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Alternaria alternata in cotton (Gossypium hirsutum) cv. Acala: effects on gas exchange, yield components and yield accumulation

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Abstract

The effect of *Alternaria alternata* on gas exchange processes, on total yield and on yield components in cotton *Gossypium hirsutum* cv. Acala SJ-2, was examined under field conditions. Variations in disease severity levels were achieved by using three fungicide treatments (Fentin Acetate). Disease developed more rapidly on the upper canopy layer (> 61 cm height) than on lower ones. Infections were not accompanied by leaf shedding. The main effect of the disease was a reduction on bolls' number. A significant increase in seedcotton and lint yield, as compared to the untreated control, was achieved by applying fungicides. It was found that omitting early and late applications was not followed by significant yield reduction. Alternaria leaf spot reduced photosynthetic rate more and transpiration rate less, than could be explained by the extent of infected leaf area alone.

Additional keywords: photosynthesis, transpiration, crop loss assessment.

Introduction

Alternaria leaf spot is pathogenic to cotton foliage in many countries (Ellis and Holliday, 1970). *Alternaria macrospora* Zimm was the main pathogenic species found in the high quality 'Pima' type cultivars of *Gossypium barbadense* L. (Bashi et al., 1983b; 1983c; Ellis and Holliday, 1970), whereas *Gossypium hirsutum* L. was found to be resistant to this pathogen (Bashan, 1986). *A. alternata* which was not previously considered as a primary pathogen in cotton but infecting only senescent foliage (Watkins, 1981), was reported recently to be pathogenic in: India (Patel et al., 1985; Singh et al., 1985), Egypt (Youssif et al., 1977), and Israel (in cv. Acala SJ-2) (Bashi et al., 1983a; Rotem et al., 1988b). This pathogen was the main cause of lesions in cv. Acala SJ-2 in Israel (Rotem et al., 1988b).

Some information on the epidemiology of *A. macrospora* may be found in the literature: effects of temperature and wetting periods (Bashi et al., 1983b), effects of water and nutrient stresses on host susceptibility (Rotem et al., 1982); susceptibility of plant organs at different ages (Bashi et al., 1983b) and development at different heights of the crop (Bashi et al., 1983c). However, only the effects of flower removal and sun light on *A. alternata* of cotton was investigated (Rotem et al., 1988a, 1988b).

Epidemics of *A. macrospora* reduced yields of susceptible 'Pima' type cultivar by up to 25%, mainly as a result of leaf shedding following infection (Bashi et al., 1983b; 1983c; Rotem et al., 1988b). On the other hand, epidemics of *A. alternata* in commercial cotton fields (cv. Acala SJ-2) in Israel did not result in significant yield losses (Bashi et al., 1983a). Therefore, Rotem et al., (1988b) concluded that this pathogen may not justify the amounts spent on control measures in cotton.

The objectives of this study were: (1) to quantify the effects of *Alternaria alternata* on physiological processes in cotton, (2) to assess its influence on yield accumulation, quantity and quality and (3) to investigate the effectiveness of fungicide application in controlling the disease.

Materials and methods

Experiment description. Twenty four experimental plots (18 × 40 m each) were established in 1986 on a part of an adequately fertilized sprinkler irrigated field in the coastal plane of Israel. Cotton (*Gossypium hirsutum* cv. Acala SJ-2) was planted on April 11th, in east-west rows with 1 m between rows and 10 plants per m row. Pre-planting and germination irrigations were applied on March 2nd (100 mm) and April 13th (50 mm) respectively. Additional irrigations were applied on June 27th, July 16th and August 3rd (100, 110, 110 mm respectively).

Four treatments were included, with six replicates, in a randomized block design as follows: (1) unsprayed control; (2) Fentin Acetate (FA) (Bedilan, 60% wettable powder, produced by Makhteshim, Israel) applied by spraying seven times at biweekly intervals starting from June 1st; (3) FA sprayed four times at biweekly intervals starting from July 6th; (4) FA applied twice at biweekly intervals starting from July 23rd. Each application consisted of 50 g of the product in 100 l water per ha, applied by ground equipment.

Visual assessment of disease severity. A scale for assessing the proportion of leaf area covered by leaf spots was drawn up for two leaf sizes (100 and 200 cm^2) (a miniature scale is presented in Fig. 1). The scale specified eight levels of disease severity: 0, 1, 5, 10, 20, 40 60 and 100% (James, 1974). Disease severity was assessed using this scale in the lower (< 30 cm); middle (31-60 cm) and upper (> 61 cm height) canopy layers. Fifteen randomly chosen leaves having an area of at least 100 cm^2, were assessed weekly in each canopy layer of each plot.

