REPORT
for
The Australian Cotton CRC

USA – Scientific Exchange
July 20 to August 9, 2002

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Summary

The scientific exchange involved meeting with researchers and extension specialists from the University of California - Merced, the University of Arizona - Maricopa, Texas A&M University, Monsanto - St Louis and the University of Georgia – Tifton.

The scientific exchange had the following objectives:

- Examine farming systems relevant to tropical Australia, e.g. peanut / cotton on light soils, drip / overhead head irrigation, conservation tillage systems.
- Meet with researchers engaged in crop adaptation and climatic risk assessment work similar to my own professional expertise and relevant to tropical Australia.
- Meet researchers with expertise with growing cotton in hot arid climates.
- If possible visit one Native American / cotton farming partnership in Arizona with respect to its relevance to similar potential partnerships between cotton growers and indigenous Australians.

The exchange met the above objectives, highlights were:

- The light soil overhead / drip irrigated farming systems of south Georgia: which showed the benefits of a peanut rotation with cover crop and conservation tillage on light textured soils similar to tropical Australia. However it also highlighted important challenges for tropical Australia. Firstly from nematodes, where rotations / cover crops and breeding are critical for control. Secondly, the increased importance of sucking pests with the change to transgenic varieties. Thirdly, nutritional issues such as the link between K and Alternaria on light soils with overhead irrigation.

- The methodologies used to study water use in overhead and drip systems at a larger scale were seen first hand at research sites conducted by the University of Georgia and the USDA.

- The research into effects of supra-optimal temperatures on cotton production in a hot arid climate. Where a locally derived formula based on mean daily temperatures is successfully applied to predict risk to fruit retention and growth. Severe stress is most likely with mean daily temperature of > 30C. Similar temperatures are observed on late sown crops in northern Australia.

- To see successful production of cotton and other irrigated crops by Native Americans at the Ak-Chin reservation in Arizona, where some 10, 000 ha of irrigated crops including cotton are grown.

- The importance of independent comparison of herbicide resistant transgenic systems with conventional weed management systems in tropical Australia.

- Visiting the Monsanto Research facility at Chesterfield, St Louis. Where I gave a seminar on cotton in tropical Australia with emphasis on issues for the use of glyphosate-tolerant cotton. One conclusion was that research emphasis in northern Australia should be on enhanced roundup ready varieties.

- Making contacts with researchers at Texas A&M that are independently studying the effect of changed herbicide usage (e.g. glyphosate on transgenic cotton) on soil microbial activity and biomass.

- Research to manage grass weeds in zero tillage systems, where the cover crop is also a grass. No solutions yet but a very similar problem in tropical Australia.

Itinerary

Day	Date	Program	Contact Details
Saturday	20-Jul-02	Arrive San Francisco 1222	
Sunday	21-Jul-02	Travel to Merced CA	
Monday	22-Jul-02	Merced	**Bill Weir - Uni of California**
Tuesday	23-Jul-02	**ARIZONA**	
		Maricopa Ag Centre – University of Arizona	**Peter Ellsworth- UAZ**
Wednesday	24-Jul-02	Casa Grande	
		Casa Grande	**Pat Clay - UAZ**
			Steve Hausman - UAZ
Thursday	25-Jul-02	Maricopa Ag Centre	
			Ed Martin _ UAZ
			Pat Clay - UAZ
Friday	26-Jul-02	Maricopa Ag Centre	**Richard Percy - USDA**
Saturday	27-Jul-02		
Sunday	28-Jul-02		
Monday	29-Jul-02	**TEXAS**	
			Tom Cothren
Tuesday	30-Jul-02	College Station	**Ty Whitten**
		Texas A @ M University	
Wednesday	31-Jul-02		
Thursday	1-Aug-02	**St Louis**	**Monsanto - Chesterfield**
			Mark Oppenhuizen
Friday	2-Aug-02	**St Louis**	
Saturday	3-Aug-02	**St Louis**	
Sunday	4-Aug-02	St Louis to Valdosta Georgia	
Monday	5-Aug-02	**GEORGIA**	
		University of Georgia	**Lloyd May**
Tuesday	6-Aug-02	Tifton	
			Philip Roberts
Wednesday	7-Aug-02		**Steve Brown**
			Marshal Lamb - USDA
Thursday	8-Aug-02		**Craig Bednarz**
			Glen Harris
Friday	9-Aug-02		
Saturday	10-Aug-02	Return to Australia	
Sunday	11-Aug-02		

