Cotton Research and Development Corporation

Final Report

"Improving the Prediction and Amelioration of Potassium Deficiency in Cotton"

DAN82C

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Project Title:	Improving the Prediction and Amelioration of Potassium Deficiency in Cotton
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Summary Report

Introduction:

With improved nitrogen management and continued intensive cropping, premature senescence has the potential to become a limiting step in the production of cotton. Premature senescence occurs in all cotton growing areas of Australia. It is difficult to predict which crops will get the problem and to what extent lint yield and quality will be affected. In some years the problem can be widespread, while in other years it may occur only in small pockets in some valleys.

The symptoms have been associated either with low potassium soils (QLD) or with stress and cool weather superimposed on cotton crops with a high boll load (QLD & NSW). Yield losses caused by this syndrome may be as high as 30% (Harden and Kochman, 1990; Harden, 1992). Further, the impact of this syndrome is not limited to yield as poor potassium nutrition can also down grade fibre quality (Hearn, 1981; Cassman *et al.* 1990; Wright, 1994).

Objectives:

A). To establish the uptake and partitioning patterns of potassium in cotton.
B). To establish the most suitable predictor of deficiency amongst soil, leaf blade, leaf petiole and leaf petiole sap potassium; including the most appropriate potassium test.
C). To establish appropriate methods of within season amelioration of potassium deficiency.

Summary:

The above objectives were addressed with 10 field experiments over three seasons. Further, commercial crops were sampled and symptoms observed in as many commercial crops as possible.

A) The uptake of potassium by current commercially available cultivars is higher than has been reported in the past (as high as 200 kg K ha^{-1}). The partitioning patterns of potassium with the plant was found to differ between cultivars, with the more susceptible cultivars not storing as much potassium in the leaves as the less susceptible cultivars. It is likely that these differences partly explain differences in susceptibility and provide an avenue for the future breeding of less susceptible lines.

B) The traditional method of sampling petioles to predict potassium status of the crop was found to be inadequate. Leaf blades were a better indicator. However, more work is required to develop a good diagnostic for premature senescence (currently being carried out in DAN107C). The use of hand held potassium selective electrodes (Cardy meter) to measure sap potassium levels was found to be to inaccurate for the range of potassium found in cotton plants and is not an appropriate diagnostic. Soil tests should be used to establish if a site needs to have soil applied potassium (eg potassium levels below 150ppm {or 0.4 meq 100g soil} in the top 30 cm of the soil profile using the ammonium acetate extraction method {or $CaCl_2$ or $BaCl_2$}).

C) For the majority of the industry which is based on soils with high levels of available potassium (>150 ppm) soil applied potassium is not an appropriate management tool. Foliar applied potassium needs more work to determine if it is a suitable method (being tested in DAN107C). Currently the best management option available to growers is the choice of the correct cultivar. Long season cultivars such as Sicala V2 being the least susceptible.

Communication of Results:

Wright, P.R. (1994) "Premature Senescence on High Potassium Soils". In - The Seventh Australian Cotton Conference Proceedings, pp 315-321.

Wright, P.R. (1996) "Premature senescence - Is it a threat to the industry ?". In - The Eighth Australian Cotton Conference Proceedings, pp 443-450.

Full Report

1. Introduction:

The understanding of the syndrome called "premature senescence" or late season potassium deficiency is limited. Application of potassium to effected crops is reputed to remove the symptoms and improve yield and fibre quality under American conditions. However, affected crops do not show the "typical" symptoms of potassium deficiency, for example the symptoms occur on young rather than old leaves and the syndrome is often associated with either low potassium soils or with stress and cool weather superimposed on cotton crops with a high boll load. Further there appears to be an interaction with plant pathogens, with premature senescence often being associated with *Verticillium dahliae* in America (Weir et al. 1986) and with *Alternaria macrospora* in Australia (Harden 1992). In addition to this is the fact that cotton is one of the most sensitive of all crop plants to potassium deficiency (Kerby and Adams 1985) suggesting inefficient uptake and/or partitioning. Some evidence exists to suggest that the cultivar differences in uptake and partitioning occur (Halevy 1976, Cassman et al 1989). However, this work was carried out using older American cultivars and is equivocal with others reporting no differences (Mullins and Burmester 1990). Scientific knowledge in this area is lacking and has lead to the identification of nutrient accumulation under high yielding irrigated conditions being assessed as one of the four major gaps in the knowledge of cotton nutrition in the US (Hodges 1991), this is even more strikingly the case in Australia for potassium and highlights why this project was undertaken. A further gap in the knowledge prior to this project being commenced was the lack of a good diagnostic test to predict when the syndrome will cause yield and quality loss and what are the best methods of within season correction of this problem.

