Mechanisms of resistance to mites in okra leaf cottons.

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Introduction

Previous research at Narrabri Agricultural Research Sation and elsewhere has shown that mite populations increase more slowly on okra leaf cotton genotypes than on normal leaf genotypes (Bailey *et al.*, 1978; Thomson, Reid and Fitt, 1984; Wilson and Fitt, 1987). Experimentally this difference has resulted in far lower yield reductions on Siokra than DP90 when artificial mite infestations were initiated in each variety at the same time. This paper sumarizes the findings of experiments designed to determine the underlying cause of the resistance to mites found in the okra leaf genotypes and also reports some more recent findings.

Previous Research

Six potential sources of difference between okra and normal leaf genotypes have been identified as possible mechanisms of resistance to mites. Each of these alternatives has been studied previously (Wilson, 1992) and the results are presented briefly below along with selected key data;

1) *Reduced leaf area* - Mites may exploit okra leaves more quickly because they are smaller in area than normal leaves. This was tested by following the development and leaf damage caused by mite infestations which were initiated in plots of Siokra or DP90 at the same date. Mite numbers began to differ between the varieties, with more in DP90, when only a relatively small proportion of the available leaf area was damaged (Figure 1). Hence mite populations on the two varieties diverged well before food was limiting and this explanation was discounted.

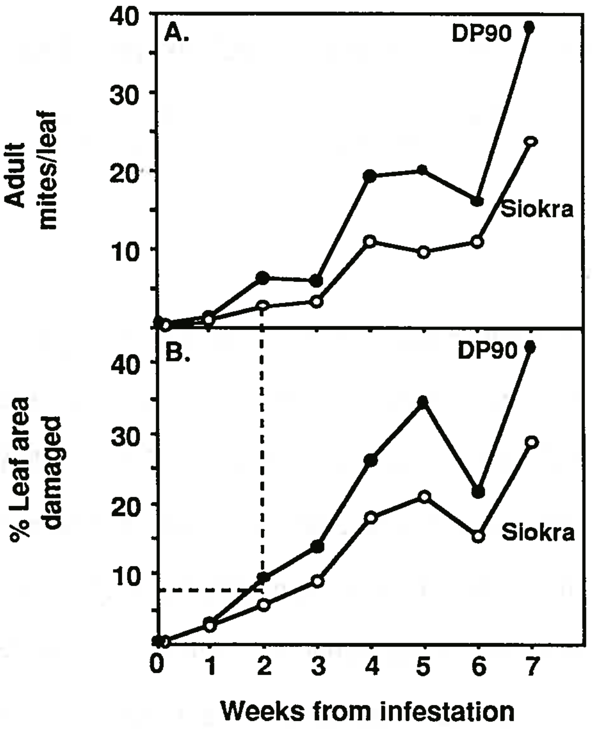

Figure 1. Mean number of adult female *T. urticae* per leaf (A) and mean percentage of leaf area damaged (leaf 3 below the terminal) (B) in plots of Deltapine 90 or Siokra which were artificially infested with mites. The dashed line indicates the mean percentage leaf damage when mite numbers on the two varieties began to diverge.

2) *Differences in nutritional quality* - Okra leaf genotypes may be nutritionally less suitable for mite reproduction and development. This was tested by rearing mites in the laboratory on leaf discs taken from near-isogenic okra and normal leaf lines which differ only in the gene which determines leaf shape. The results showed that developmental rates, fecundity and survival were very similar on leaves of either genotype (Table 1). Further experiments showed that there was no difference between Siokra or DP90 in suitability for mite development and reproduction (Table 1). Analysis of leaf tissue also revealed no differences in nitrogen content or condensed tannins between the pairs of genotypes. Furthermore, in preference tests, mites colonised and oviposited on leaf tissue from okra or normal leaf genotypes equally. Hence nutritional factors seem unlikely to explain the resistance of okra leaf genotypes.

Table 1. Mean values (se) of demographic parameters of *T. urticae* reared at 30°C on cotton leaf tissue from near-isogenic lines with okra or normal leaf shape in 1989 and from Siokra or DP90 in 1990.

