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Effects of foliar application of potassium nitrate on suppression of Alternaria leaf blight of cotton (*Gossypium hirsutum*) in northern Australia

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Abstract. Alternaria leaf blight is the most prevalent disease of cotton in northern Australia. A trial was conducted at Katherine Research Station, Northern Territory, Australia, to determine the effects of foliar application of potassium nitrate (KNO_3) on the suppression of Alternaria leaf blight of cotton. Disease incidence, severity and leaf shedding were assessed at the bottom (1–7 nodes), middle (8–14 nodes) and the top (15+ nodes) of plants at weekly intervals from 7 July to 22 September 2004. Disease incidence, severity and shedding at the middle canopy level were significantly higher for all treatments than those from bottom and top canopies. Foliar KNO_3, applied at 13 kg/ha, significantly ($P < 0.05$) reduced the mean disease incidence, severity and leaf shedding assessed during the trial period. KNO_3 significantly ($P < 0.001$) reduced the disease severity and leaf shedding at the middle canopy level. Almost all leaves in the middle canopy became infected in the first week of July in contrast to infection levels of 50–65% at the bottom and top of the canopy. Disease severity and leaf shedding in the middle canopy were significantly ($P < 0.05$) lower in KNO_3-treated plots than the control plots from the second and third weeks of July to the second and third weeks of August. This study demonstrates that foliar application of KNO_3 may be effective in reducing the effect of Alternaria leaf blight of cotton in northern Australia.

Additional keywords: *Alternaria macrospora*, *A. alternata*.

Alternaria leaf blight of cotton occurs in most cotton growing countries in the world (Ellis 1971). At least two pathogens, *Alternaria macrospora* Zimm. and *A. alternata* (Fr.) Keissler are considered to be causal agents (Bashan and Hernandez-Saavedra 1992). Alternaria leaf blight has been considered a minor disease of cotton in the cotton growing areas of southern Australia (Nehl and Allen 2002), but cotton grown in northern Australia (Kununurra and Katherine) had 100% of leaves infected in some years (S. Yeates and J. Moulden, pers. comm.). Several surveys confirmed that Alternaria leaf blight was the most prevalent disease of cotton in the northern Australia (Nehl *et al*. 2000; Bellgard 2001). A yield loss of 37% was reported in India by Padaganur *et al*. (1989), and of 25% in Israel by Bashi *et al*. (1983*b*) due to Alternaria leaf blight of cotton. High disease severity has been reported in Katherine (Northern Territory, NT), Kununurra (Western Australia, WA) and Burdekin (Queensland, Qld) over the last few years and may be a problem for the developing cotton industry in northern Australia.

Most of the cotton cultivars grown in Australia are considered to be resistant to Alternaria leaf blight. However, they may become susceptible to infection due to stress factors such as nutrient imbalance (in particular, potassium deficiency), water stress (Miller 1969), insect damage, root pruning, poor drainage, soil compaction or nematode attack (Sciumbato and Pinckard 1974). Potassium is required in large amounts by cotton for normal crop growth and fibre development. Cotton is more sensitive to low potassium availability than most other field crops, and often shows symptoms of potassium deficiency on soils not considered to be potassium deficient (Cassman *et al*. 1989). Oosterhuis (1994) reported that cotton plants became deficient in potassium during flowering and boll formation. Hillocks and Chinodya (1989) reported foliar discolouration due to potassium deficiency and the onset of Alternaria leaf blight during flowering and boll formation in Zimbabwe (Hillocks and Chinodya 1989). The developing bolls are strong sinks for potassium which is diverted from leaves

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(Bashan and Hernandez-Saavedra 1992). It was observed that mechanical flower removal prevented both development of potassium deficiency symptoms and expression of Alternaria leaf blight on leaves (Hillocks and Chinodya 1989). Deficiency of potassium was considered to be one of the prerequisites for the development of Alternaria leaf blight (Bashan and Hernandez-Saavedra 1992).

Foliar application of potassium may correct deficiency and protect plants from Alternaria leaf blight. However, no work has been done on this in Australia. The objective of the study was to determine the effect of foliar application of potassium nitrate (KNO_3) on the incidence and severity of the disease on cotton leaves, and the subsequent defoliation. KNO_3 was used because it was the most efficacious form of K for foliar application (Howard *et al*. 1998; Oosterhuis 1994), and has been used effectively on Alternaria leaf diseases of cotton (Janes *et al*. 1993) and other crops (Blachinski *et al*. 1996).