2. Objectives:

A). To establish the uptake and partitioning patterns of potassium in cotton.

B). To establish the most suitable predictor of deficiency amongst soil, leaf blade, leaf petiole and leaf petiole sap potassium; including the most appropriate potassium test.

C). To establish appropriate methods of within season amelioration of potassium deficiency.

3. Methods:

A series of ten core field experiments and two grower based trials were conducted in the project. The focus of the field experiments was on the response of different cultivars to soil and foliar applied potassium. All experiments were randomised complete block designs. Three of the experiments were carried out at ACRI (N92,N93,N94) and two on Ken Platts property "Lowana" (L93,L94) located approximately 10 km from Pilliga. A further two experiments were conducted on John Quigley's property "Killowen" (K94,K95) close to Warren, and one each on properties near Boggabri (Bo95) and Breeza (Br95). In all cases at least four replicates of each treatment was used with the exception of L93 where three replicates were used.

Two grower based replicated trials near warren were also monitored in the project, located at Auscott Ewenmarh and Tywnam Buttabone.

A further three experiments were conducted in cooperation with G. Harden at Emerald (see final report by G. Harden).

4. Results and Discussion:

4.1 Symptoms of premature senescence

The earliest visual symptom of premature senescence is a slight yellowing occurring between the veins of the youngest leaf, however, you need to look carefully to pick this up. More obvious symptoms occur on the third or fourth leaf from the top of the canopy with these leaves turning yellow and then rapidly red or bronze. As the season progresses the symptoms may spread further down the canopy and cause defoliation.

However, leaf reddening does not automatically mean that the crop is suffering from premature senescence, leaves turn this colour for many reasons. For example both mites and some organophosphate pesticides can cause leaf reddening. Further, the syndrome's name is *premature* senescence, leaves turning red in late March, especially after cool weather probably reflect natural senescence, not a potassium problem.

4.2 Causes of premature senescence

A substantial effort has been made in this project to understand what causes premature senescence as it was impossible to develop management options to prevent the problem until this understanding was available. The work in this project shows that premature senescence is a syndrome, that is many factors contribute to a crop developing the problem. These different factors influence the crop, apparently, mainly by influencing potassium nutrition, although other nutrients such as nitrogen and phosphorus may also play a role.

The four most important factors that predispose a crop to developing premature senescence are: I) soil type II) boll load, III) stress and IV) cultivar.

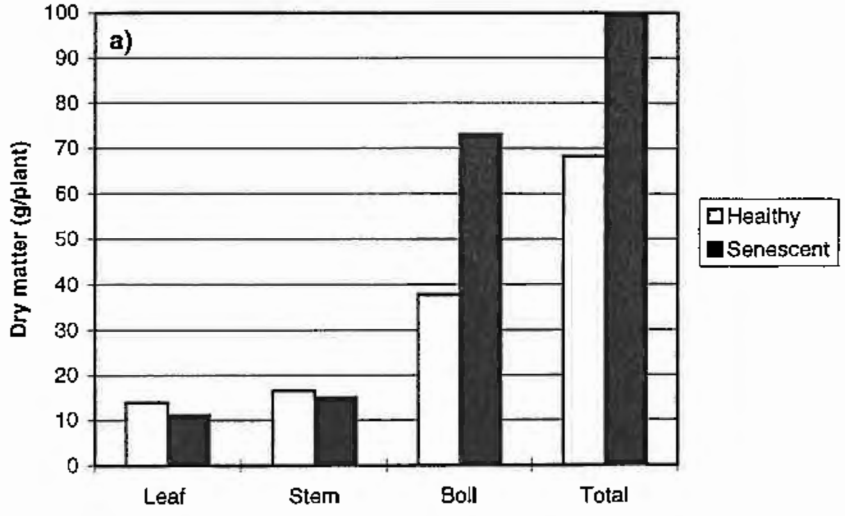
I) Soil type: some soils, particularly around Emerald, have low levels of available potassium (less than 150 ppm, or 0.38 meq/100g soil, in the top 15 cm when extracted with ammonium acetate) and these should be managed as deficient soils, as the symptoms of premature senescence are greatly reduced when this is done. Growers should apply potassium as KCl in a band 5-10 cm from the plant line and at 20 cm depth prior to sowing under these conditions. Rates should be sufficient to raise the available levels above those of the critical value. For the Emerald area this requires 40 to 70 kg K per ha (Harden 1994).

