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Three decades of cotton disease surveys in NSW, Australia

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Abstract. Three decades of disease survey data have shown Verticillium wilt was one of the first major diseases of cotton recorded in the 1984–85 season. Survey reports the mean incidence was 4.1% in the 1984–85 season and rose to 16.6% in the 1989–90 season. Prior to 1984 all commercial varieties of cotton available in Australia were susceptible to bacterial blight and the disease was common. The adoption of the resistant varieties contributed to a dramatic decline in the incidence of bacterial blight and the removal of bacterial blight as a significant pathogen to Australian cotton crops by 1992.

Survey results showed the incidence of black root rot increased on farms with a long history of growing cotton during the 1990s. Fusarium wilt of cotton was first reported in New South Wales (NSW) in 1994. The disease is now widespread, being confirmed on 86 NSW farms in six of the eight cotton production areas in NSW. These four significant plant disease 'problems' have challenged the cotton industry in NSW.

Data provided by the surveys have indicated the relative importance of each of the diseases present and the impact of cultural practices and the adoption of new varieties on disease distribution, incidence and severity. The results have therefore been used to support and justify requests for research funding and have contributed to the development of Integrated Disease Management strategies.

The NSW Department of Primary Industries continues to monitor the distribution of disease and the incidence and severity present in commercial cotton crops in all production areas of NSW. The aim of this paper is to highlight four significant cotton diseases in Australia and show relationships between cultural practices and declining and increasing incidence of disease.

Additional keywords: bacterial blight, black root rot, Fusarium wilt, Verticillium wilt.

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Introduction

Cotton (*Gossypium hirsutum* L.) production areas of New South Wales (NSW) are confined to latitudes between 28°S and 35°S. The majority of the crop is furrow irrigated, on alkaline clay soils, located on or near flood plains, associated with river systems draining to the west. The NSW Department of Primary Industries has been making quantitative assessments of disease incidence and severity in cotton for three decades, with the first commencing in 1983–84. As a result of the recent expansion of cotton production into southern NSW, the number of fields surveyed has increased from ~40 to 112, covering a distance of over 20 000 km per year (see Fig. 1).

The standard cotton production practices used in Australia favour the dispersal and survival of plant pathogens. Furrow irrigation and tail-water recirculation disperse pathogens efficiently. Reduced or minimum tillage increased pathogen survival season to season. The introduction of permanent bed systems facilitates optimum placement of developing seedlings directly above pathogens in the soil. Pathogen dispersal increased due to frequent movement of machinery, vehicles and people.

Changing farming practices and genetic technology has meant there continues to be a need to monitor diseases on commercial cotton farms. Survey results are maintained in a database, which includes information on field history, crop establishment and cultural practices. Disease data is entered and stored on the Filemaker (Filemaker Pro 11.0 version 3 1984–2011, Filemaker, Inc., Santa Clara, CA, USA) database.

Environmental conditions have had a big impact on cotton production in Australia. Years of drought contributed to a 60% reduction in crop size in the 2003–04 season (Cotton Australia 2013). The 2007–08 cotton crop was the smallest in more than 30 years, a direct result of the drought. Production peaked at 578 500 ha in the 2010–11 season, with NSW growing 66% of the total crop (Cotton Australia 2013).

Method

Cotton disease surveys are conducted early in the season, 3–6 weeks after sowing and before the first irrigation and again after the final irrigation but before defoliation. In order to carry out quantitative assessment of diseases in NSW cotton crops, a systematic method of sampling was initiated following the step-point method described in Nehl *et al*. (2004*b*). Information collected from each field included cropping history, ground preparation, variety, seeding rate, sowing date, carryover of crop residues, survey date and crop growth stage as