Effect of disease on yield components. Leaf dry weight per m^2 ground area was determined by cutting off and oven drying (48 h at 80 °C) of all the leaves of 20 randomly selected plants from each fungicide treatment.

Representative 2 m row segments were marked in each plot. All opened bolls were harvested from these segments beginning just after initiation of boll opening (September 3rd) and continuing at weekly intervals untill the final commercial harvest date (September 24th). The bolls were counted, weighed and ginned. Each week the following yield components were recorded: boll number, seedcotton and lint weight per m^2 ground area and seedcotton and lint weight per boll.

The 'critical point' method (James, 1974) was used for quantifying the effect of disease severity on yield. The relationship between disease severity, which was assessed 12 times

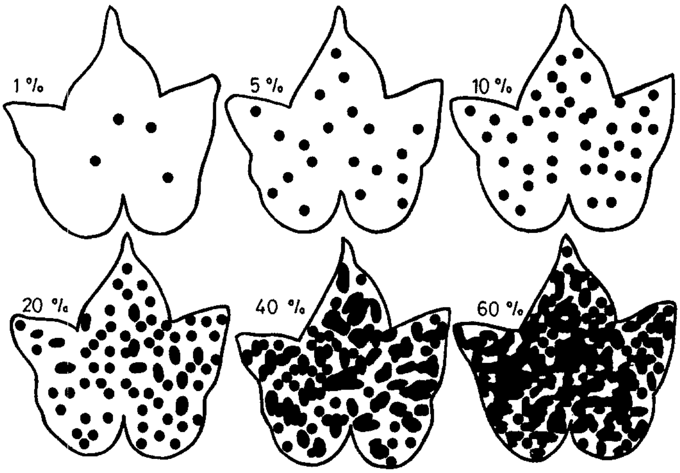

Fig. 1. A scale for assessing the proportion of leaf area covered by leaf spots in cotton (*Gossypium hirsutum*) cv. Acala SJ-2. The scale describes six levels of disease severity: 1, 5, 10, 20, 40 and 60%.

during the growing season at three canopy layers, and yield components, was determined by means of regression technique. R^2 and the t statistics were used to evaluate the significance of the effect in each case.

Photosynthesis and transpiration measurements. Photosynthetic and transpiration rates were determined four times at weekly intervals during the period of boll development. Measurements were carried out on fully expanded young leaves, (usually the 4th or 5th from the top). Photosynthetic rate and stomatal conductance were measured using LI-6000 Portable Photosynthesis System (LI-COR, Inc., 1983). Five leaves (replicates) were selected for each one of the eight disease severity levels, inspected at similar levels of radiation intensity (1800 μmol $m^{-2}s^{-1}$ photosynthetically active radiation, PAR, 400-700 nm).

Results

The rate of disease development varied with canopy level. It was slow, moderate and rapid at the lower, middle and upper parts of the canopy respectively (Fig. 2A and Fig. 2B).

Phytotoxic effects of FA (expressed as scald lesions) developed following treatments (Fig. 2B). Scald lesions were in similar area and shape to disease symptoms. Young plants were more susceptible to FA than adult ones, particularly on their lower parts. Susceptibility decreased as the plants grew, and the proportion of scalded foliage diminished as the growing season proceeded (Fig. 2B).

Disease development on the upper part of the canopy was suppressed within about one week after the first application of FA in each treatment (Fig. 3). During the period in which canopy was protected by the fungicides, disease developed slower than in the unsprayed control. About two weeks after the last FA applications the rate of disease

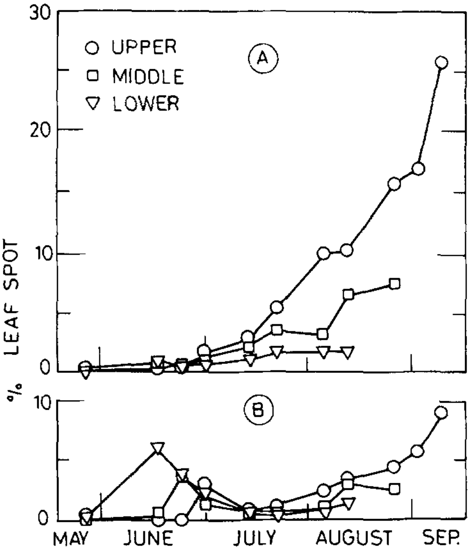

Fig. 2. Leaf spots development in the lower (< 30 cm height), middle (31-60 cm) and upper (> 61 cm) canopy layers of cotton plants (*Gossypium hirsutum*) cv. Acala SJ-2 affected by *Alternaria alternata*. A) Disease of unsprayed control; B) Leaf spots caused by disease and phytotoxic effects in treatment 2 (see text for explanation).