However, crops grown on other soil types with inherently high levels of potassium also develop the symptoms; mainly due to the interaction of the other important factors, boll load, stress, and cultivar. However, this does not mean that soil type does not play a role in these areas as well. For example, crops grown on soils near the river at Warren appear to be more susceptible than those further away from the river.

II) Boll load: crops with good yield potential are the most likely to be affected (eg greater than 7 bales per hectare) reflecting the fact tbat premature senescence is in many ways a problem associated with the high yields achieved by the industry. High boll loads predispose a crop to the problem because boll development and maturation require a large amount of potassium and other nutrients. For example in a 7 bales per hectare crop up to 90 kg K per hectare is stored in the boll walls, 40 kg K per hectare in seed and 15 kg K per hectare in lint. The importance of boll load is also illustrated by the differences between plants with or without the symptoms within the same field. In Figure 1a the dry weight of plants with or without the symptoms is compared, there was no difference in stem or leaf dry weights yet the plants with the symptoms had double the boll weights of those without. Thus the chief difference between these plants was their boll load. In Figure 1b the boll numbers of these plants is presented with the plants with the symptoms having twice the boll number compared to the healthy plants. Further, the number of open bolls was much greater in the plants with the symptoms. These measurements were made in early February hence the early opened bolls probably had fibre quality problems.

III) Stress: cool temperatures, waterlogging, water stress, soil compaction and soil salinity all affect the crops ability to take up nutrients from the soil. Hence, if a crop with a high boll load is or was exposed to one or more of these stresses then it can not supply the very high demand for potassium and other elements placed on it by the bolls. Work carried out at the University of New England suggests that when waterlogging is the trigger for premature senescence, the crop suffers a shortage of phosphorous as well as potassium.

IV) Cultivar: differences in the susceptibility of cultivars exist. For example the least susceptible cultivar appears to be Sicala V-2 while the most susceptible appear to be Siokra 1-4 and Siokra V-15. These differences may be related to differences between the cultivars in their ability to store potassium during the season. Sicala V-2 appears to store more potassium in its leaves than Siokra 1-4, while for most other plant parts the use of potassium appears similar for the two cultivars (Fig 2). In general the short season cultivars are more susceptible than long. Okra leaf cultivars may be more susceptible, possibly because they are not able to store as much potassium in their leaves as conventional cultivars. These general trends support the theory that the main cause of premature senescence is an imbalance between boll load and plant storage of potassium.



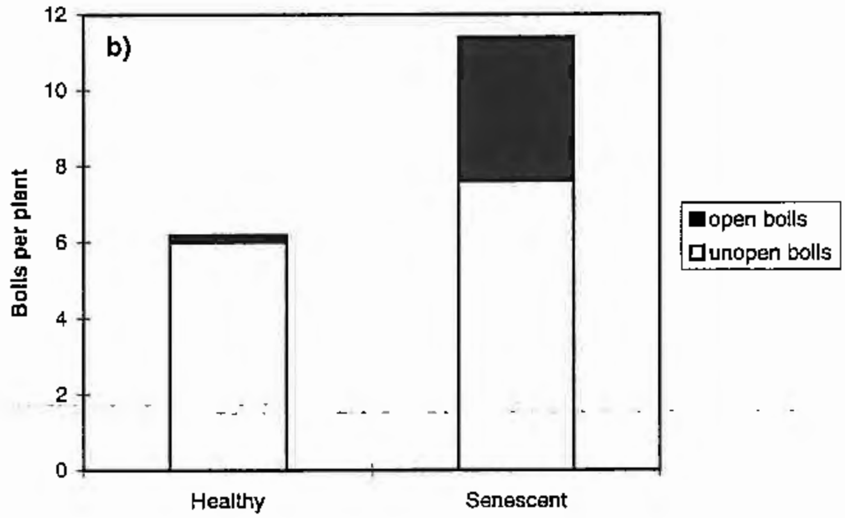


Figure 1. Differences in dry matter a) and boll number b) of plants with or without symptoms of premature senescence in the same field.