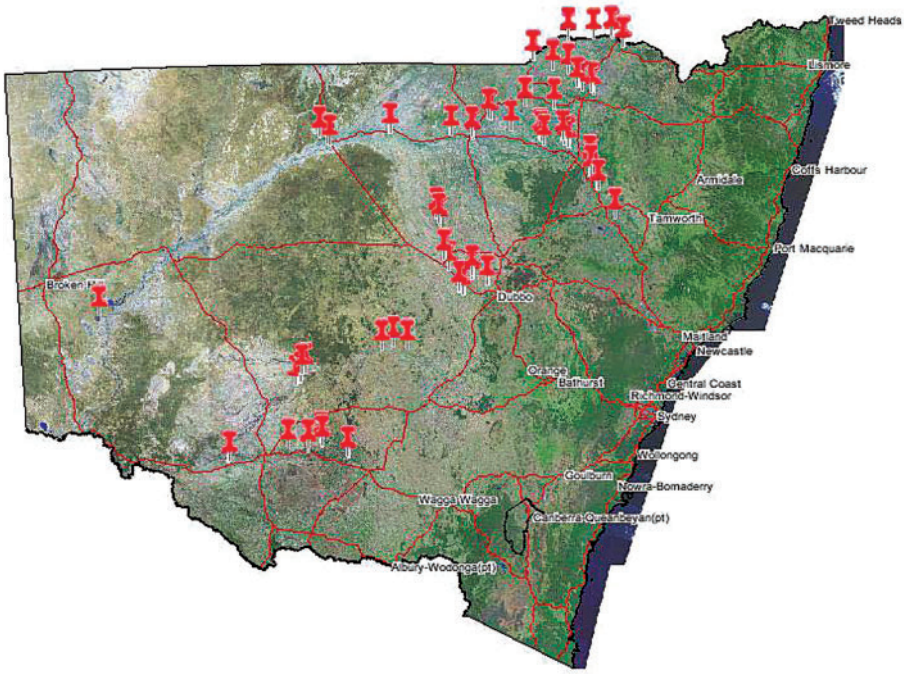

Fig. 1. Location of farms included in the annual surveys of cotton crops of NSW. Distance travelled during each early and late season covers more than 20 000 km.

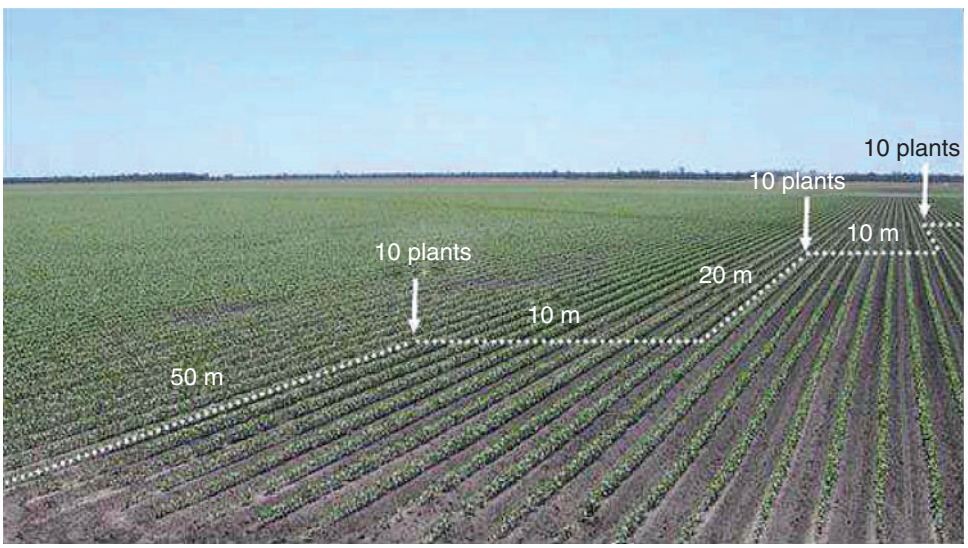

Fig. 2. Transect used in disease surveys. One-hundred plants surveyed along each transect with two transects per field. (Image C. Anderson, 2010).

well as the incidence and severity of those diseases present within crops.