Introduction

The scientific exchange had the following objectives:

- Examine farming systems relevant to northern Australia (NA), e.g. peanut / cotton on light soils, drip / overhead head irrigation, conservation tillage systems.
- Meet with researchers engaged in crop adaptation and climatic risk assessment work similar to my own professional expertise and relevant to research needs identified for cotton in northern Australia (e.g. growth regulation).
- Meet researchers with expertise with growing cotton in hot arid climates.
- If possible visit one Native American / cotton farming partnership in Arizona with respect to its relevance to similar potential partnerships between cotton growers and indigenous Australians.

1. Merced California – University of California

The day here was not originally planned, I had arranged to have the day in Arizona with Jeff Silvertooth but he was unavailable at short notice. So I visited Merced en route to Arizona.

Dr Bill Weir showed me the diverse farming system in Merced County, which is part of the San Joaquin valley. Bill pioneered twin row cotton where yield increases of 6.8 to 11.6% had been measured in previous experiments. Fibre quality benefits are also being investigated (Plate 1). This season extending the flowering period of cotton grown in twin rows was being considered as an additional treatment.

Research in this area had quantified potassium fertiliser requirements in response to soil and plant tests. An understanding of at least the methods needed to do this type of research was of benefit because many soils in northern Australia (NA) are considered inherently low in potassium and require the development of fertilization practices for cotton to be grown. A threshold soil level of 110 ppm available K is used (where soil available K is 80 to 110ppm, similar to northern red earths, 224 kg/ha of K_2O is recommended for yield levels of 7.5b/ha, which is greater than currently applied in NA. However the amount of K fixation may be higher on Californian soils.

I also saw upland and Pima variety trials; the later has increased in area in recent years at the expense of the traditional growing area in Arizona.

Plate 1: Twin row cotton at Merced CA, improved fibre quality (mic) due to a higher proportion of lower P1 bolls, is seen as a key benefit.

2. Maricopa Agricultural Centre - University of Arizona

In addition to what is described below I was given a tour of the research facility and was shown the cropping mix of the region. Hesperelo was being evaluated as an alternative fibre, Tequila cactus and turf grass evaluation were major research activities.

The area sown to cotton has fallen by 67% in recent years due to competition from alternatives such as lucerne for dairying and demand for land for housing. There has also been a move of Pima production to California with only 6,000 ha now sown to Pima in Arizona.

I was shown the Ak-Chin Native American reservation, which borders the research centre. The Ak-chin are one of several groups in Arizona that generate income and employment from growing irrigated crops and other enterprises (e.g. Casino's). The Ak-Chin successfully farm 10,000 ha of irrigated cotton, lucerne and other crops.

2.1. Conservation tillage / cover crop systems.

I visited replicated experiments at the research centre and on two commercial farms. Zero tillage was compared with reduced till and conventional tillage with or without a winter cover crop, usually oats that had been sprayed out prior to flowering. The objectives were broadly similar to NA, that is, for soil protection and reduced machinery passes.

In crop weed control was an issue as the mulch cover had bound up many of the soil incorporated herbicides, similar to NA (Plate 2). Round up ready varieties had permitted the use of glyphosate over the top but many weeds continued to germinate past the 4 node stage. Hence spot-spaying technology was being evaluated to reduce the amount of expensive selective herbicides applied.

Of interest because of low cotton prices one farmer had grown a crop of barley through to harvest and sown cotton later with the risk of lower yield to improve net returns.

Plate 2: Zero tillage left and conventional tillage right in a replicated experiment at Buckeye Arizona, the cotton followed a winter crop of oats, grass weeds were a problem in both forms of tillage, similar to NA.