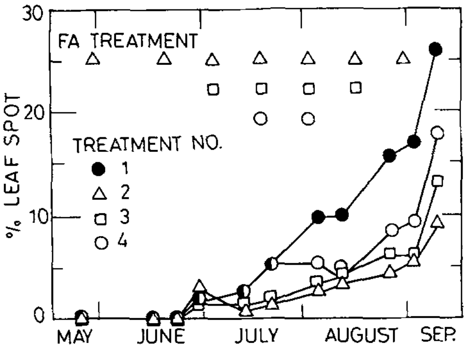

Fig. 3. Effect of Fentin Acetate treatments on the development of *Alternaria alternata* in the upper (> 61 cm height) canopy layer of cotton (*Gossypium hirsutum*) cv. Acala SJ-2 plants. Symbols indicate dates of fungicide applications.

Table 1. Effect of Fentin Acetate treatments on yield components and final yield of cotton (*Gossypium hirsutum* L.) cv. Acala SJ-2 affected by *Alternaria alternata*.

Control treatment[1]	Number of FA aplications[1]	Leaf dry weight per ground area ($g\ m^{-2}$)	Open bolls per ground area (number m^{-2})	Yield per open boll (g)		Yield per unit area ($g\ m^{-2}$)	
				seed-cotton	lint	seed-cotton	lint
1	0	143a	52b	6.50a	2.63a	338 b	137 b
2	7	124a	65a	6.55a	2.69a	426a	175ab
3	4	120a	64a	6.84a	3.05a	438a	195a
4	2	136a	59a	6.66a	2.86a	393ab	169ab

Values with different subscripts are significantly different, by the SNK multiple range test ($P < 0.05$).

[1] See text and Fig. 3 for details.

[2] Sampled on September 10th.

development increased rapidly (Fig. 3). Similar effects of FA application were observed on the lower and middle canopy layers (not shown here).

Differences in leaf dry weight per unit ground area or in seedcotton and lint weight per boll were not significant for the different fungicide treatments (Table 1). However, the number of open bolls and seedcotton yield per unit ground area were significantly higher in treatment 2 and 3 than in the untreated control. The yield of lint per unit ground area was significantly higher for treatment 3, relative to the control (Table 1).

Lint quality (length, strength and fineness as determined by standard instrumentation) was not significantly improved by FA treatments on any of the sampling dates.

Curves depicting the cumulative number of open bolls and cumulative yield of seedcotton and of lint are shown in Figures 4A and 4B. FA treatments affected these yield components only at the beginning of yield accumulation. (The difference at the first harvest date stays till the end of the season).

By using the 'critical point' method, a significant correlation was found between disease severity at the lower canopy layer on July 31st and the number of open bolls on September 3rd. On these dates (in this layer) a decrease of 7.2 bolls per m^2 in September, was associated with an increment of 1% in disease severity in July (Fig. 5).

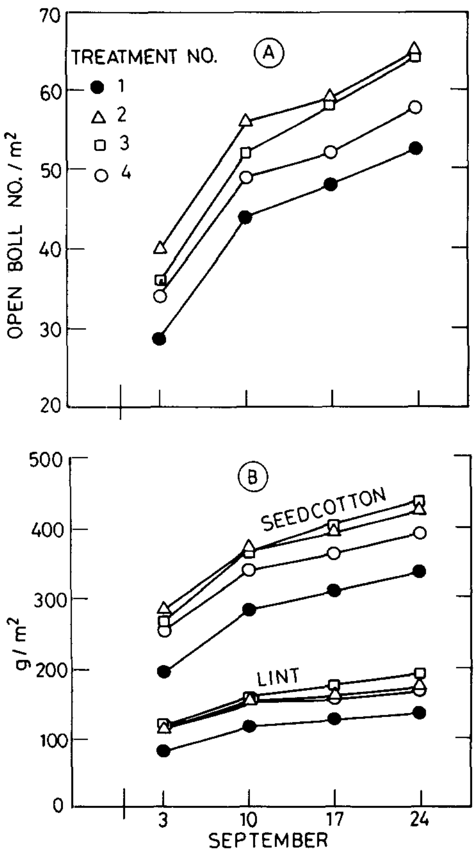

Fig. 4. Effect of Fentin Acetate treatments on yield components in cotton (*Gossypium hirsutum*) cv. Acala SJ-2 infected by *Alternaria alternata*. A) Open boll numbers; B) Seedcotton and lint weight.

