

DISTRICT YIELD POTENTIAL: AN APPROPRIATE BASIS FOR NITROGEN GUIDELINES FOR SUGARCANE PRODUCTION

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KEYWORDS: Sugarcane,
Nitrogen Input, Regulation.

Abstract

THE QUEENSLAND Government has developed a Reef Protection Package aimed at enhancing the water quality and health of the Great Barrier Reef Lagoon. It has focused on nitrogen (N) and phosphorus (P) inputs within the sugarcane production system as these two nutrients have been identified as posing the greatest risk to water quality in the Great Barrier Reef lagoon. Over the past decade, BSES Limited and its collaborators have developed the SIX EASY STEPS program to underpin the adoption of sustainable nutrient management practices in sugarcane production. The nitrogen (N) guidelines within the SIX EASY STEPS program are based on a combination of district yield potential (DYP) and a soil N mineralisation index. This paper describes the concepts of estimated highest average annual district yield (EHAADY) and DYP and relates these to average annual yields at a range of levels within sugarcane-producing districts in Queensland. Mill statistics data indicated that the established EHAADY values used within the SIX EASY STEPS program are appropriate for the various districts within the Queensland sugarcane industry. Data from sub-districts indicated that DYP values, determined as EHAADY multiplied by a factor of 1.2, are realistic, particularly when individual farm data are considered. It was found that the average sugarcane yields on a substantial number of farms reached or exceeded the established DYP value during seasons that were characterised by favourable rainfall conditions. DYP was not reached on the majority of farms during seasons with unfavourable rainfall patterns (which could include high, low or unevenly distributed annual rainfall). Sugarcane yield plotted against block numbers for particular soil types illustrated the

reason why actual yield should not be used as a basis for determining N input. The difficulty of predicting seasonal weather conditions curtails our ability to formulate N input strategies prior to a particular growing season. This means that the only appropriate management option is to apply fertiliser with the aim of producing an optimum / sustainable sugarcane crop and to assume that the forthcoming season will be characterised by favourable weather conditions (particularly rainfall). Further R&D is required to assess the inclusion of accurate seasonal climate forecasting into the SIX EASY STEPS package to assist in guiding N inputs.

Introduction

The Queensland Government, via the Department of Environment and Resource Management (DERM), has developed a Reef Protection Package with the aim of enhancing the water quality and health of the Great Barrier Reef Lagoon. This government initiative targets the reduction of nutrient, pesticide and sediment losses emanating from agricultural activities that are conducted primarily in the coastal fringes from Mackay northwards. In particular, DERM has focused on nitrogen (N) and phosphorus (P) inputs within the sugarcane production system. These two nutrients have been identified by certain environment scientists and environmentally-based organisation as posing the greatest risk to water quality in the Great Barrier Reef lagoon (Anon., 2008a).

Over the past decade, RD&E staff working within BSES Limited, CSR Ltd and DERM, have developed the SIX EASY STEPS program to underpin the adoption of sustainable nutrient management practices within the sugarcane production system. This was done with the belief that the use of best-practice nutrient management on-farm will provide the most appropriate means of contributing to optimised sugarcane productivity and profitability, and minimised nutrient losses to the environment (Wood *et al.*, 2003; Calcino *et al.*, 2008; Schroeder *et al.*, 2007, 2008a, 2009a, b, c). This strategy therefore aims to ensure a combination of environmental responsibility and the continued survival of tropical coastal economies that rely predominantly on a viable sugarcane industry.

Nitrogen (N) guidelines within the SIX EASY STEPS program are based on a combination of district yield potential (DYP) and a soil N mineralisation index, with built-in discounts for various other sources of N within the sugarcane cropping system (Schroeder *et al.*, 2005). The DYP is determined from the best possible yield averaged over all soil types within a district. It is defined as the estimated highest average annual district yield (EHAADY) multiplied by a factor of 1.2 (Schroeder *et al.*, 2010). Although this overall concept is well documented (Schroeder *et al.*, 2005, 2006, 2007, 2009a), supporting information relating to EHAADY and DYP values have not previously been presented in detail.

This paper describes the process of determining DYPs for the various sugarcane growing districts within the Queensland sugar industry and uses intra-

district yield data to illustrate why this concept is more appropriate than specific block yields for determining N inputs.