After 1996, the disease survey method was standardised (Nehl *et al*. 2004*b*). A total of 200 plants from each field were sampled using a step-point method across two transects. The first sampling was taken 50 m into the field at the tail drain end where a GPS coordinate was recorded. The second sampling was done by walking across 10 m and up the row 20 m. This pattern was repeated until 10 sampling sites had been surveyed (Fig. 2).

During the early season surveys, at each sampling point, the number of plants present along 1 m of the row was recorded. Seedling mortality was derived from the proportion of surviving plants in 1 m divided by the number of seeds planted/m. Quantitative assessment of black root rot severity was done using the method described by Nehl *et al*. (2004*b*). Briefly, at each of the 10 sampling points, 10 plants were carefully removed from soil and tap roots inspected for symptoms of black root rot. Severity was rated on a scale of 0–10 where 0 = total absence of

disease symptoms and 10 = tap root completely blackened. Plants were also examined for the presence of *Rhizoctonia*, *Pythium* and exotic diseases.

During late season surveys, sampling was similar to that described for early season surveys; however, stems were cut near the base of 10 plants and assessed for symptoms of Verticillium wilt, Fusarium wilt, boll rot, leaf spots, cotton bunchy top and presence/absence of exotic disease. Score cards (Fig. 3*a*, *b*) were used to record all relevant information for each field. Disease identification was confirmed where necessary using microscopy and standard laboratory isolation techniques.

In 2007–08 the Australian cotton industry adopted a National Biosecurity Plan that included surveillance for the presence/absence of priority pests (exotic strains of Verticillium wilt and Fusarium wilt, hypervirulent strains of bacterial blight, blue disease, cotton leaf curl disease and Texas root rot).

Results and discussion

Throughout the three decades of disease surveys in NSW, Verticillium wilt, bacterial blight, black root rot and Fusarium wilt diseases have been particularly significant.

Verticillium wilt

The disease Verticillium wilt is caused by the pathogen *Verticillium dahliae* Kleb. It was first recorded in Australia in 1959 (Anon. 1959) and later reported in cotton crops in the Namoi Valley by Evans and Paull (1967). Allen and Nehl (1999) reported the standard practice for irrigated cotton was to slash the crop after harvest, disc in crop residues and relist the field into hills for the next cotton crop. During the late 1980s the rapid adoption of permanent bed systems with reduced tillage led to an increase in the carryover of crop residues from season to season and an increase in the average incidence of Verticillium wilt followed. Mean incidence reached a peak of 16.6% of plants affected in NSW in 1989–90 (Fig. 4).

Release of resistant varieties in 1990 resulted in an immediate and steady decline in incidence to less than 3%. A subsequent drop in the use of resistant varieties was accompanied by a rise in the average incidence of the disease (Fig. 4). Between 2001–02 and 2007–08 the mean incidence ranged from 5.7 to 11.2%. The 2010–11 and 2011–12 seasons were characterised by wet starts and cool conditions, favouring the disease. Consequently disease severity was higher than previous years. Average incidence for those seasons was 4.1 and 6.8%, respectively.

Bacterial blight

Bacterial blight of cotton is caused by *Xanthomonas axonopodis* pv. *malvacearum* (Xam) (Kado 2010). Bacterial blight is a major disease of cotton worldwide causing up to 70% yield losses during severe epidemics (Kirkpatrick and Rothrock 2001).