Parameter	Genotype			
	Isoline		Cultivar	
	Okra leaf	Normal leaf	Siokra	DP90
Developmental time	6.8 (0.07)	6.7 (0.07)	6.0 (0)	6.0 (0)
Immature survival	98.4 (1.1)	96.9 (1.2)	95.1 (2.0)	95.4 (1.8)
Pre-oviposition period	1.0 (0.03)	0.9 (0.03)	1.1 (0.05)	1.0 (0.03)
Fecundity	117.9 (7.17)	125.7 (7.19)	131.1 (8.31)	122.6 (7.46)
Reproductive period	22.7 (0.90)	22.6 (0.91)	21.6 (1.17)	20.2 (0.94)
Life span	24.9 (1.00)	25.2 (1.14)	23.4 (1.23)	23.1 (1.10)
Sample size	35	37	31	33

3) *Differences in induced responses to insect damage* - Cotton plants respond to damage caused by mites (and probably other sources such as abrasion and other herbivores) so that the future ‘performance’ of mites is negatively affected (Karban and English-Loeb, 1988). It is possible (but not known) that okra leaf genotypes produce higher levels of induced defences or that such defences may be triggered by lower levels of mite damage. However Wilson and Fitt (1987) found that mite populations increased more rapidly on a normal than an okra leaf near-isogenic genotype. The induced responses of the near-isogenic genotypes would presumably be very similar. Therefore although this explanation cannot be discounted it seems unlikely. However, induced responses may be involved in the greater resistance of Siokra compared with DP90 as these cultivars have quite different genetic backgrounds (N.J. Thomson, pers. comm.). Since this explanation was not specifically tested it cannot be discounted completely.

4) *Differences in predator abundance or efficiency* - Predators of mites may be more abundant or more effective on okra leaf genotypes. Experimental evidence showed that the abundance of omnivorous thrips (*Thrips tabaci* and *Frankliniella schultzei*), which are

important predators of mites, was similar on Siokra and DP90. Futhermore circumstantial evidence from other experiments indicated that mite populations increase more rapidly on DP90 than Siokra even when predators were eliminated by a broad spectrum insecticide. Hence this explanation is unlikely.

5) *Differences in canopy or leaf temperature or humidity* - The temperature or humidity conditions in the canopy of normal leaf genotypes may be more suitable for mite reproduction and development than that of okra leaf canopies. However, measurements of temperature and humidity in okra and normal leaf canopies revealed only very minor differences (Table 2). Furthermore when okra and normal leaf near-isogenic genotypes were interplanted, creating a mixed canopy, mites still increased more quickly on the normal leaf genotype. Hence this explanation seems unlikely.

Table 2. Mean leaf temperature in the upper and lower canopy and mean relative humidity in the lower canopy of okra and normal leaf shape near-isogenic cotton genotypes at different times of the day from December 23, 1988 to March 1, 1989. Values are means (se).

Time of day	Leaf temperatures (°C)				Relative humidity (%)	
	Upper canopy		Lower canopy		Lower canopy	
Hours	Okra	Normal	Okra	Normal	Okra	Normal
0600 - 1200	26.3 (0.35)	26.5 (0.37)	24.6 (0.33)	23.7 (0.29)	86 (1.0)	88 (0.7)
1200 - 1800	31.2 (0.21)	31.3 (0.20)	28.5 (0.20)	28.2 (0.18)	74 (1.0)	74 (0.9)
1800 - 2400	22.2 (0.26)	22.2 (0.27)	22.0 (0.24)	21.8 (0.22)	83 (1.0)	84 (0.9)
2400 - 0600	18.3 (0.24)	18.2 (0.24)	18.5 (0.22)	18.7 (0.21)	96 (0.5)	96 (0.5)

6) *Reduction in the proportion of leaf area that is acceptable for mite reproduction or oviposition* - Mites live in the boundary layer of still air close to the leaf surface. The depth and stability of the boundary layer is variable over leaf surfaces. The boundary layer should be deeper and more stable (more constant humidity) near leaf veins and in folds, and shallower and less stable (more variable humidity) near edges (Wilmer, 1986).

As the survival and development of mite eggs is favoured by higher humidity (Ferro and Chapman, 1979), mites should prefer to oviposit in areas where humidity is higher and more stable, such as near major veins and in leaf folds. This prediction was confirmed by observation of the pattern of development of mite colonies on either leaf shape (Figure 2). Further, given a choice, mites preferred to oviposit on leaf tissue with a vein than on identical tissue without. It is proposed that okra leaves have less acceptable areas for mite reproduction and development than normal leaves which leads to more rapid exploitation and density-dependent competition on okra leaves.

Testing the hypothesis

The evidence available indicates that okra leaf varieties are more resistant because less of their leaf area is suitable for mite development. If this explanation is correct then varieties with even more exposed leaves such as super-okra, where the leaves are often reduced to a single blade, should have even higher resistance. We tested this by monitoring mite population development on a super-okra genotype (M8 super-okra), its normal leaf isoline M8 Normal and Siokra. Several other normal leaf varieties were included for comparison (DP90, Sicala 33, CS189) as well as an experimental line 82104 which showed a high level of mite resistance in previous work.

Methods

The resistance of the genotypes was assessed in the field. Plots of each of the 7 varieties were planted in a 4 x 7 randomised block design. The plots were each 4 rows by 20m. The crop was grown according to standard practise. On Jan 7 all plots were artificially infested with two-spotted mites which had been mass reared in a glasshouse. The development of the mite populations was monitored weekly by counting the number of adult mites on ten leaves from the 3rd and 10th nodes below the terminal in each plot.