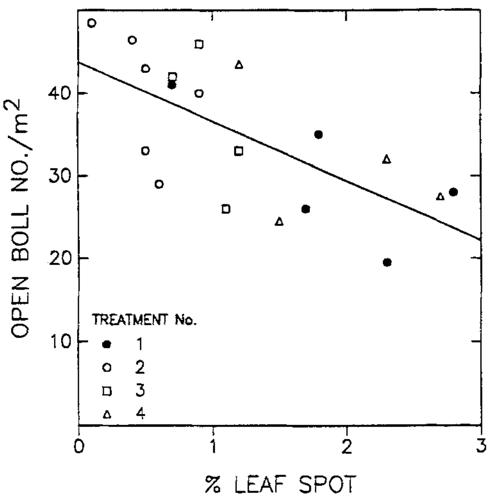

Fig. 5. Effect of *Alternaria alternata* (assessed on July 31st in the lower canopy layer) on open boll numbers (harvested on September 3rd) in cotton (*Gossypium hirsutum*) cv. Acala SJ-2. Linear regression $Y = 43.8 - 7.2X$ $r = 0.664$.

The effect of disease severity on the rates of photosynthesis and transpiration in a representative day (measured on July 30th), are shown in Figure 6. Photosynthesis rate of uninfected leaves was 27.6 μmol CO_2 $m^{-2}s^{-1}$ and transpiration rate of those leaves was 6.8 mmol H_2O m^{-1}. The reduction in photosynthesis was more severe than could be explained by the size of the infected area (Fig. 6). Transpiration rate decreased in a linear fashion, but at the more severe disease levels it was higher than could be expected from the disease infected area.

Discussion

Rate of disease development and severity levels varied at different heights of the canopy. The upper leaf layer was affected more severely than the lower ones as the disease developed. Non-uniform development of foliar diseases in the different canopy layers

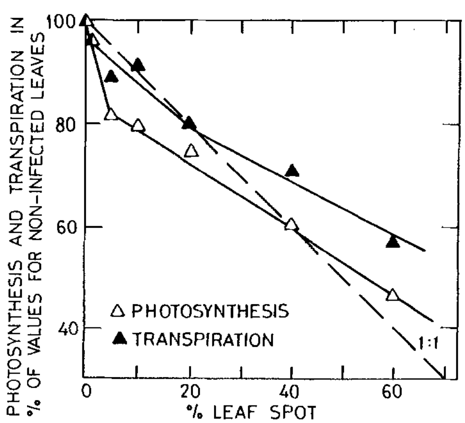

Fig. 6. Effect of *Alternaria alternata* on photosynthesis and transpiration rates of cotton (*Gossypium hirsutum*) cv. Acala SJ-2, as measured on July 30th. Results are relative to rate recorded on uninfected leaves. The 1 : 1 line indicates expected perfect coincidence between the reduction of the gas exchange processes and disease severity.

has also been reported for other diseases and in other crops (eg. Bashi et al., 1983c; Plaut and Berger, 1980; Droby et al., 1984). It is thought to be due to differences in factors affecting disease development among canopy layers such as the amount of inoculum, environmental conditions (temperature, wetting periods) and tissue susceptibility.

Within each canopy layer disease severity was affected by the dates of control initiation and termination. Evaluation of the effectiveness of the fungicide application might be used to establish an optimal spraying schedule. Furthermore, from an analysis of yield components affected by disease, it is possible to suggest the period in which the crop should be protected by the fungicides. Throughout most of the growing season, treatments 2 and 3 were less heavily infected than the untreated control (Fig. 3). However, the differences between these two treatments were not significant, indicating that the first two sprays applied in treatment 2 were probably superfluous and therefore, unnecessary. Application of the first spraying on as late as July 27th, as in treatment 4 was too late since only a moderate degree of control was achieved (Fig. 3).

Constable and Rawson (1980) have shown that in the early stages of the cotton plant growth, any reduction in carbon availability through a diminution in photosynthetic rate will adversely affect boll and square retention. The number of opened bolls which developed early in the season, and was recorded at the first harvest (September 3rd) was the only yield component affected by disease (Fig. 5). It thus seemed, that in this experiment fungicide protection was necessary only during the period of initiation of those bolls (July 3rd to July 23rd).