Prior to 1984 all commercial varieties of cotton available in Australia were susceptible to bacterial blight and the disease was widespread. For the susceptible varieties the cotton industry

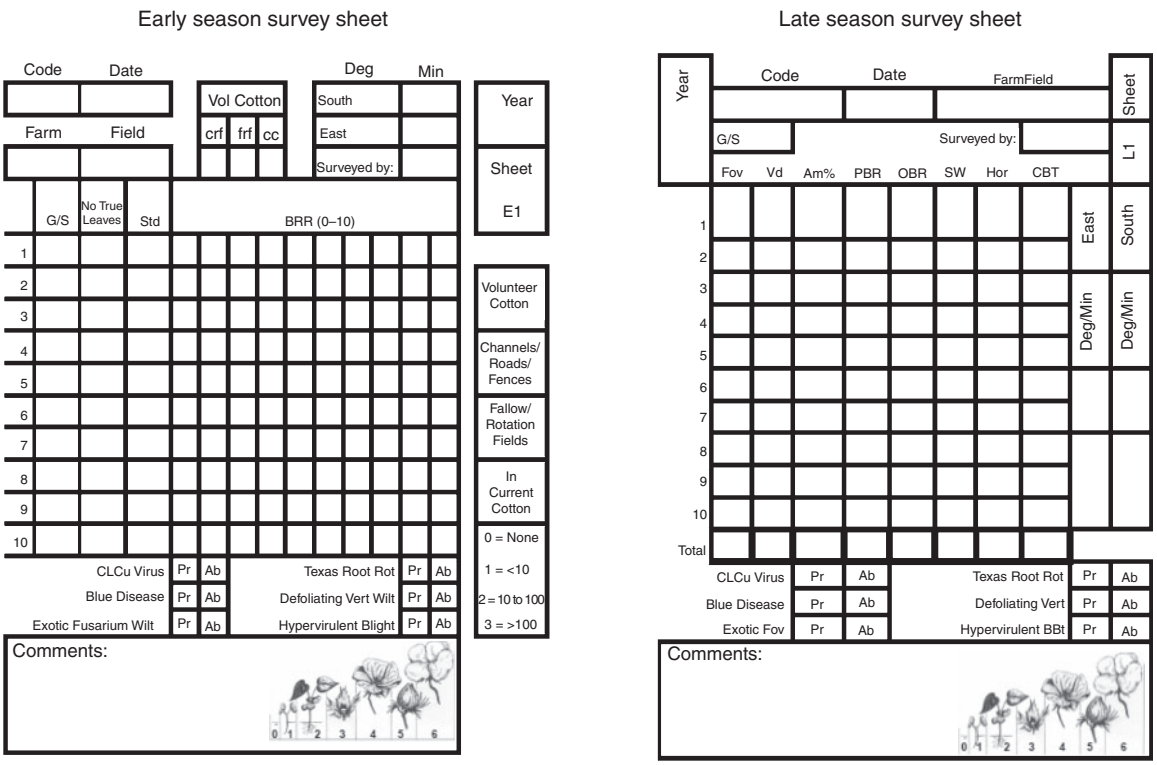

Fig. 3. Early and late season score cards used to record disease information. Vol Cotton – volunteer cotton; crf – channels, roads and fences; frf – fallow rotation fields; cc – current cotton; G/S – growth stage; Std – stand count in 1 m; BRR – black root rot severity on a scale 0–10; Pr and Ab – presence or absence of priority pests; CLCu – Virus cotton leaf curl virus, Blue disease, Exotic Fusarium wilt, Texas root rot, defoliating Verticillium wilt and hypervirulent bacterial blight.