2.2. Irrigation Scheduling / water use

Arizona is similar to NA because the crop is grown with no in-crop rainfall, VPD's are large and heat units are usually not limited. Most crops are furrow irrigated, but this is considered expensive and there is increasing need for improved efficiency of usage due to greater demand for water by urban users. Recent extension efforts have focused on improved efficiencies of scheduling and application.

Dr Ed Martin gave me a copy of a training manual for irrigators, which was targeted for the farm workers that apply the water and who mostly speak Spanish. The course and manual are bilingual. Most of the emphasis in the manual is on accurate calculation, using a simple slide chart, of the duration of irrigation based on knowledge of the volume of water to be applied. The consequences of extending irrigation by as little as 30 min are calculated. Calculation of the leaching requirement to prevent salt accumulation in the soil surface is also given.

There is a good knowledge of the plant available water content of the soils and seasonal crop water usage to develop the above decision aids. The absence of rainfall combined with a good network of meteorological stations permits scheduling to be based on evapotranspiration using locally derived crop factors.

I was shown research evaluating different methods of rapidly applying irrigation water to fields. A key issue is to spread water evenly across the field quickly without eroding sections of the field; several designs are under evaluation see prints (Plate 3).

Plate 3: Modifications to allow rapid application of irrigation water to field and minimise soil movement. Note channels are concrete.

I was shown the locally derived heat stress indices developed by Paul Brown at Tucson. This uses a locally derived formula based on critical mean daily temperatures of 28 to 30^{o}C for moderate (some fruit shedding and smaller bolls) and > 30^{o}C for more severe stress which causes more fruit shedding and malformed bolls.

2.3. Pima Breeding Program

Dr Richard Percy USDA is the sole government Pima (*G. barbandense*) breeder in the USA. I discussed the current program and issues relevant to Pima in NA. I showed Richard data from varieties in NA using many of his lines, the key issue being the poor fibre length of all lines when grown in the tropical dry season.

Key objectives of Richards' program are improved lint quality as length and strength, heat stress tolerance and evaluation of okra leaf for white fly tolerance (Plate 4) (this material has already been introduced to CSIRO's breeding program). The improved fibre quality lines were of interest, however, there has been no commercial success with Bt transgenic *G. barbadense* cultivars.

Plate 4: Left Okra leaf Pima (*G. barbadense*), long fibre Pima (Dr. Richard Percy).

2.4. Twin Row Cotton

Replicated experiments were being conducted at the research centre and on-farm with the objective of validating the California work and had similar difficulties with suitable planting equipment (Plate 5).

2.5. I.P.M.

One day of my visit coincided with CRDC's white fly study tour. So I sat in on the presentation by Dr. Peter Ellsworth on white fly IPM in Arizona. I also met with Peter later in the week to discuss the adoption of Bt cottons and their value in management of pink bollworm, which is a native of northern Australia and a potential pest. In summary, adoption of Bt varieties was very high and they had been very effective in controlling pink bollworm with a consequential reduction in the use of insecticides. Resistance management is important as the pest is not native hence most of the population reside in cotton crops.

Plate 5: Twin row left single row right of Steve Hausman UAZ, note difference in leaf area.

3. College Station Texas A and M University – Dept. of Soil and Crop Sciences.

I visited the Department of Soil and Crops Sciences lead by Dr. Tom Cothren. Tom is known for his research on growth regulators in cotton. I discussed with Tom his past and current growth regulator research. He did some of the early work to evaluate seed treatment with Pix, which was relevant to some of my work in NA. However the objectives in a temperate climate, i.e. seedling vigour in dry cold conditions were different to the tropics (early growth suppression). Tom's group are currently evaluating some new growth regulators, I was particularly interested in experiments evaluating a Mepiquat with Br as the halogen instead of Cl and Pix Plus (mepiquat chloride and *Bacillus cereus*).

Ty Whitten (research associate) showed me some of the field research conducted by the group at the university. Of interest was his PhD work that is using C_{14} labelling to determine time of physiological maturity i.e. termination of C transport into bolls.