Procedure

Average annual mill statistics acquired by BSES Limited from across the Queensland sugar industry were used to determine EHAADY values and to confirm or set DYPs for individual districts and regions. The distribution of yield data at sub-district and farm-scale was then determined for particular years using sugarcane productivity data from two specific areas (Tully and Herbert). Additional data available from the Herbert district via Herbert Cane Productivity Services Limited (HCPSL) also enabled the range of ratoon sugarcane yields in particular years to be determined for all blocks located on a particular soil type. This spread of data across several scales provided a sound basis for assessing the use of DYP for determining N inputs.

Results and discussion

District average yields

Mill statistics covering the period 1990 to 2008 indicated that the EHAADY value for most districts within the Queensland sugarcane industry is most appropriately set at 100 t cane/ha (as indicated by the horizontal lines in Figures 1–6). In particular, this is relevant to the following regions:

- Wet Tropics that includes the Mossman and Mulgrave (Figure 1), Babinda, former Mourilyan, South Johnstone, current Bundaberg Sugar (northern mills) and Tully mill areas (Figure 2).
- Herbert (moist tropics) that includes the Victoria and Macknade, and current CSR Herbert mill areas (Figure 3).
- Bundaberg that includes Millaquin, Bingera, the former Fairymead and current Bundaberg Sugar (southern mills) mill areas (Figure 4).

The mill data also showed that some districts have the ability to produce higher average annual yields than the standard 100 t cane/ha. This is particularly relevant to the Burdekin region. Its fertile soils, higher temperatures and sunlight, and availability of adequate irrigation water enable substantially higher sugarcane yields than most other areas. When the SIX EASY STEPS program was first developed for this region, the EHAADY value was pegged at 125 t cane/ha (indicated by the horizontal line in Figure 5). However, local expertise and individual farm data suggested that higher average annual yields are possible in some sub-districts / farms in the Burdekin district (not shown here), particularly the delta soils. As a result, two productivity levels (higher and lower yielding areas) were established for the Burdekin region with the EHAADY values set at 125 and 150 t cane/ha respectively. The mill statistics indicated that the EHAADY is also higher than the standard 100 t cane/ha for Proserpine and Mackay (Mackay–Whitsunday / Central region). A value of 110 t cane/ha is more appropriate in this case (indicated by the horizontal line in Figure 6).

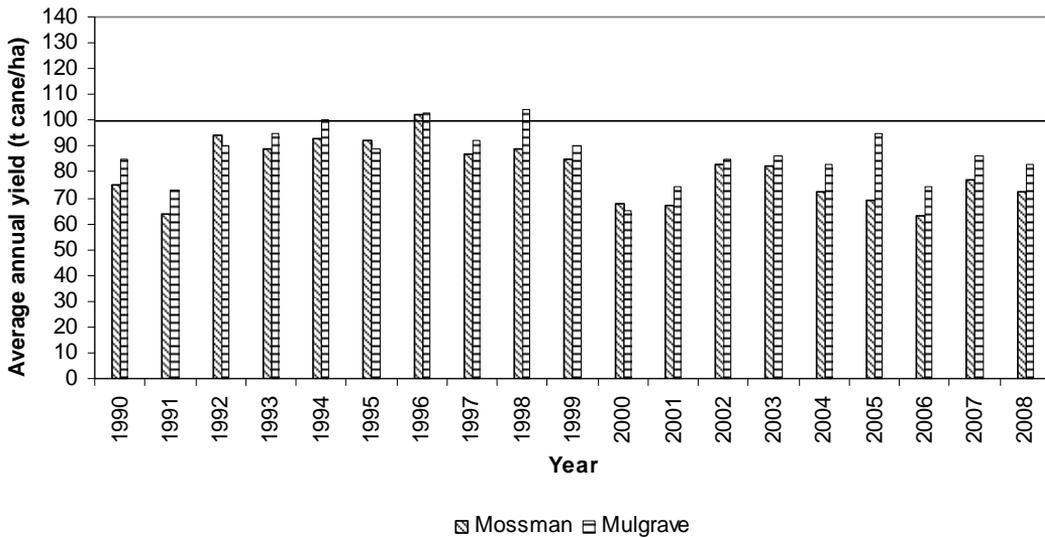


Fig. 1—Average annual district yields for Mossman and Mulgrave mill areas within the Wet Tropics (1990–2008).