Disease severity affected differently the rates of photosynthesis and transpiration. Photosynthetic rate was affected more severely than could be explained by the reduction of green leaf area alone. This phenomenon has also been reported for rust in wheat (Livne, 1964) and powdery mildew in winter wheat (Rabbinge et al., 1985). Rabbinge et al., (1985) found, as was shown in this study, that low infection levels resulted in a considerable reduction of photosynthetic rate. Substantial reduction of the photosynthetic rate by low levels of disease was also reported in Cercospora leaf spot of peanuts (Boote et al., 1980). One possible explanation is that the fungus secretes a phytotoxic compound which diffuses to the area surrounding each lesion producing an invisible halo. Phytotoxins produced by *A. alternata* have been isolated in *Datura innoxia* (Janardhanam and Husain, 1983) and pear (Park et al., 1981). The invisibly affected area would at first increase linearly with the increase in lesion numbers, and the reduction in photosynthesis during this phase would be much larger than could be accounted for by the visibly spotted area. When halo overlapping begins, the incremental effect of the spots may decrease. Once the leaf was completely covered by the spots and halos, the photosynthetic rate would be reduced as an effect of the necrotic lesions alone since no healthy area would remain. the relatively large effect of a slight disease infestation on the photosynthetic rate, might be explained by a remarkably adverse influence of each lesion on the surrounding tissue.

Transpiration rate was also reduced as a result of the necrotic leaf spots but at a lower extent than could be expected from the size of the necrotic area alone (Fig. 6). Ayres and Jones (1975) explained a similar phenomenon in *Rhynchosporium* sclad of barley by uncontrolled water loss through open stomata that lost their capacity to close. A similar phenomenon was observed in rust infected beans. the explanation for this phenomenon caused by a biotrophic pathogen is of course differnt: uncontrolled water loss through the ruptured epidermis (Duniway and Durbin, 1971). In the case of alternaria leaf spot, a necrotrophic pathogen, the explanation should be similar to that offered by Ayres and Jones (1975). In addition, we think that the effects of toxins produced in the diseased leaves might be far reaching beyond the lesions and thus affect transpiration rate as well as photosynthesis.

Since *A. alternata* reduced the photosynthetic rate, the supply of photosynthates to the various sink organs, mainly the developing bolls, decreased in infected plants. During the stage of boll development the cotton plant responds to assimilate shortage mainly by boll shedding (Turner et al., 1986). In our study, disease developed during the main period of boll growth (July 15th to August 5th) and the plants responded by boll shedding. Low levels of disease severity (up to 3% of the total leaf area at the lower canopy layer) caused a significant decrease in boll number (Fig. 5); this was especially pronounced during the early stage of boll development (Fig. 4a). Boll shedding was thus indicated as the main factor accounting for the significant reduction in yield of infected plants.

Although data from only one year is presented in this study, it demonstrates the potential yield loss that may be caused by *A. alternata* to cotton (*Gossypium hirsutum*) cv. Acala SJ-2. However, our findings concerning the optimal timing for initiation and termination of the chemical control of this pathogen should further be investigated before being recommended to growers.

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Samenvatting

Alternaria alternata in katoen (Gossypium hirsutum L.) cv. Acala: effecten op fysiologische processen, opbrengstcomponenten en opbrengsttoename

Het effect van *Alternaria alternata* op fotosynthese en transpiratie, opbrengstcomponenten en totale opbrengst bij katoen (*Gossypium hirsutum* L.), werd onderzocht onder veldomstandigheden. Verschillen in aantastingsniveaus werden verkregen door fungicide (fentin acetaat) behandelingen. De ziekte ontwikkelde zich het snelst boven in het gewas (> 60 cm). Infectie ging niet gepaard met bladval. Het belangrijkste effect van de ziekte vormde een afname van het aantal vruchtdozen ('bolls'). Een significante toename van zaadkatoen ('seedcottton') en van vezels ('lint') ten opzichte van de onbehandelde controle werd verkregen door toediening van fungiciden. Achterwege laten van vroege en late bestrijdingen had geen significante opbrengstverlaging tot gevolg. *A. alternata* verlaagde de fotosynthesesnelheid meer en de transpiratiesnelheid minder dan verklaard kon worden uit de geïnfecteerde oppervlakte van het blad.

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