I went with Tom and Ty to a defoliation field day in Upper Coast region about 100 km to the south (Plate 6). Most crops are dryland or supplementary irrigated and the mild climate permits sowing in February hence crops were being defoliated in late July. The low input nature of the cropping system meant that low cost was the priority in defoliant selection, hence the chemicals / rates being evaluated were not relevant to NA.

Plate 6: Defoliation experiment Wharton county Texas.

After the field day we looked at crops suffering from premature senesence, which was increasing in importance in the region. I also met the IPM extension agent Dan Fromme. The region has similar sucking insect pests to Katherine e.g. GVB, *Creontiades*, Aphids, I collected information on thresholds and scouting techniques.

Tom had arranged meetings with several of the other scientists in the group:

- Scott Senseman is researching bioremediation and biodegradation of pesticides. His current work is measuring the effect of glyphosate as the active ingredient and in commercial formulation on soil microbial activity and biomass. The increased use of glyphosate-tolerant crops had raised concerns regarding the impact on the soil environment. Having Scott, as a contact plus access to his publications will be a valuable independent resource in the evaluation of glyphosate tolerant cotton in current production regions and in northern Australia.

- Sam Feagley is a soil chemist. He provided some useful information of P and Zn interactions such as the 60:1 rule of thumb ratio for soil availability.

- Paul Baumann and Dudley Smith work on weed control and management systems. Glyposhate resistant cotton has lead to a significant change in the in-crop herbicides used and other weed management practices used. Glyphosate application to cotton has increased from 3% to 57% of U.S. fields over the period 1992 to 2001, replacing other herbicides such as trifluralin. A high proportion 86% of U.S. fields are monitored prior to making weed management decisions.

Plate 7: Red Cotton, Texas A&M University, College Station Texas

4. Monsanto – Chesterfield Missouri.

Entomologists consider transgenic Bt cotton as an essential component of any NA cotton production system and Monsanto are currently the only marketers of this technology. Hence Monsanto are important collaborators in the CRC effort in NA. I spent 2 days at Monsanto's Chesterfield research centre. The visit was organised by John Greenplate who visited NA in 2000 with Stewart Addison.

My objectives for the visit were:

- To learn more about herbicide tolerant transgenic cotton developments, particularly glyphosate tolerance.
- To give a seminar on issues relating to cotton development in northern Australia (as requested by Monsanto).
- To see a research facility that develops this type of technology for the first time.

Mark Oppenhuizen gave me a tour of the research facility. I met with Graham Head (insect ecologist), Saku Sivasupamaniam, Fred Perlak, Randy Deaton and Kent Croon.

Of relevance to NA were discussions I had with Doug Sammons and Mark Oppenhuizen on enhanced roundup ready cotton, which will replace round up ready in 2006. Enhanced Roundup Ready has the advantage that it permits safe application of glyphosate up till the 16 node stage without damage to fruit.

I presented a 90 min seminar to about 25 of their R&D staff. I provided an overview of tropical cotton R & D in Australia with emphasis on conservation tillage systems under evaluation that use glyphosate. There was good discussion on the merits of glyphosate resistant varieties in this system. Enhanced RR was preferable but research should also focus on resistance management issues in weed management systems. .

5. University of Georgia – Coastal Plain Experiment Station – Tifton.

I spent a week in South Georgia with the research and extension staff from the University of Georgia and USDA. Cotton production in South Georgia has more similarities to light textured soils in NA than any where in the developed world. That is, sandy or red earth soils of low inherent fertility, overhead (pivot / lateral) or drip irrigation, peanut as the main rotation crop, a cover crop, conservation tillage, a non contiguous area of cropping where individual fields are usually surrounded by uncleared forest and there is integration with animal industries such as beef.

I was shown research and extension work on important components of the farming system: breeding, crop adaptation, irrigation scheduling and water use, the impact of transgenic (glyphosate tolerant and Bt), rotations / cover crops/ tillage, and crop nutrition.