The horizontal line indicates the estimated highest average annual district yield (EHAADY) = 100 t cane/ha

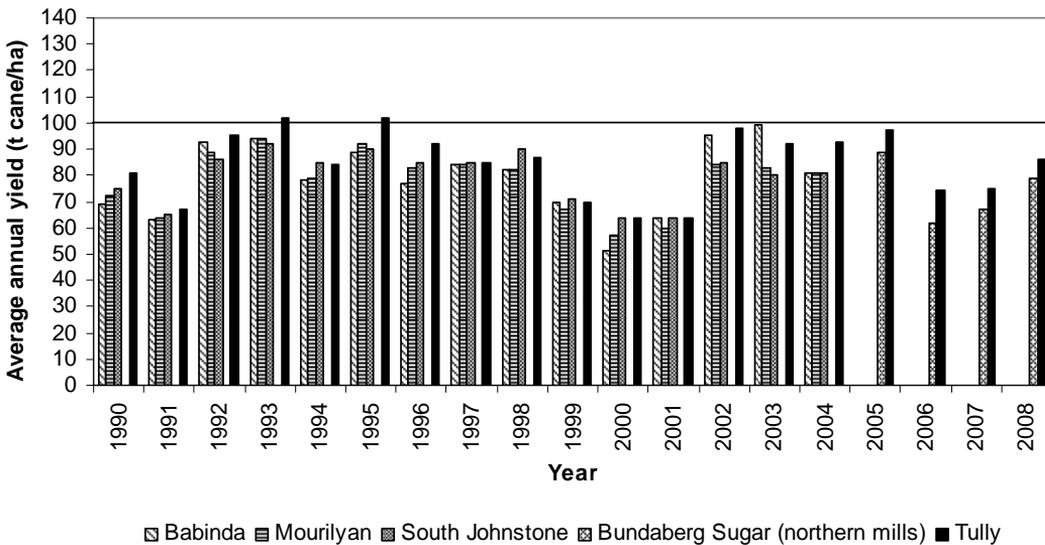


Fig. 2—Average annual district yields for Babinda, former Mourilyan, South Johnstone and current Bundaberg Sugar (northern mills) mill areas within the Wet Tropics (1990–2008).

The horizontal line indicates the estimated highest average annual district yield (EHAADY) = 100 t cane/ha

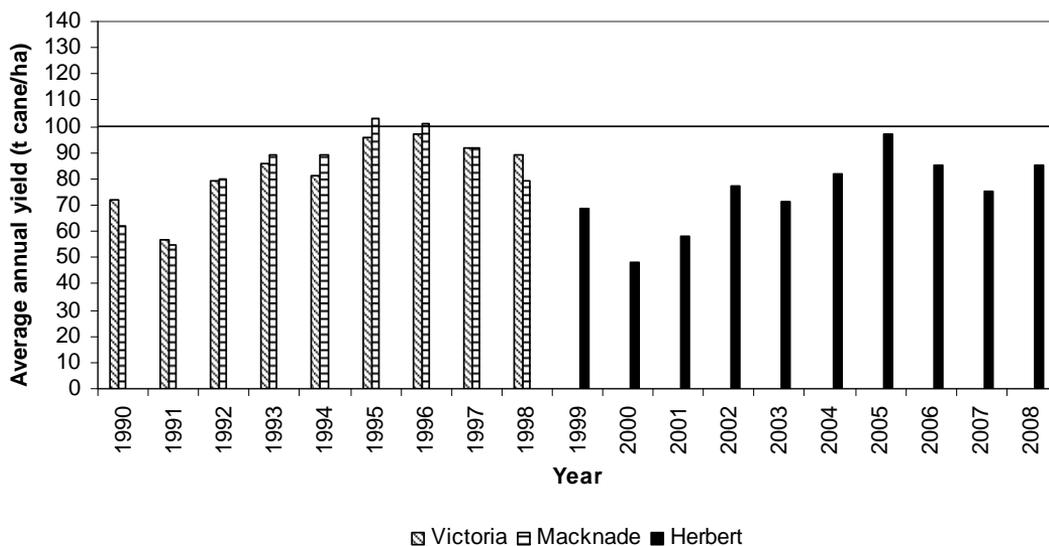


Fig. 3—Average annual district yields for former Victoria, Macknade and current CSR Herbert mill areas within the Herbert district (moist tropics) (1990–2008).