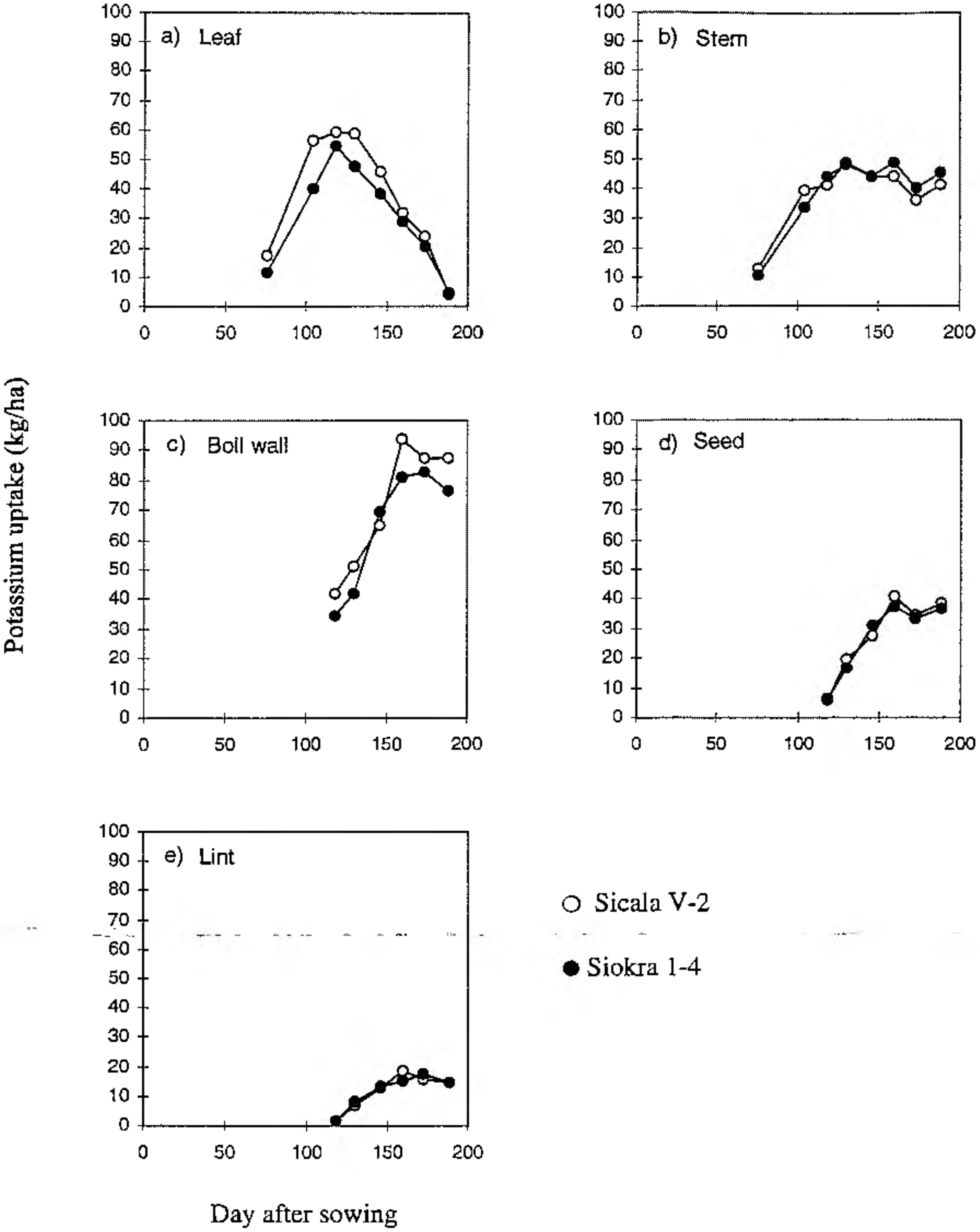


Figure 2. Uptake of potassium by different plant parts a) leaf, b) stem, c) boll wall, d) seed and e) lint with time for Sicala V-2 (open symbols) and Siokra 1-4 (closed symbols)

4.3 Uptake patterns of potassium

The amount of potassium taken up by the crops in this project were higher than has been previously reported (Halevy 1976, Cassman et al 1989) with most cultivars taking up at least 175 kg K ha^{-1} (Fig 3). The reason for the higher uptake rates may be the high yields now obtained in Australian irrigated crops, with much of the data on potassium uptake been based on old none irrigated American cultivars. The uptake rates are placing a large demand on the soils ability to supply potassium. For example for the uptake curves shown in Figure 3, the peak daily demand for potassium was 3.6, 2.6 and 4.4 kg K ha^{-1} day^{-1} for Sicala V2, Siokra 1-4, and N74-199b respectively. Daily demands of this magnitude are greater than the typically accepted daily supply rate of vertisols of 2 kg K ha^{-1} day^{-1} (C. Dowling, pers comm) and may be a further factor in causing premature senescence.