The experiment was undertaken at the Katherine Research Station (14°28′S; 132°18′E), Katherine, NT, Australia. The cotton variety Sicot 289B was sown on 14 April 2004 with a no-till planter to a depth of ~3 cm. Eight to ten seeds/m were sown in rows 1 m apart. The crop was irrigated twice weekly with a lateral-move irrigator. Total water applied was 5.5 ML/ha. Total fertiliser applied (most in the irrigation water) per hectare was 40 kg P, 80 kg K and 190 kg N. Insecticides and herbicides were applied when needed, and other crop husbandry practices were performed in accordance with normal procedures at Katherine Research Station.

The experiment was a completely randomised design with two treatments: control and 13 kg/ha of foliar KNO_3 applied four times, with three replicates. Plots were 9 × 50 m. KNO_3 was applied in 100 L water/ha with a tractor-mounted boom sprayer at a pressure of 350 kPa. The first application was ~7 days (31 May) before flowering, and the three applications after flowering were at two weekly intervals (14 June, 28 June, 12 July). Sprays contained no spreader, sticker or adjuvant of any type. The trial plots were not artificially inoculated with *Alternaria* isolates because a heavy and continuous disease incidence had been observed on cotton in the last few years.

Ten randomly selected plants from each plot were used for disease assessment. These were adjacent to plants marked with marking paint to exclude the effect of paint on plants and disease expression. Disease assessment was done at weekly intervals for 12 weeks, from July to September 2004. Main stem leaves (Colson-Hanks *et al*. 2000) at three canopy levels: (i) bottom (1–7 nodes); (ii) middle (8–14 nodes); and (iii) top (15+ nodes) were assessed visually for disease incidence, severity and leaf shedding. The percentage of disease incidence at each assessment date was determined by the following equation:

$$\alpha = \frac{x}{y} \times 100$$

where α = disease incidence (%); x = number of infected leaves; and y = total number of leaves assessed.

The mean percentage of infected leaves for the whole plant or at each canopy level was determined by the equation:

$$\text{Incidence} = \frac{(\alpha_1 + \ldots + \alpha_{12})}{12}$$

where α = percentage of infected leaves at each assessment period.

A visual scale, modified from Rotem *et al*. (1988), was used for the assessment of disease severity as follows: 0, healthy leaves; 1, leaves with up to five lesions; 2, leaves with 6 to 20 lesions; 4, leaves with more than 20 lesions without marked necrosis; 8, leaves with more than 20 lesions with marked necrosis; 16, necrotic leaves, badly damaged tendency to shed; 20, leaves fallen off from nodes. The number of shed leaves at each canopy level was assessed by counting the abscission marks of fallen leaves on the main stem. The mean disease severity and leaf shedding for the whole plant or at each canopy level was calculated using procedures similar those used for disease incidence.

Data were analysed using Statistica® (Release 7.1, StatSoft Inc., Tulsa, OK). Analysis of variance was performed using the general linear model (GLM) and means were compared using Fisher's least significant test at $P \leq 0.05$.

Although the mean disease incidence in KNO_3-treated plots was significantly ($P = 0.048$) lower (1.4%) than in control plots (Table 1), there was no significant difference at any canopy level. Almost all leaves at the middle canopy level and more than 50% of leaves at the bottom and top canopy levels, whether treated or not, were infected within the first week of July (data not presented). There were no significant differences of disease incidence at the bottom canopy level between KNO_3-treated and control plots except at second week of July. Disease incidence at the top canopy level fluctuated throughout the growing season. Disease incidence of treated and control plots at the top canopy level reached 91 and 100%, respectively (4 August and 1 September 2004); decreased to 83 and 87%, respectively (8 and 15 September); and reached maxima of 91 and 94%, respectively (end of September).

Mean disease severity was significantly ($P < 0.001$) higher (0.71) in control plots than in KNO_3-treated plots (Table 1). Disease severities were significantly higher ($P < 0.001$) in the middle canopy than the bottom and top canopy levels in both KNO_3-treated and control plots; it was in the middle canopy where KNO_3 was effective ($P < 0.001$) in decreasing severity (Fig. 1); there was no effect of KNO_3 at the other canopy levels. Significantly ($P < 0.05$) lower disease severity was observed in KNO_3-treated plots at the middle canopy level from 14 July to 11 August 2004 (Fig. 2). The same, but not significant, trends were observed at the other canopy levels.