The horizontal line indicates the estimated highest average annual district yield (EHAADY) = 100 t cane/ha

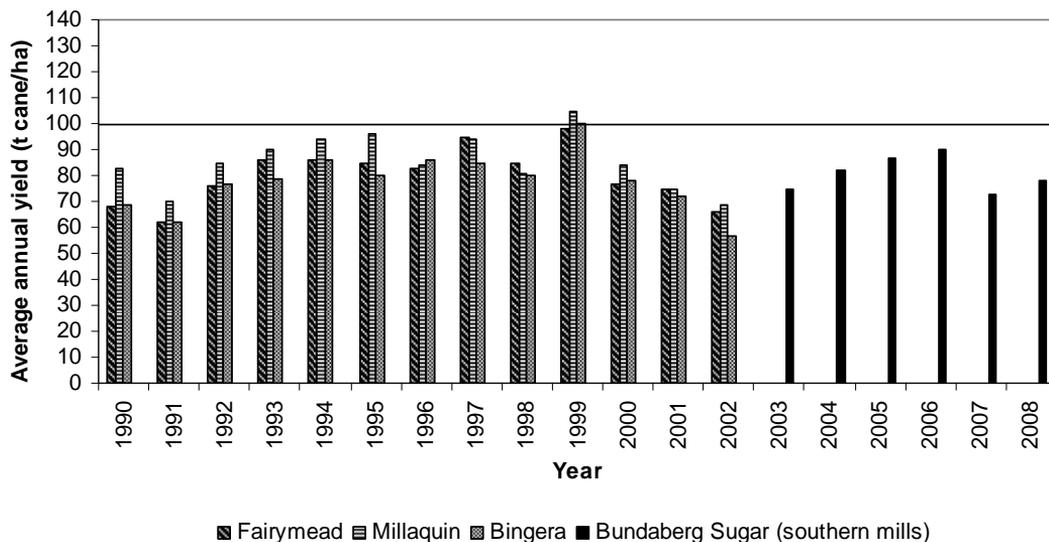


Fig. 4—Average annual district yields for former Fairymead, Millaquin, Bingera and current Bundaberg Sugar (southern mills) mill areas within the Bundaberg district (1990–2008).

The horizontal line indicates the estimated highest average annual district yield (EHAADY) = 100 t cane/ha

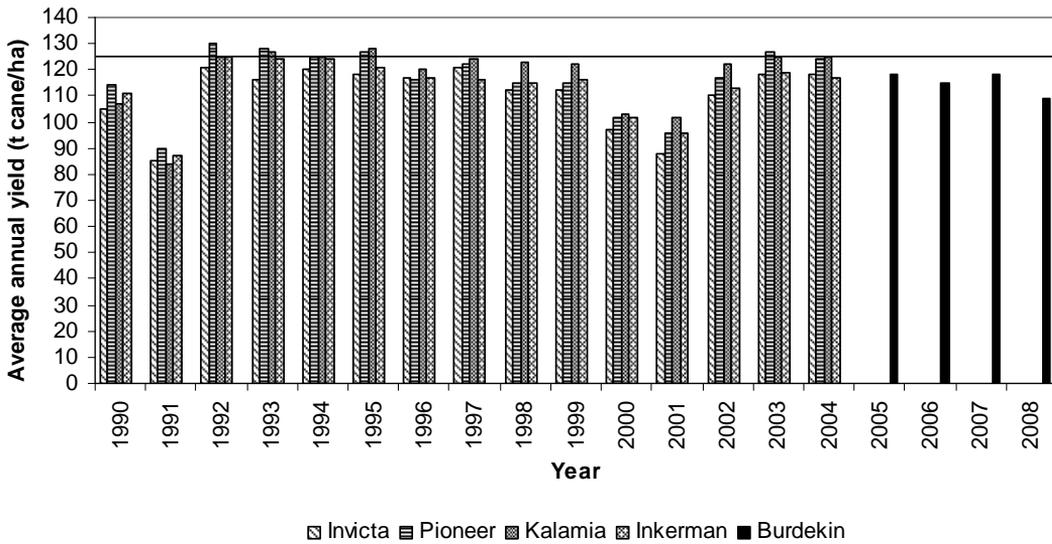


Fig. 5—Average annual district yields for former Invicta, Pioneer, Kalamia and Inkerman and current CSR Burdekin mill areas within the Burdekin region (1990–2008).

