Premature Senescence in Cotton in Relation to Potassium Availability in Soil: Preliminary Results

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Introduction

In Australia, premature senescence (PS) is occurring with increasing frequency in cotton crops on soils with high levels of available K. However, by the time PS is noticed, it is generally too late to take corrective measures and the use of plant tissue testing as a diagnostic tool has not been widely successful in predicting K deficiency (Kerby and Adams, 1985). Therefore, it is important to detect beforehand susceptible crops, so that timely action can be taken.

Wright (1999) suggests that the disorder is caused by the nutrient demands of a heavy boll load. Plants affected by PS have a 55-66% heavier total boll mass. Insufficient K is believed to be one of the main contributing factors of PS. Australian farmers currently use 150 mg kg^{-1} of ammonium acetate extractable K as a guide to whether their soil is K deficient or not. However, there have been reports of soils with levels of K greater than this which are still showing signs of PS (Wright, 1999).

Cotton plants take up relatively large quantities of K and thus rapidly deplete the K concentration in the zone around the root. While total K uptake varies according to soil K supplying capacity, it is the exchange-phase K which is the most readily available to the plants. However, sometimes K removed by plants greatly exceeds the initial exchangeable K levels (Reitemeier *et al.*, 1951).

The objective of this project is to develop a methodology to determine the K levels in the soil which reflects PS in the cotton crops and to test the hypothesis that the soil under the cotton affected by PS has different mineralogy (and available K) than the soil which does not show PS.

Material and Methods

Soil samples were taken from fields affected by PS and paired with similar soils under cotton crop not affected by PS. Soil samples were also taken from the Australian Cotton Research Institute (ACRI) station, which shows PS symptoms depending on weather conditions and crop cultivar. The experimental sites are located in cotton fields in northern NSW Australia, 25 km west of Narrabri (ACRI Station), 10 km north of Moree ('Red Mill'), 15 km east of Pilliga ('Lowana'), 12 km south east of Warren ('Killowen') and 22 km south east of Warren ('Twynam Elengerah'). Samples were taken at depths of 0-15 cm, 15-30 cm, 30-60 cm, 60-90 cm and 90-120 cm.

The soil samples were air-dried and crushed to pass through a 2 mm sieve. Soil pH and electrical conductivity (EC) were determined in 1:5 soil water extracts following shaking for half an hour. The particle size distribution was determined by the sedimentation procedure using the pipette method after dispersing the soil with calgon (Gee and Bauder, 1986). The organic carbon was determined by the wet oxidation method as described by M^{c}Cleod (1975). Various size fractions of soil samples were obtained by sedimentation and wet sieving techniques. The

dispersed soil suspension was allowed to stand, so as the sand and silt to drop out of suspension, leaving the clay in suspension to be decanted off. The sand fraction was separated from the silt by using a 200 micron sieve for the coarse sand and 20 micron sieve for the fine sand.

The cation exchange capacity (CEC) and exchangeable cations including K were determined using 1 M ammonium chloride (pH 7) (Rayment and Higginson, 1992).

During the last cotton crop, plant samples were twice taken from the same sites as the soil samples. The first were taken at first square and the second after cotton boll development. The K, Ca, Mg and Na content in the plant samples was determined after digestion in a mixture of nitric and perchloric acids (Johnson and Urlich, 1959). Digested samples were analysed using a GBC908AA double beam atomic absorption spectrophotometer.

The mineralogy of the soil was determined using both basally oriented and random powder specimens. X-ray diffraction (XRD) patterns were obtained with a Siemen D5000 diffractometer using a CuKα radiation. The oriented clay fractions were examined after Mg saturation, glycerol solvation following Mg saturation and K saturation followed by air drying and heating at 335°C and 550°C for four hours (Brown and Brindley, 1980). The random powders were packed in a circular aluminium holder and filled using a sieve and razor blade to minimise preferred orientation. The samples were scanned in 0.02° 2θ steps at a speed of 0.6° 2θ per minute. The random powders were run from 4 – 65° 2θ and the oriented samples from 3 – 15° 2θ and 3 – 30° 2θ (Mg saturated samples only).

Results and Discussion

The pH of the surface samples ranged from 6.5 to 8.5, with the subsoil being higher pH (from 8.5 to 9.5), indicating an alkaline soil reaction trend. The electrical conductivity (EC) varied from 30.5 to 210.0 μS cm^{-1} in the surface sample and generally increased with depth. Some subsoil samples had EC as high as 829 μS cm^{-1}. The clay content in the soil ranged from 31 to 77% and there was an increase in clay content with depth in all soils except for Warren samples. The organic carbon (OC) content ranged from 1.11 to 2.44% for the surface samples, with a mean value of 1.81% which decreased to 0.42% in subsoil samples.

Table 1. Soil properties of premature senescence and non- premature senescence fields

Soil properties	Soil samples from fields showing PS symptoms			Soil samples from fields showing no PS symptoms			Soil samples from the ACRI field *		
	Range	Mean	Median	Range	Mean	Median	Range	Mean	Median
pH (1:5 H_2O)	7.17 – 9.54	8.34	8.34	6.13 – 9.71	8.89	9.14	8.67 – 9.24	8.97	8.98
EC (1:5 H_2O, μs/cm)	30.5 – 371.0	157.0	156.5	50.3 – 829.0	314.0	277.5	81.3 – 280.0	162.4	140.0
OC (%)	0.08 – 0.96	0.43	0.51	0.06 – 1.38	0.49	0.45	0.28 – 0.63	0.42	0.40
Clay (%)	31.3 – 55.3	43.7	44.0	32.2 – 67.3	52.0	52.0	60.7 – 76.8	66.1	64.2

* The ACRI field showed both PS and Non-PS characteristics between seasons

The mineralogy of the clay fraction consisted predominantly of smectite, illite and kaolinite. Minor amounts of interstratified clay minerals and quartz were also present. The proportion of various minerals in the clay fraction was estimated from the peak areas of the various minerals. Based on the mineralogy of various samples, we classified the samples into three groups. Group 1 consists of soils which had kaolinite, illite and smectite in nearly equal amounts, Group 2 consists

of soils dominated by smectite followed by kaolinite and small amounts of illite and, in Group 3, illite the dominant clay mineral followed by kaolinite then smectite.

Table 2. Mineralogy grouping

Group	Sites	Clay Mineralogy		
		Smectite	Illite	Kaolinite
1	Narrabri (1), Pilliga Non-PS (4)	XX	XX	XX
2	Moree PS (2), Moree Non-PS (3), Pilliga PS (5)	XXX	X	XX
3	Warren 12 Non-PS (6), Warren 12 PS (7), Warren 22 Non-PS (8), Warren 22 PS (9)	X	XXX	XX

XXX – dominant mineral (>50%)
XX – 30-50%
X – <30%

There are no systematic differences between the PS and non-PS sites for common soil properties such as pH, EC, clay content and organic carbon. The clay mineralogy of the various sites is different but, except for the Pilliga site, there is no difference in the clay mineralogy of PS and non-PS sites.

Several analyses are currently being undertaken and results on the quantitative mineralogy and total K content in the soil and plant samples will be determined in the next stage of the project.

Conclusion

It is important to be able to determine beforehand whether there is a likelihood of PS occurring in a cotton crop. In our research we will be looking at the relationship between K availability and PS in cotton. Although insufficient K is implicated as a main contributing factor of PS in cotton crops, the relationship between the amount of K in the soil and the occurrence of PS is not straightforward. The knowledge of the various forms of K present in the soil and the relationship between these different forms of K and PS would facilitate the development of better management practices and consequently increased cotton production.

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