The mean number of leaves shed was significantly ($P < 0.001$) higher (0.33 leaf) in control plots (Table 1). Mean leaf shedding was highest ($P < 0.001$) at the middle canopy level. KNO_3 significantly ($P < 0.05$) reduced leaf shedding at

Table 1. Mean incidence, severity and number of leaves shed due to Alternaria leaf blight of cotton at Katherine Research Station 2004

Treatment	Incidence (%)	Severity (0–20)	Number of leaves shed from main stem
KNO_3	90.94	9.13	2.39
Control	92.34	9.84	2.72
Probability ($n = 145$)	$P = 0.048$	$P < 0.001$	$P < 0.001$

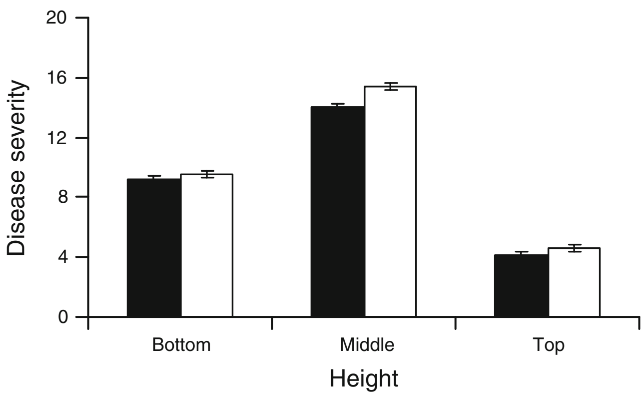

Fig. 1. Alternaria leaf blight severity at various canopy levels on KNO_3-treated and control plots (■, KNO_3; □, control). Data are means of 12 assessments conducted weekly on 30 selected cotton plants for each treatment. Bars denote standard error of means.

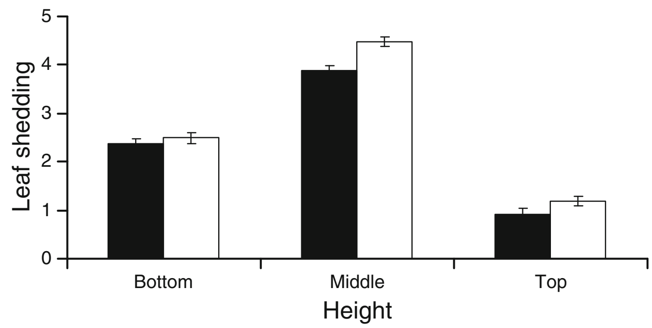

Fig. 3. Number of leaf shedding at various canopy levels on KNO_3-treated and control plots (■, KNO_3; □, control). Data are means of 12 assessment conducted weekly on 30 cotton selected plants for each treatment. Bars denote standard error of means.

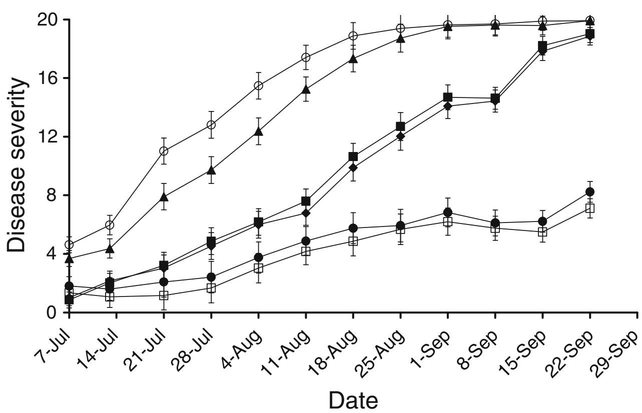

Fig. 2. Effects of KNO_3 on suppression of Alternaria leaf blight severity at various canopy levels during the growing season at Katherine Research Station, 2004 (◆, KNO_3/bottom; ■, control/bottom, ▲, KNO_3/middle; ○, control/middle; □, KNO_3/top; ●, control/top). Data are mean disease incidence on main stem leaves of 30 selected cotton plants for each treatment. Bars denote standard error of means.

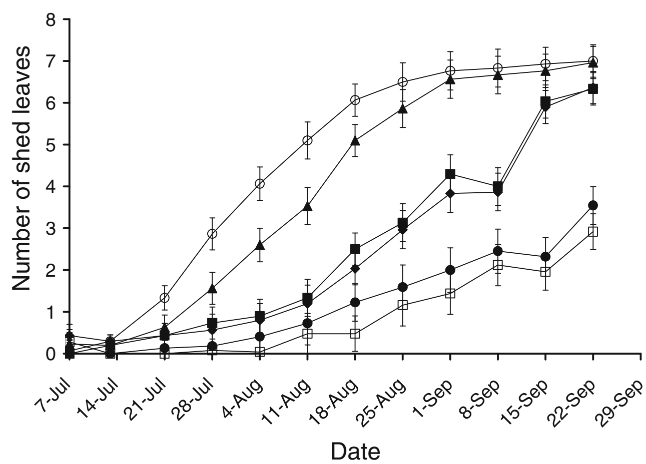

Fig. 4. Effects of KNO_3 on number of leaf shedding at various canopy level during the growing season at Katherine Research Station, 2004 (◆, KNO_3/bottom; ■, control/bottom, ▲, KNO_3/middle; ○, control/middle; □, KNO_3/top; ●, control/top). Data are mean disease incidence on main stem leaves of 30 selected cotton plants for each treatment. Bars denote standard error of means.