Following the eradication of the boll weevil cotton production in Georgia has increased from 828,000 bales from about 200,000 ha in early 1990's to 2,200,000 bales from 600,149 ha in 2001. Over 80% of the cotton acreage is now sown to transgenic varieties, i.e. Bt and glyphosate tolerant.

5.1. Breeding

Dr. Lloyd May organised my visit, he is the university cotton breeder. A major objective of the program is nematode resistance (Plate 8). Nematodes are a major pest on the light textured soils and in the absence of resistant varieties rotation with non-susceptible crops (e.g. peanuts) and nematicides are the only management tools.

Plate 8: *Screening lines for nematode resistance, Bainbridge, south Georgia (Lloyd May). Note sandy soil and trees surrounding pivot and okra leaf lines from CSIRO.*

Another component of the program is the independent evaluation of transgenic varieties. I was shown one of the few Roundup Ready / enhanced Roundup Ready comparisons to be conducted in the U.S. by non-Monsanto researchers. Using the same variety background, enhanced roundup ready could tolerate glyphostate applied at 4, 8 and 12 and 16 nodes without fruit loss compared with the round up ready gene which lost fruit with treatment > 4 node stage (Plate 9).

I also met Peng Wah Chee a molecular biologist who is identifying novel genes from non-cultivated *Gossipyium* species.

Plate 9: Left - Roundup Ready, Right - Enhanced Roundup Ready, note the difference in boll growth and retention after spraying with glypohsate at 4, 8 and 12 nodes.

5.2. Rotations / cover crops

Cotton is most commonly rotated with peanut, although, corn and vegetables are used to a lesser extent. A cover crop is grown over winter (usually a winter cereal), which is killed with a knock down herbicide prior to seed set then the summer crop established using strip tillage (Plates 10, 11). The soils are often hard setting (natural or compaction) so subsoiling (deep ripping) to 40cm is often part of the operation.

This rotation system has many benefits.

- Peanuts are not a host for the important cotton nematodes, root-knot (*Meloidogyne incognita*), reniform nematode (*Rotylenchulus reniformus*) and Columbia lance nematode (*Hopolaimums columbus*).

- Peanuts provide about 30 units of N to following cotton crops.
- Cotton is a break for cercosperia in peanut and the peanut specific nematodes
- On some farms cattle are fattened on the winter cover crop.

The species of cover crop is important in Nematode management. Legumes such as vetch are hosts to root-knot nematode and will negate the benefits of peanut in the rotation. However, rye is a poor host of root-knot nematode and will complement peanut in reducing the population.

The increased sowing of transgenic varieties has driven research to compare conventional production systems with the transgenic systems (Plate 11). These comparisons if properly conducted offer an independent assessment of the technology the economic trade-offs. With systems involving RR varieties not yet developed in NA similar studies would be valuable.

Plate 10: Strip till planter, A) coulter, ripping tyne, coulter for tilled band B) harrow, C) disc planter + presswheels.

Plate 11: Above – oat and previous peanut trash under late flowering strip tilled cotton. Below - Independent transgenic systems experiments run by University of Georgia, at Bainbridge GA (Eddy McGrif).

5.3. Irrigation / water use

There is increased demand for the aquifer water that supplies the crops in the coastal plane of South Georgia, Alabama and South Carolina. Hence in recent years research has been targeted at improving efficiency of water usage. I looked at research conducted by UGA Tifton (Craig Bednarz) and USDA (Marshal Lamb).

The University of Georgia research is focused on improving the efficiency of overhead irrigation systems. I was shown scheduling research at Tifton and visited the new irrigation research centre at Carmila. The specifics required for efficient scheduling are not highly relevant to NA as the Georgian crop is grown with significant in-crop rainfall. Of interest at the Tifton site was the lateral move irrigator being set to deliver different volumes of water at variable times from each span, which allowed for replicated experiments using the one irrigator in the field (Plate 12 - top). A similar experiment with more treatments was located at the Camilla site, however the newer lateral move was set up so that irrigation could be applied separately to smaller plots within each span (Plate 12 - bottom).