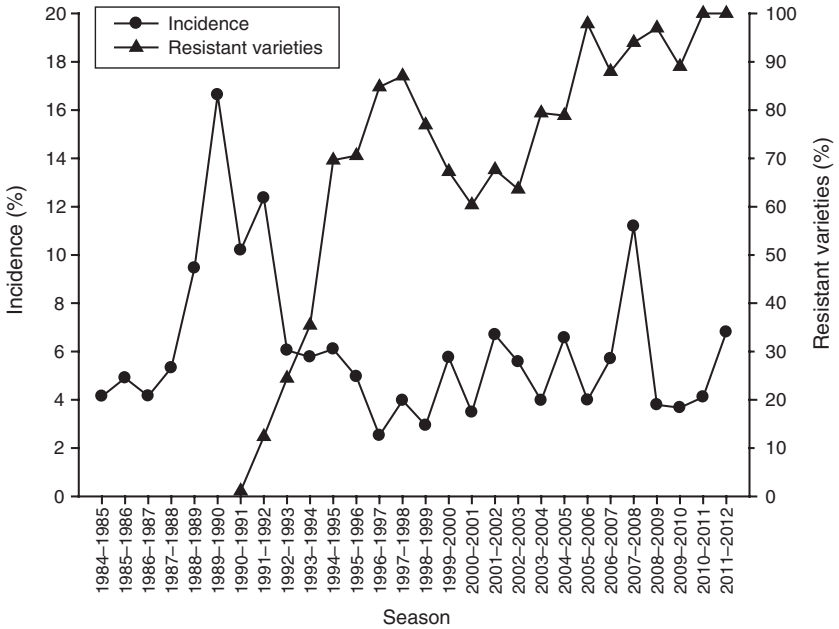

Fig. 4. The average incidence of Verticillium wilt of cotton in NSW and the use of varieties with resistance to Verticillium wilt.

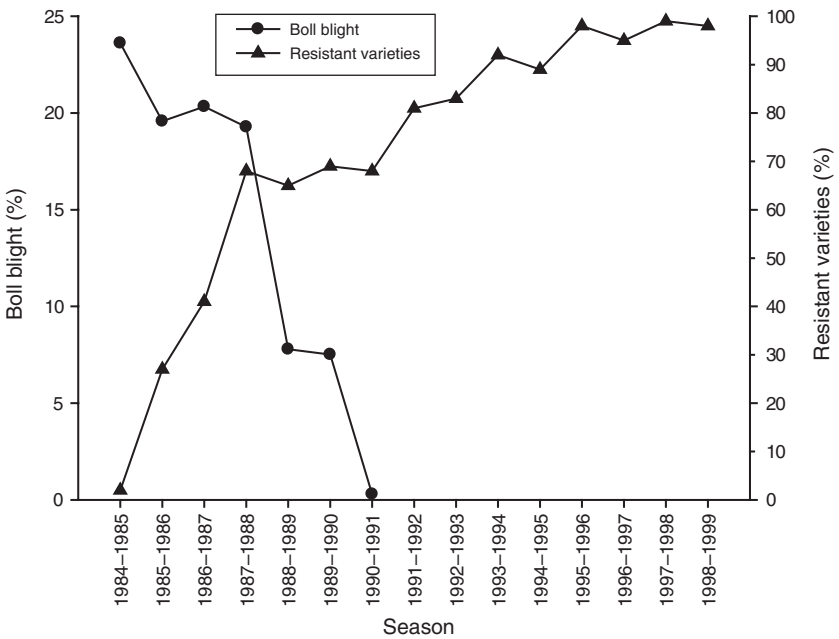

Fig. 5. Incidence of bacterial blight on cotton bolls and the increasing percentage of fields sown with blight-resistant varieties.

formed the Blight Investigation Group, which developed a seed production strategy to reduce seed infestation to less than 0.03% by 5 years. Australian varieties with resistance to this pathogen were released in 1985–86 and within three seasons these varieties were being grown in 65% of fields. The rapid adoption of the resistant varieties and the reduction in seedborne transmission contributed to a dramatic decline in the incidence of bacterial blight and the removal of bacterial blight as a significant pathogen to Australian cotton crops by 1992 (Fig. 5). Since 1990 bacterial blight on bolls has only been observed on the susceptible Pima cultivar *Gossypium barbadense*. Trace amounts were observed in a field of Pima S7 in the Bourke region in the 2001–02 season.