The nutritional suitability of the M8 super-okra and M8 normal lines for mite development and reproduction was compared by rearing mites on discs of either genotype in the

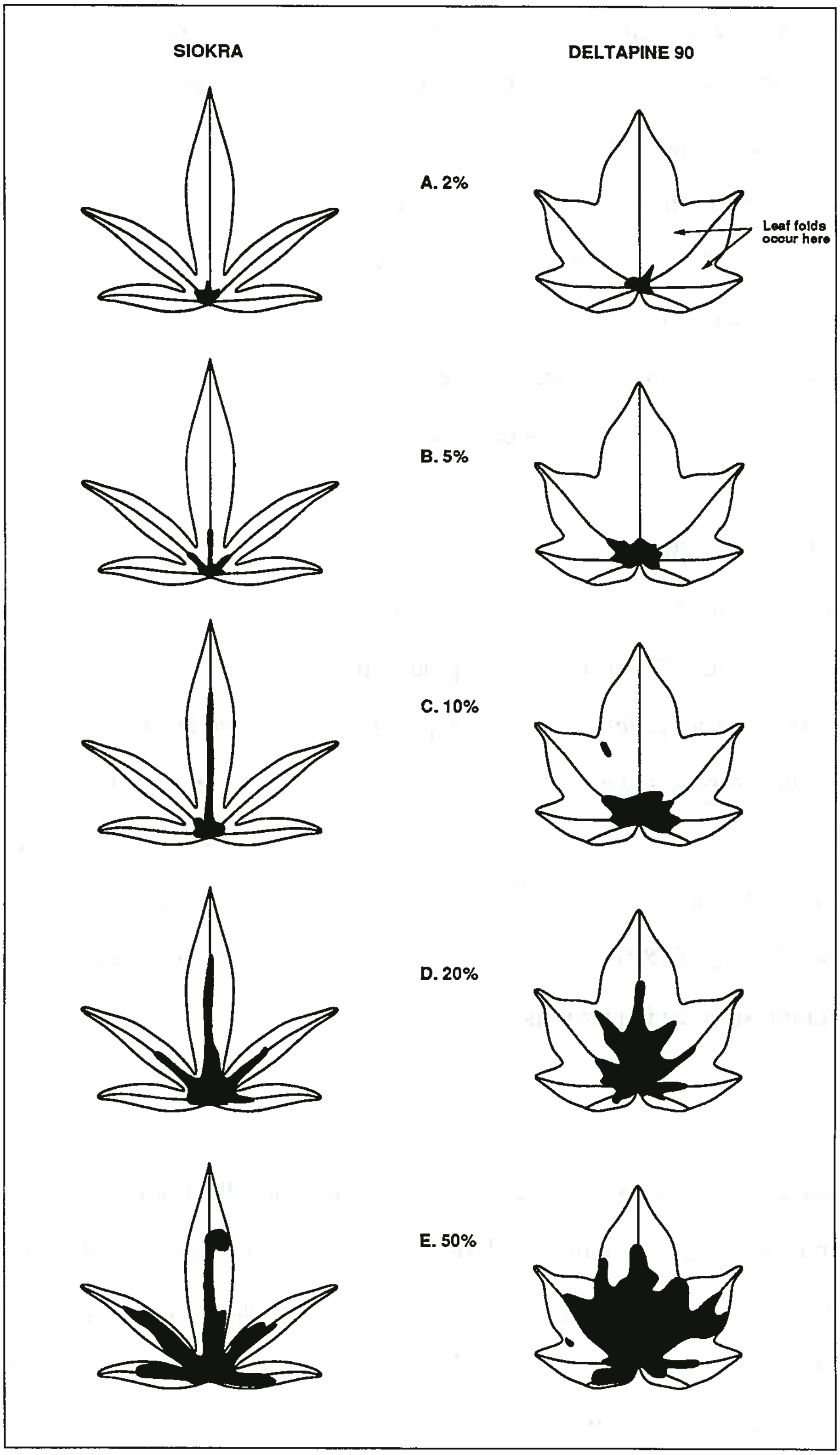

Figure 2. Typical shape of colonies of *T. urticae* causing increasing levels of leaf damage from (A) 2% to (E) 50% of the leaf surface damaged on Siokra and Deltapine 90 cotton varieties, 1987. Colonies are indicated by shaded areas.

laboratory. Leaf samples were also collected for analysis of nitrogen, sugars, terpenoids, condensed tannins and gossypol.

