.42 | -0.49 |
| Growth rate 3 | 0.88 | -1.3 | 0.66 | -0.01 | -1.29 | -0.14 | 0.13 | 0.69 | 0.08 | -0.98 | 1.70 | -0.27$^{P}$ | 0.14 | -0.40 | -0.24 |
| Tannins (10 days grain | 0.70 | -1.04 | 0.49 | 0.02 | -1.07 | -0.11 | 0.10 | 0.68 | 0.06 | -0.62 | 1.26 | -0.26 | 0.14$^{P}$ | -0.40 | -0.32 |
| Tannins (matured grain) | 0.58 | -0.93 | 0.41 | 0.004 | -1.11 | -0.44 | 0.07 | 0.33 | 0.01 | -0.67 | 2.25 | -0.21 | 0.11 | 09.52$^{P}$ | -0.32 |

Superscript P = Direct effect, Column r = Correlation coefficient
Residual = 0.68

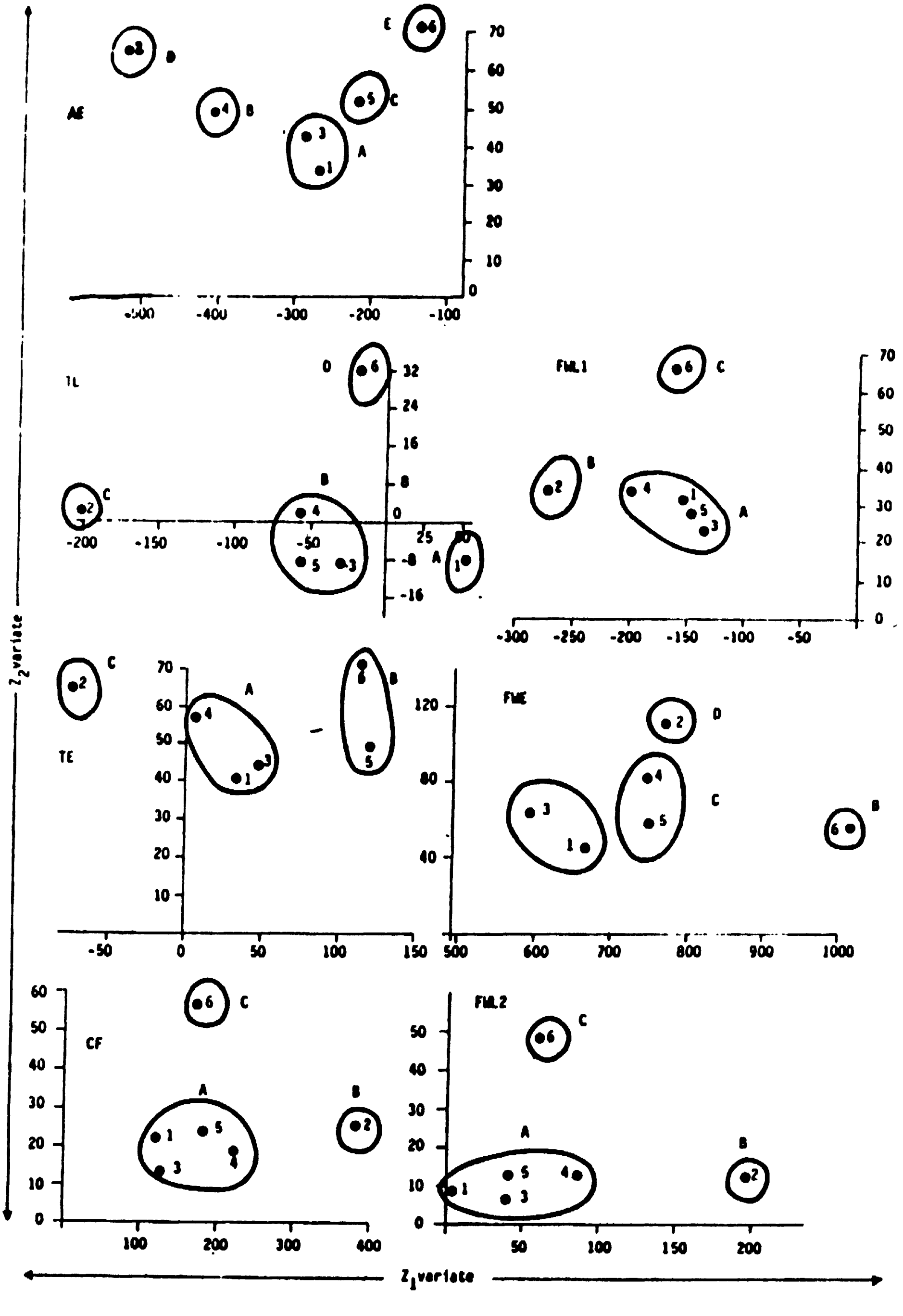


Fig 1. Canonical clusters of six cultivars based on chaffy florets (CF), florets with larvae 15-days after infestation (FWL2), total number of eggs/ 100 florets (TE), florets with eggs (FWE), total number of larvae/100 florets (TL), florets with larvae 10-days after infestation (FWL1), and adult emergence/panicle (AE). 1-DJ 6514, 2-AF 28, 3-TAM 2566, E-IS 15107, 5-CSH1, and 6-Swarna.