Black root rot

Black root rot of cotton, caused by *Thielaviopsis basicola* (Berk. and Broome) Ferraris was first observed in Australia in 1989

(Allen 1990). Nehl *et al*. (2004*a*) reported the exponential increased incidence of black root rot on farms with a long history of growing cotton during the 1990s. The disease has now been recorded in all cotton-producing areas of Australia and on 95% of the farms visited during annual disease surveys in NSW. The average incidence in commercial crops during 2000–01 to 2003–04 increased rapidly to over 30%. Incidence declined over the next three seasons before rising again to 41.2% in the 2010–11 season. The incidence was 38.5% in the 2011–12 season (Fig. 6).

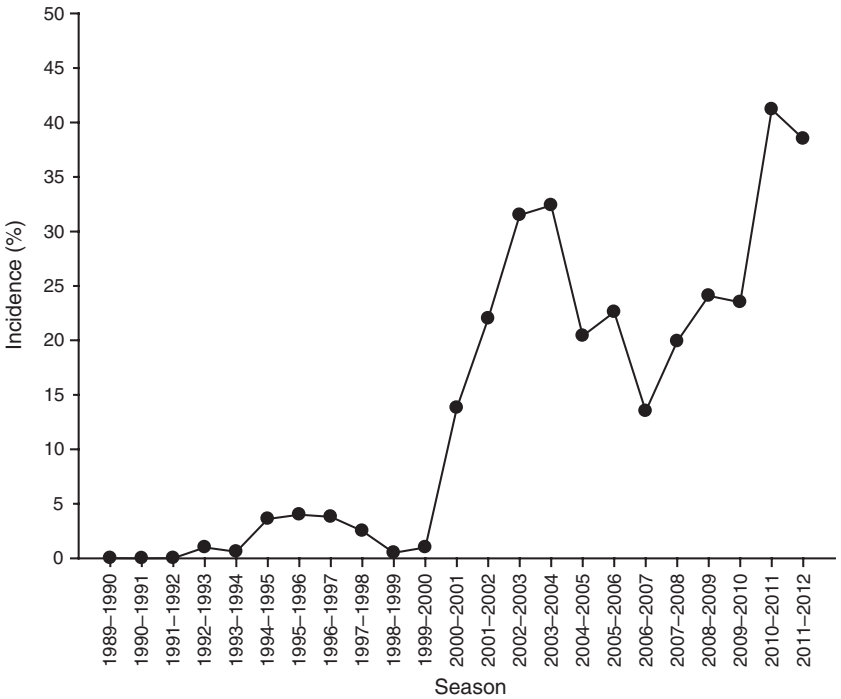

Fig. 6. The incidence of black root rot of cotton in NSW over three decades.