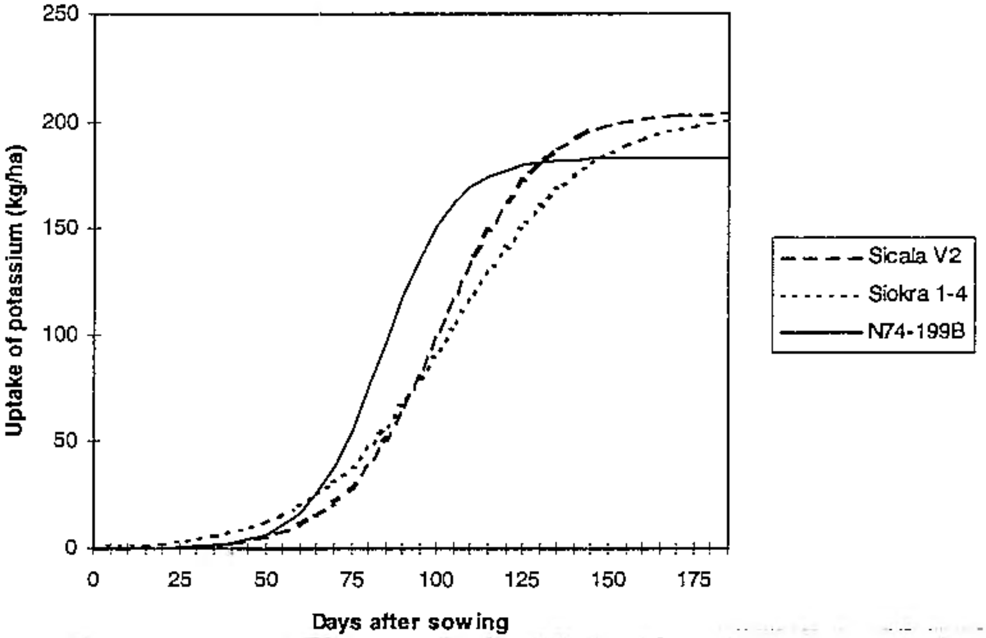


Figure 3. Uptake of potassium by three different cultivars of cotton

4.4 Effects of soil and foliar applied potassium

4.4.1 Yield

With the exception of the work carried out in conjunction with G. Harden at Emerald, the sites used in this project all had adequate levels of potassium in the soil. The addition of potassium to the soil at these sites only significantly increased lint yield on one out of the eight occasions tested (Table 1). However there was a fairly consistent trend for the potassium treatments to be numerically larger than the controls. Across all experiments and cultivars this resulted in an average lint yield increase of 2%.

Foliar applied potassium was also tested, though to a lesser extent. Results from these experiments were also not encouraging (Table 1) with no significant yield increases, though with a numerical trend to a small increase (1%). Similarly a combination of soil and foliar potassium had no significant effect. However, in these last two cases the foliar sprays were not all ways applied at the ideal time and hence work is continuing on these as a possible management tools.

Table 1. Summary of the effects of additional potassium on lint yield in 10 experiments