Results

The results show mites increased more slowly on the M8 super-okra genotype, resulting in fewer mites on this genotype than on any other genotype, including Siokra (Figure 3). It is interesting to note also that there was considerable variability in resistance between the normal leaf varieties. The genotype 81024 in particular appears to be quite resistant to mites and in the field remained green when most of the other normal leaf genotypes were heavily 'bronzed' due to mite damage. CS189 appears to be particularly susceptable to mites, which is in line with the observations of many growers, consultants and researchers.

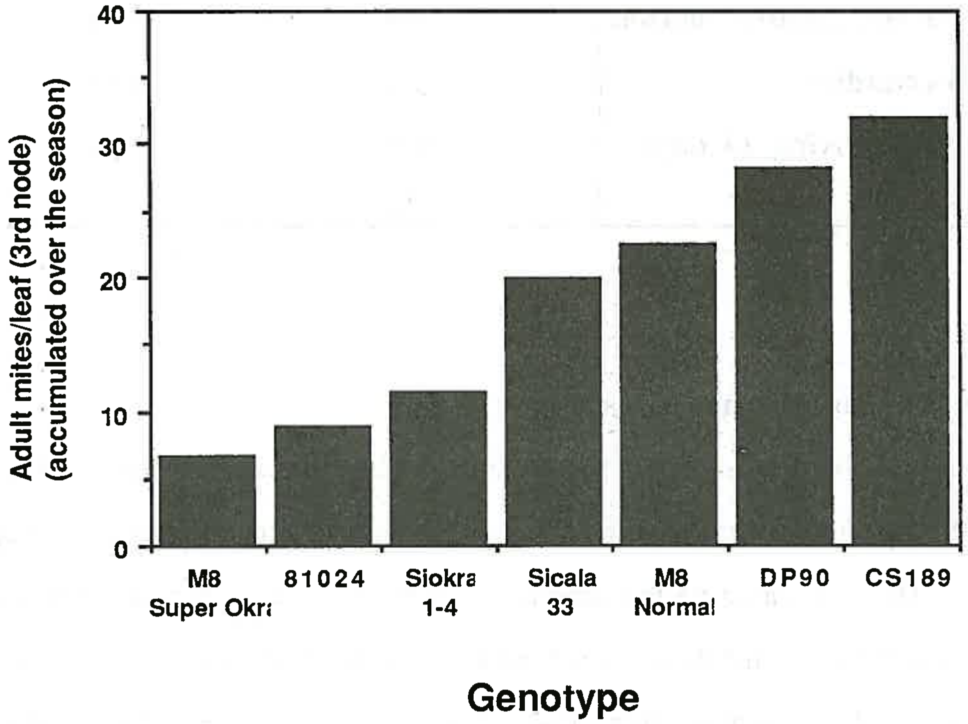

Figure 3. Mean number of adult mites per leaf, accumulated over the season, for each variety in varietal comparison.

The rearing studies showed that there was no difference in developmental times, fecundity or longevity between the M8 super-okra and M8 normal isolines (Table 3). Therefore the differences in mite population development on the two genotypes cannot be attributed to nutritional factors. This at least partially confirms the hypothesis that the narrower and more 'exposed' the leaf shape the lower will be the proportion of its area suitable for mite development and reproduction.

Table 3. Mean values of demographic parameters of *T. urticae* reared at 30°C on cotton leaf tissue from M8 normal leaf or M8 super-okra leaf isolines in 1992. Fecundity and adult survival were assessed for 14 days after eclosion.

Parameter	Genotype	
	Super-okra	Normal
Developmental time	7.17	7.04
Immature survival	96.7	85.2
Pre-oviposition period	1.08	1.04
Fecundity	122.9	116.8
% surviving 14 days	80.0	91.6
Sample size	24	25

Discussion and Conclusions

Willmer (1986) suggested that having small or highly dissected leaves with shallow humidity gradients might be one tactic that plants can employ against phytophagous insects. This was based on the observation that heat and water balance in insects are intimately linked so that the choice of "mild moist lower leaf surfaces by feeding insects will inevitably assist them in regulating both of these aspects of their physiology" (Willmer, 1986). The plant resistance of okra leaf genotypes appears to support this. The evidence presented here suggests that the slower increase of mite populations on okra leaf genotypes is caused by morphological rather than chemical factors. Changed leaf morphology results in okra shaped leaves having a lower proportion of their total surface where conditions are favourable for mite reproduction and development than normal shaped leaves. Differences in boundary layer humidity directly influencing egg survival and development, as well as the choice of oviposition sites by adult females, may be the key attribute.

Development of commercially acceptable varieties with narrow leaf profiles, such as 'super okra' may result in even higher levels of resistance to mites than that already found in commercial okra leaf genotypes such as Siokra. In combination with selection for high levels of secondary compounds which adversely affect mites, such as condensed tannins, such leaf shapes may lead to even further gains in plant resistance to mites.

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