the middle canopy level, although the mean differences from the control was ~0.6 leaf (Fig. 3). A similar, but not significant, reduction occurred at the other canopy levels. After 14 July, leaf shedding was highest ($P < 0.05$) at the middle canopy level for both treated and control plots. KNO_3 decreased leaf shedding at all levels but significant ($P < 0.05$) only in the middle canopy from 21 July to 18 August, although actual differences in leaf shedding between treated and control over this period was ~1.5 leaf (Fig. 4).

These results show that foliar application of KNO_3 may reduce the incidence, severity and defoliation caused by Alternaria leaf blight in cotton in northern Australia. This is in agreement with the findings of other workers who showed that foliar application of KNO_3 suppressed early leaf blight (*Alternaria solani* Sor.) of tomato (*Lycopersicon esculentum* Mill.) in Israel (Blachinski *et al*. 1996) and Verticillium wilt (*Verticillium dahliae* Kleb.) of cotton in the USA (Janes *et al*. 1993). Foliar application of KNO_3 with fungicide chlorothalonil also significantly reduced Alternaria leaf blight of cotton in Tennessee, USA (Oosterhuis 1994).

One of the drawbacks of this experiment was that no yield data were recorded for treated and control plots. Bashi *et al*. (1983*b*) reported that loss of production due to Alternaria leaf blight was related to leaf shedding rather than disease incidence. Our results showed that KNO_3 reduced leaf shedding by ~0.6 leaf in the middle canopy, and whether this level of leaf shedding has any effect on cotton yields remains undetermined. Shtienberg (1993) reported a linear relationship between disease severity and loss of boll (one of the causes of yield loss) in Israel. In Zimbabwe, ground application of muriate of potash (KCl) or fungicides significantly reduced disease severity, but both fungicide and KCl applications were required for yield increase (Hillocks and Chinodya 1989).

Our study revealed that the highest disease incidence, severity and leaf shedding occurred at the middle canopy level followed by the bottom and top canopy levels. Two possible explanations may be given. First, during boll formation, K, along with other nutrients, is withdrawn from the older leaves and petioles and retranslocated via phloem to the bolls (Oosterhuis 1994) which may predispose mature leaves (middle and lower) to Alternaria leaf blight. Unfortunately, leaf potassium levels were not determined. Second, duration of dew on leaves influences disease incidence (Bashi *et al*. 1983*a*) and this probably played a part in Katherine. Heavy overnight dew on middle canopy leaves and associated cooler night temperatures in June, July and August may have predisposed the middle leaves to the disease. Due to the continued production of new leaves at the top canopy level, the overall severity of disease and leaf shedding was less. As lower canopy leaves had less exposure to heavy dew, disease severity was less. Considerable variation of disease incidence and severity, and leaf shedding at various heights of cotton plants has been reported. Bellgard (2002) observed similar phenomena of Alternaria leaf blight expression on cotton plants in northern Australia. In Israel, higher disease incidence (Bashi *et al*. 1983*b*) and disease severity (Ephrath *et al*. 1989) were observed at the top canopy level. Bashi *et al*. (1983*b*) reported increased leaf shedding at the bottom canopy level, followed by middle and top canopy levels. Differential disease expression reported in various studies may be due to several causes. The main ones would include microclimate within the canopy, and stress factors. More work is required to understand the cause of these differences.

In conclusion, this work has shown that foliar application of KNO_3 may reduce the incidence of Alternaria leaf blight in cotton. However, its impact on cotton yield needs to be determined. More trials, at various geographical locations from Kununurra to Burdekin in northern Australia, would be required before formulating recommendations for the use of KNO_3 against Alternaria leaf blight of cotton.

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References

Bashan Y, Hernandez-Saavedra NY (1992) Alternaria-blight of cotton: epidemiology and transmission. In 'Alternaria biology, plant diseases and metabolites. Topics in secondary metabolism. Vol. 3'. (Eds J Chelkowski, A Visconti) pp. 233–266. (Elsevier Scientific Publishers: Amsterdam, The Netherlands)

Bashi E, Rotem J, Pinnschmidt H, Kranz J (1983*a*) Influence of controlled environment and age on development of *Alternaria macrospora* and on shedding of leaves in cotton. *Phytopathology* **73**, 1145–1147.