The irrigation research centre at Carmilla was established only a year previously and was well equipped. One large-scale experiment was evaluating the scheduling and water use of crops irrigated with using a centre pivot. Of interest was the methodology used, where 4 small 2 span pivots located within the one paddock provided replication and within each pivot scheduling treatments were imposed (Plate 13 - top). Telemetry was used to download capacitance probes and control the pivots.

Precision pivot irrigation application was also being evaluated at Carmila (see Plate 13 - bottom). The pivot had been modified to apply variable amounts of water to each nozzle in the pivot by using pressurised air to vary out put. To calculate the volume of water to apply to different areas within the field involved detailed mapping of the paddock for soil variability in moisture availability and nutritional statues and monitoring the crop within the field for moisture stress. This type of system, if successful, could be useful in areas of NA were light textured soils are very heterogenous such as the Daly Basin of the NT.

Plate 12: Water use / scheduling research. Above – Tifton lateral move set to deliver variable watering times and amounts from each span. Below – Carmila lateral move configured to deliver variable watering times and volumes within each span; arrow shows sprinklers with 180° distribution. (Standing Dr. Craig Bednaz).

Plate 13: Above - Replicated water use study at Carmila GA using 4 2 span pivots i.e. 1 replicate per pivot. Below – Precision irrigation research at Carmila GA. The pivot has a compressor (arrow) to apply air to each sprinkler and vary the output as determined by detailed paddock maps.

I visited the Multi-Crop Irrigation Research Farm at the USDA-ARS National Peanut Research Laboratory, Dawson GA. This is a multi-disciplinary project to evaluate crop rotations involving peanut, cotton, corn and sorghum, irrigation systems (sprinkler, surface and sub surface drip) and 12 different irrigation amounts. There is an economic component and interactions between irrigation with pesticide fate and movement are measured. I was shown the experiment by Marshal Lamb an economist.

Of interest was the successful production of peanuts using sub surface and surface drip irrigation on a red clay loam soil (Plates 14 and 15). A twin row configuration was also being evaluated for peanuts. Sub-surface drip placed at 15cm was proving the most efficient for cotton at although at higher levels of water supply there was no difference between the systems for yield. However, irrigated cotton yields are low (4.3-5.0 b/ha) compared to Australia.

Plate 14: Multi-Crop Irrigation Research Farm at the USDA-ARS National Peanut Research Laboratory, Dawson GA. Surface tape irrigation of peanuts, cotton, sorghum and maize. (Left - Steve Brown UGA, Right Marshal Lamb USDA)

Plate 15: Multi-Crop Irrigation Research Farm at the USDA-ARS National Peanut Research Laboratory, Dawson GA. Top – subsurface drip irrigation treatments. Bottom – surface drip irrigation of peanuts.

5.4. Insect Pest Management

I spent half a day with Philip Roberts, IPM extension specialist. The eradication of boll weevil combined with Bt varieties has dramatically reduced insecticide usage, particularly broad-spectrum insecticides. However, there has been a change in the pest species with 'stink bugs' (*Nezara viridula, Acrosternum hilare, Eusschistus servus, Proxys puctulatus*) increasing in importance. Control strategies for these pests were still evolving and were linked in part to research into rotation / cover crops systems that Philip showed me. Research is in progress to determine optimum sampling procedures and spray thresholds. Similar pests have become more prevalent in NA.

I also saw independent trials evaluating the efficacy of BollgardII, under irrigated and dryland conditions.

5.5. Crop Nutrition

I spent half a day with Glen Harris who specialises in crop nutrition. Georgia soils are similar to the red earths in NA that is highly weathered, low inherent fertility and organic carbon.

Potassium deficiency is being increasingly observed in cotton in Georgia and according to Glen in almost every case it has been associated with leafspot diseases *Alternaria*, *Cercospera* and *Stemphylium,* which are considered secondary to the primary cause, K deficiency. Moreover once plants become K deficient fungicide sprays do not alleviate the condition. Diagnosis of K deficiency is by soil testing, petiole and / or tissue analysis. Split fertiliser applications to the soil at sowing and at squaring are recommended.