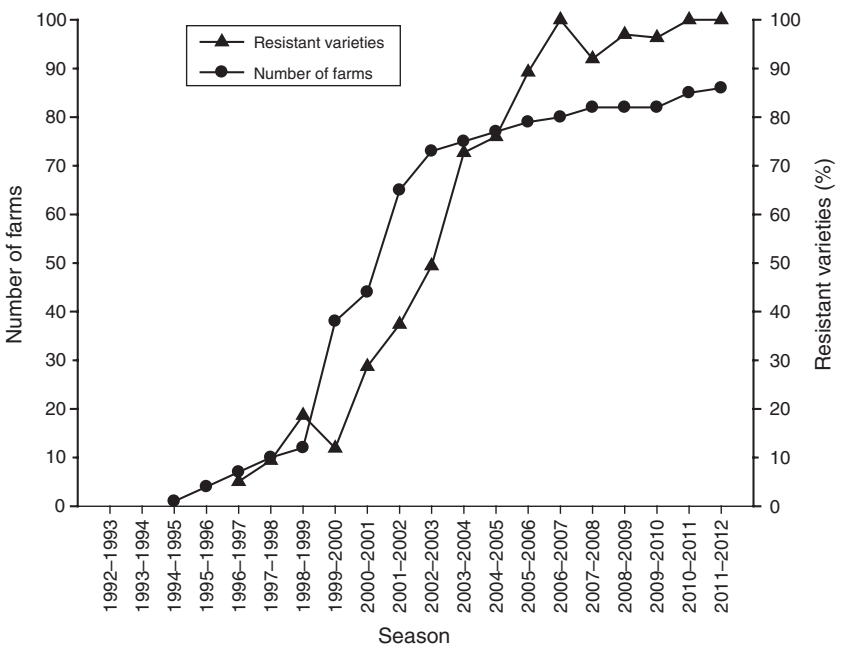

Fig. 7. The increasing number of farms in NSW where Fusarium wilt of cotton has been confirmed and the increasing adoption of Fusarium-resistant varieties.

Lower mean incidence recorded in previous seasons can be attributed to drier weather and years of drought before the wet start of 2010–11. Long-term survey data has shown the rapid rate of introduction and dispersal of the pathogen throughout the industry, particularly into the cooler southern regions of NSW.

Fusarium wilt

Fusarium wilt of cotton, caused by *Fusarium oxysporum* Schlect. f.sp. *vasinfectum* (Atk.) Snyd. and Hans. (Fov), was first reported in NSW in 1994 (Kochman 1995). By the end of 1999, the disease was present in six of the eight cotton production areas in NSW. Fusarium wilt has now been confirmed on 86 farms in NSW (Fig. 7). According to Kochman *et al*. (1994), the isolates in Australia appear to be distinct from those overseas. DNA fingerprinting techniques and Vegetative Compatibility Group (VCG) analyses identified three strains unique to Australia: VCG 01111 (known as the Darling Downs strain), which is widespread and detected in disease surveys within NSW. VCG 01112 (known as the Boggabilla strain) has only been found on a few farms in northern NSW (Smith *et al*. 2006). More recently a third strain known as the Mungindi strain has been identified in the Macintyre Valley. These strains have been allocated to Race 6 of the pathogen using their reaction on a set of differential hosts. More recently Races 1, 2 and 6 have been placed together and designated as 'Group A'.

Prior to 2002, the number of farms in NSW where Fusarium wilt was confirmed, appeared to be rapidly increasing and some projections estimated that the disease would be on 90% of farms in NSW by 2010 (Nehl *et al*. 2004*a*). However, since 2002, the rate of spread had slowed considerably (Fig. 6). Possible reasons for the reduced spread to new farms include (*i*) the severe drought conditions, (*ii*) the use of new varieties with better host plant resistance, (*iii*) the reticence of some growers to report that the disease had been detected on their farm, and (*iv*) the impact of increased attention to farm hygiene (Come Clean, Go Clean). Survey results have recorded pathogen distribution, adoption of resistant varieties and the effect of Integrated Disease Management strategies or drought on incidence and severity of the disease.

Conclusions

Results of three decades of data collected from NSW disease surveys has illustrated the different trends of the four major diseases of cotton in Australia. Increased understanding of pathogen survival and transmission, plant genetics and better management strategies have all contributed to reducing the effects of disease. Biosecurity of the Australian cotton industry has also been enhanced with the inclusion of surveillance for the presence/absence of exotic diseases. To date there have been no priority pests reported in NSW.

Survey results were first published in the Annual Plant Disease Survey from 1983–84 to 1987–88 (Fahy and Allen 1985), then in the Cotton Irrigator, then since 1990–91 in the CSD Variety Trial Results (Allen 1991) and also printed in the Cotton Pest Management Guide (Smith *et al*. 2013). Over time, more field/farm history information has been collected such as hormone damage to crops and more recently the development of an assessment card for volunteer/ratoon cotton on farms.

The development of the Industry Biosecurity Plan for the cotton industry and the industry's recent expansion into southern NSW has presented new opportunities for further application of the annual disease surveys. The surveys document the spread of diseases established in northern NSW into southern NSW and surveillance for the 'priority exotic pests' indentified in the biosecurity plan.

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