Bashi E, Sachs Y, Rotem J (1983*b*) Relationship between disease and yield in cotton fields affected by *Alternaria macrospora. Phytoparasitica* **11**, 89–97.

Bellgard S (2001) Northern Cotton Disease Survey. Australian Cotton Cooperative Research Centre, Narrabri, NSW, Australia.

Bellgard S (2002) Variation in the incidence and severity of Alternaria leaf spot in relation to irrigation-type and cultivar at KRS 2000.2001. Technical report. Australian Cotton Cooperative Research Centre, Narrabri, NSW, Australia.

Blachinski D, Stienberg D, Dinoor A (1996) Influence of foliar application of nitrogen and potassium on Alternaria disease in potato, tomato and cotton. *Phytoparasitica* **24**, 281–292.

Cassman KG, Roberts BA, Kerby TA, Bryant DC, Higashi SL (1989) Soil potassium balance and cumulative cotton response to annual potassium additions on a vermiculitic soil. *Soil Science Society of America Journal* **53**, 805–812.

Colson-Hanks ES, Allen SJ, Deverall BJ (2000) Effects of 2,6-dichloroisonicotinic acid or benzothiadiazole on Alternaria leaf spot, bacterial blight and Verticillium wilt in cotton under field conditions. *Australasian Plant Pathology* **29**, 170–177. doi: 10.1071/AP00030

Ellis MB (1971) 'Dematiaceous Hyphomycetes.' (CAB International: Kew, UK)

Ephrath JE, Shtienberg D, Drieshpoun J, Dinoor A, Marani A (1989) *Alternaria alternata* in cotton (*Gossypium hirsutum*) cv. Acala: effects on gas exchange, yield components and yield accumulation. *Netherlands Journal of Plant Pathology* **95**, 157–166. doi: 10.1007/BF01999971

Hillocks RJ, Chinodya R (1989) The relationship between Alternaria leaf spot and potassium deficiency causing premature defoliation of cotton. *Plant Pathology* **38**, 502–508. doi: 10.1111/j.1365-3059.1989.tb01443.x

Howard DD, Gwathmey CO, Sams CE (1998) Foliar feeding of cotton: evaluating potassium sources, potassium solution buffering, and boron. *Agronomy Journal* **90**, 740–746.

Janes LD, Oosterhuis DM, Bourland FM, Rothrock CS (1993) Foliar-applied potassium nitrate effects on cotton genotypes. Arkansas Soil Fertility Studies 1992. *Arkansas Agriculture Experiment Station Research Series* **425**, 77–79.

Miller JW (1969) The effect of soil moisture and plant nutrition on Cercospora-Alternaria leaf blight complex of cotton in Missouri. *Phytopathology* **59**, 767–769.

Nehl D, Allen S (2002) Cotton diseases: threats and emerging threats. http://cotton.pi.csiro.au/Publicat/conf/coconf02/soilhelt/087/087.htm [Verified 27 June 2007]

Nehl D, Kochman J, Bellgard S, Allen S (2000) Northern Australian cotton disease survey. Australian Cotton Cooperative Research Centre, Narrabri, NSW, Australia.

Oosterhuis DM (1994) Potassium nutrition of cotton in the USA, with particular reference to foliar fertilization. In 'Challenging the Future: Proceedings of the World Cotton Research Conference – 1'. (Eds GA Constable, NW Forrester) pp. 133–146. (CSIRO: Melbourne)

Padaganur GM, Hiremath RV, Basavaraj MK (1989) Estimation of yield loss due to Alternaria leaf spot and blight in cotton. *Journal of the Indian Society for Cotton Improvement* **14**, 144–145.

Rotem J, Eidt J, Wendt U, Kranz J (1988) Relative effects of *Alternaria alternata* and *A. macrospora* on cotton crops. *Plant Pathology* **37**, 16–19. doi: 10.1111/j.1365-3059.1988.tb02190.x

Sciumbato GL, Pinckard JA (1974) *Alternaria macrospora* leaf spot of cotton in Louisiana in 1972. *Plant Disease Reporter* **58**, 201–202.

Shtienberg D (1993) Effects of *Alternaria macrospora* on the yield components of Pima cotton in Israel. *Plant Pathology* **42**, 701–706. doi: 10.1111/j.1365-3059.1993.tb01555.x

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