		Lint yield (kg/ha)									
Cultivar	**Treatment**	**N92***	**N93**	**L93**	**N94**	**L94**	**K94**	**V95**	**K95**	**Br95**	**Bo95**
CS50	Control	2153	2339	1621	-	-	-	-	-	-	-
	Soil	2144	2223	1708	-	-	-	-	-	-	-
	Foliar	-	-	-	-	-	-	-	-	-	-
	Soil+Foliar	-	-	-	-	-	-	-	-	-	-
CS189+	Control	-	-	-	2409	1956	-	-	-	-	-
	Soil	-	-	-	2152	1980	-	-	-	-	-
	Foliar	-	-	-	-	-	-	-	-	-	-
	Soil+Foliar	-	-	-	2381	-	-	-	-	-	-
Siokra 14	Control	2134	2694	1525	1251	1761	-	1213	-	-	-
	Soil	2087	2644	1540	1550	1944	-	1224	-	-	-
	Foliar	-	-	-	-	-	-	-	-	-	-
	Soil+Foliar	-	-	-	1083	-	-	-	-	-	-
Sicala V1/V2	Control	2192	2712	1938	2447	2003	2209	1877	-	-	-
	Soil	2304	2798	2001	2571	2034	2367	1671	-	-	-
	Foliar	-	-	-	-	-	-	-	-	-	-
	Soil+Foliar	-	-	-	2652	-	-	-	-	-	-
Siokra V15	Control	-	-	-	-	-	-	-	2213	1592	1956
	Soil	-	-	-	-	-	-	-	-	-	2016
	Foliar	-	-	-	-	-	-	-	2245	1575	2022
	Soil+Foliar	-	-	-	-	-	-	-	-	-	1924
199B	Control	1858	2699	-	-	-	-	-	-	-	-
	Soil	2068	2627	-	-	-	-	-	-	-	-
	Foliar	-	-	-	-	-	-	-	-	-	-
	Soil+Foliar	-	-	-	-	-	-	-	-	-	-
Mean	Control	2037	2611	1695	2036	1907	2209	1545	2213	1592	1956
	Soil	2048	2573	1749	2091	1986	2367	1448	-	-	2016
	Foliar	-	-	-	-	-	-	-	2245	1575	2022
	Soil+Foliar	-	-	-	2039	-	-	-	-	-	1924
Grand mean		2043	2592	1722	2055	1946	2288	1496	2229	1584	1980
Significance											
Pot		0.92	0.54	0.3	0.87	0.09	0.22	0.42	0.88	0.64	0.55
Cult		***	***	***	***	**		***			
Pot*cult		0.51	0.68	0.84	0.12	0.26		0.37			

4.4.2 Fibre quality

Effects of soil applied potassium on fibre quality were mainly limited to the two "Lowana" experiments. In these experiments (Table 2) the maturity ratio and percent of mature fibres were increased by soil applied potassium and the micronaire was significantly increased in the 1993 sown experiment. This site along with the "Killowen" site were the sites where the symptoms of premature senescence were most pronounced. The main conclusion from the fibre quality and yield data is that while there may be a very small yield and quality increases, soil applied potassium is not an appropriate management tool for preventing premature senescence on soils with adequate levels of potassium.

Table 2. Effect of soil applied potassium on fibre quality.

Site	Treatment	Maturity ratio	Percent mature fibres	Fineness	Length (inches)	Length Uniformity index	Strength	Elongation	Micronaire
N92	Control	-	-	-	-	-	-	-	-
	Soil	-	-	-	-	-	-	-	-
N93	Control	0.92	81	141	1.21	84.5	27.8	6.2	3.6
	Soil	0.90‡	80‡	139	1.22	84.4	35.5	6.2	3.5
L93	Control	0.92	82	156	1.19	84.0	29.4	6.0	3.9
	Soil	0.95*	85*	162*	1.20	84.2	28.7	6.0	4.1**
L94	Control	0.91	81	133	1.19	83.5	32.0	5.8	3.4
	Soil	0.94†	84‡	132	1.18	84.2*	31.9	5.8	3.5
K94	Control	0.99	87	135	1.20	84.5	30.6	5.3	3.7
	Soil	1.00	88	142	1.20	84.4	30.7	5.4	3.9
N94	Control	0.90	80	131	1.17	83.7	30.6	6.0	3.3
	Soil	0.89	79	127	1.19	84.1	30.8	6.1	3.2
Bo95	Control	0.97	85	137	1.19	85.8	29.7	6.2	3.6
	Soil	0.97	86	138	1.19	85.8	29.7	6.1	3.7
V95	Control	0.87	78	118	1.19	83.7	31.7	6.1	3.0
	Soil	0.87	78	120	1.17	82.9	31.4	6.0	3.1

‡P<0.2, †P<0.1,*P<0.05, **P<0.01

The effects of foliar applied potassium or combinations of foliar and soil applied were also examined though with fewer sites and years. In the three experiments were a foliar only treatment was used no significant effects on fibre quality were noted, with the exception of a small reduction in fibre strength in one experiment (Table 3). Curiously the soil combined with foliar application of potassium actually reduced fibre quality properties in the N94 experiment.

While the data appears to suggest little benefit in applying foliar potassium it needs to be noted that the sprays were not always applied at an ideal time and these results come from only a few experiments. As such work is continuing on foliar applied sprays as a management tool for premature senescence in the second part of the project (DAN107c).

Table 3. Effect of foliar applied potassium on fibre quality.

Site	Treatment	Maturity ratio	Percent mature fibres	Fineness	Length (inches)	Length Uniformity index	Strength	Elongation	Micronaire
N94	Control	0.90	80	131	1.17	83.7	30.6	6.0	3.3
	Soil+Foliar	0.85†	76†	125*	1.18	83.6	31.1†	6.0	3.1*
K95	Control	0.95	84	117	1.19	85.0	29.8	6.4	3.2
	Foliar	0.98	86	119	1.20	84.6	29.0†	6.2	3.3
Br95	Control	0.98	86	129	1.15	84.8	31.6	5.8	3.5
	Foliar	0.97	86	129	1.15	84.6	32.1	5.7	3.5
Bo95	Control	0.97	85	137	1.19	85.8	29.7	6.2	3.6
	Foliar	0.97	86	135	1.19	85.1	29.2	6.3	3.6
	Soil+Foliar	0.98	86	136	1.18	85.6	29.4	6.1	3.6

‡P<0.2, †P<0.1,*P<0.05, **P<0.01

4.5 Diagnosis

Diagnosis is difficult because of the nature of the problem. However, fields should be soil tested regularly to determine long term trends and to indicate if the site is a truly deficient site. This will decision to be made about the need to soil apply potassium.

Diagnosis of premature senescence on soils with adequate levels of available potassium is much more difficult. Traditionally potassium status of cotton has been assessed by petiole testing. However, my work has shown that petiole tests may be relatively unreliable. For example the petiole levels of potassium are consistently higher in the susceptible cultivar Siokra 1-4 compared to the resistant cultivar Sicala V-2 throughout the canopy (Fig 4a). However, when the leaf blades that were attached to the petioles were tested they show the exact opposite with consistently higher levels of potassium in V-2 (Fig 4b). Hence a diagnostic test is required that measures the storage of potassium (and possibly other elements). Work is continuing in DAN107c to work on better diagnostic technique. Currently, the best way of assessing the risk is to go on a combination of past history, petiole and leaf blade potassium levels and current crop history (eg. Have you had cool cloudy weather, waterlogging events, poor nitrogen nutrition).

4.6 Disease interactions

Premature senescence is often associated with Alternaria leaf spot, it can however also be associated with vascular wilts. There is a correlation between a cultivars disease susceptibility and it susceptibility to premature senescence (Table 4). These interactions may arise because potassium is an important factor in a plants defence mechanisms against disease. Thus plants that have better potassium storage (eg. Sicala V-2, Fig 2a) may be better able to tolerate disease. Further, the addition of potassium can improve the tolerance of crops to disease. For example the incidence of verticillium wilt (based on the number of plants with vascular symptoms) was reduced from 71% to 55% by soil applied potassium (100 kg K per hectare) for Sicala V-2. In contrast, applied potassium had no effect on the incidence of verticillium in Siokra 1-4 with close to 100% incidence.

Table 4. Relative tolerance (— poor, ✔ medium, ✔✔ good) of cultivars to disease and premature senescence.

Cultivar	Alternaria	Premature senescence	Verticillium	Fusarium
Sicala V-2	✔✔	✔✔	✔✔	✔
Sicot 189	✔✔	✔✔	✔✔	✔
Siokra S-101	✔✔	✔✔	✔✔	—
Siokra V-15	✔	✔	✔✔	—
CS 8S	✔	—	✔✔	✔
Siokra 1-4	✔✔	—	—	—
CS 50	—	✔	—	—
Siokra L-23	—	✔	—	—

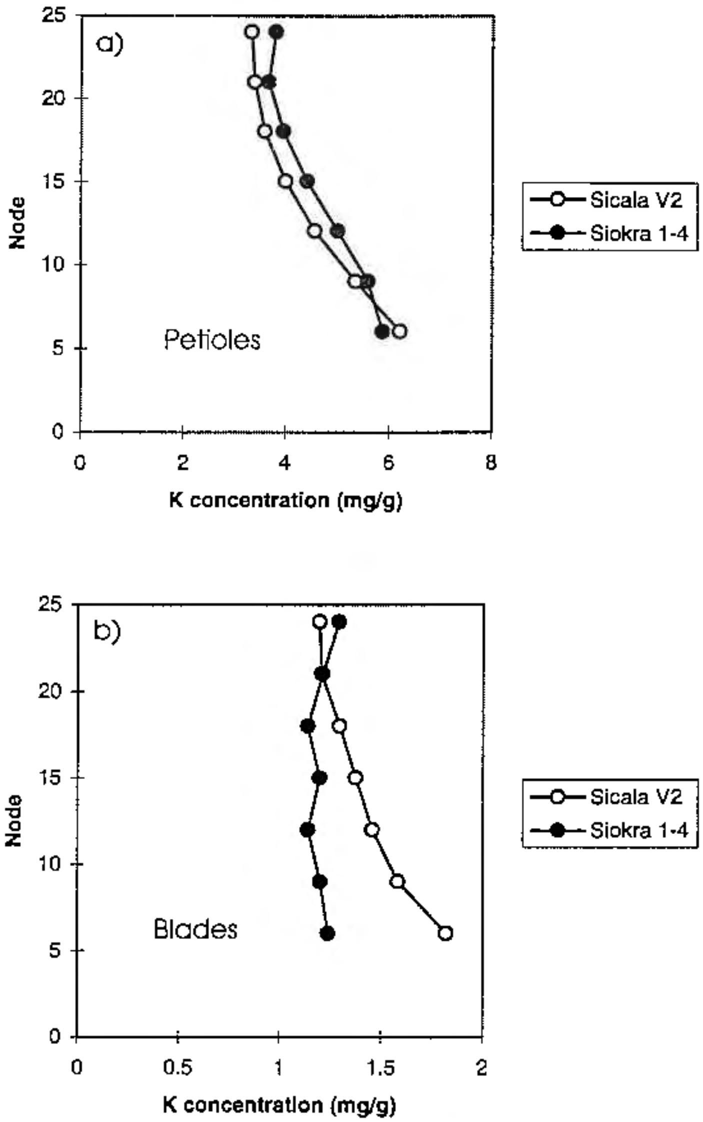


Figure 4. Potassium concentration in petioles a) and leaf blades b) of Siokra 1-4 and Sicala V-2

5. Conclusions:

1) Soil applied potassium is not an appropriate management tool for preventing premature senescence on soils with adequate levels of potassium (>150 ppm).

2) Further work is required on foliar potassium as a management tool for preventing premature senescence on soils with adequate levels of potassium (>150 ppm).

3) Cultivar differences in susceptibility are related to differences in the storage of potassium, particularly storage in the leaf blade. Of the current cultivars tested Sicala V2 is the least susceptible and has the highest leaf blade contents while Siokra 1-4 is the most susceptible and has the lowest leaf blade contents. As such the current best management approach is to chose the correct cultivar.

4) More work is required on assessing the relative susceptibility of different cultivars and on the breeding of less susceptible lines.

5) Leaf petiole testing is not an adequate diagnostic for premature senescence, work is required on a new test involving a combination of petiole and leaf blade testing.

Recommendations to Growers:

Premature senescence is in part an outcome of the high yields now being achieved by the industry. It has the potential to both reduce lint yield and quality and as such is a threat to both individual growers and the industry. However, management options are available, and are continuing to be developed, to reduce this threat. Management options that are currently available are listed below.

- Find out what your soil level of potassium is (preferable sample to 30 cm). If less than 150 ppm (or 0.38 mq 100g soil) then treat as a deficient soil by preplant applying 60 to 100 kg K per ha.

- If your soil has available potassium levels greater than 150 ppm and you have had problems with premature senescence in the past do not use soil applied potassium.

    - ***The chief management option under these conditions is to choose the correct cultivar***, use a long season cultivar such as Sicala V-2 if appropriate.

    - Ensure good nitrogen nutrition.

    - Reduce soil compaction.

    - Avoid waterlogging if possible.

    - Test petiole and leaf blade levels of potassium on three occasions, twice prior to first flower and once at first flower. We still do not fully understand what levels may indicate premature senescence, however, values in petioles below 4% and in leaves below 1.1% at that stage indicate the need for foliar applications (10 kg KNO_3 per ha on three to four occasions, starting 7 days after first flower and then repeated at 7 to 14 day intervals). With further research we may discover that in crops with a high yield potential the critical levels may need to be raised.

Communication of Results:

Wright, P.R. (1994) "Premature Senescence on High Potassium Soils". In - The Seventh Australian Cotton Conference Proceedings, pp 315-321.

Wright, P.R. (1996) "Premature senescence - Is it a threat to the industry ?". In - The Eighth Australian Cotton Conference Proceedings, pp 443-450.

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