The horizontal line indicates the estimated highest average annual district yield (EHAADY) = 125 t cane/ha

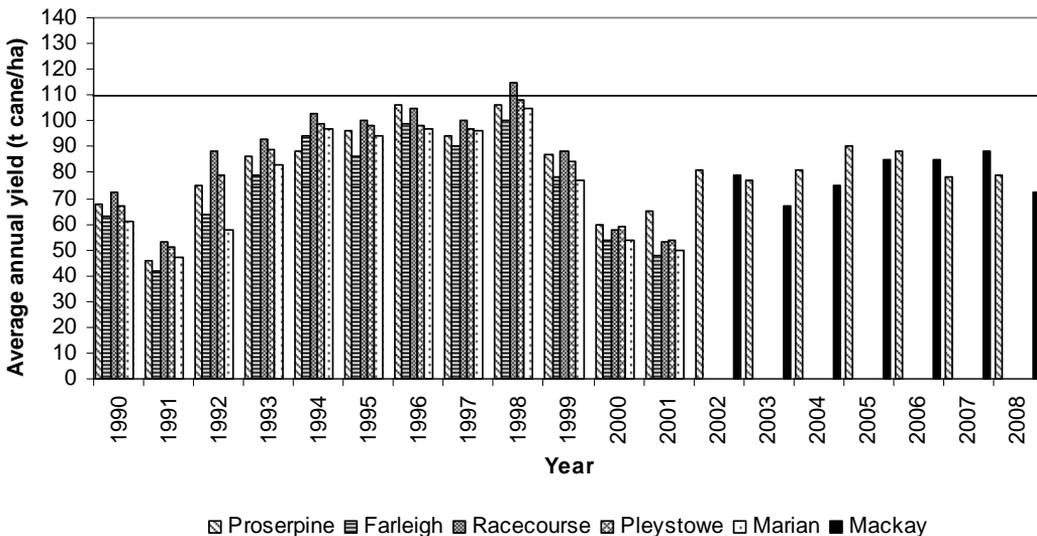


Fig. 6—Average annual district yields for Proserpine and Mackay (Farleigh, Racecourse, Pleystowe and Marian) mill areas within the Mackay/Whitsundays (Central) region (1990–2008).

The horizontal line indicates the estimated highest average annual district yield (EHAADY) = 110 t cane/ha

As indicated above, the DYP is defined as the EHAADY value for a particular district multiplied by a factor of 1.2. As a result, the DYP values range from 120 t cane/ha (in most areas) to 180 t cane /ha in the higher yielding areas of the Burdekin region (Table 1). The EHAADY value for the Mareeba-Dimbulah district (not shown here) is assumed to be similar to that of the lower productivity areas of the Burdekin region. This area has access to full irrigation and receives relatively high radiation. Hence, the DYP for this district is set at 150 t cane/ha.

Table 1—Estimated highest average annual district yields (EHAADY) and district yield potentials (DYP) used within the SIX EASY STEPS program for the different sugarcane producing regions and districts in Queensland.

Region	District	EHAADY (t cane/ha)	DYP (t cane/ha)
Wet Tropics	Cairns (Mulgrave / Mossman)	100	120
	Innisfail / Babinda and Tully	100	120
Herbert (moist tropics)	Herbert	100	120
Mareeba / Dimbulah	Mareeba / Dimbulah	125	150
Burdekin	Lower yielding areas	125	150
	Higher yielding areas	150	180
Mackay–Whitsundays (Central)	Proserpine	110	130
	Mackay	110	130
	Plane Creek	100	120
Southern	Bundaberg / Isis / Maryborough	100	120

Although the EHAADY and DYP values are respectively set at 100 t cane/ha and 120 t cane/ha for both the Tully and Herbert districts, the productivity data from sub-districts and farms within these districts illustrated differences in the distribution of annual yields from one year to another.

Sub-district and farm yields

Tully district

The Tully district lies within the so-called Wet Tropics. Although it has an estimated mean rainfall of between 3500 to 4000 mm, the rainfall pattern can vary substantially from year to year and within the district.

It is generally accepted that yields in relatively wet years are lower than those achieved in relatively dry years, particularly if above average rainfall is received during late spring or early summer when the crop is still small. This is well illustrated in Figure 2. The 2000/2001 growing season (July 2000–June 2001) was relatively wet (measured annual rainfall of 3493 mm).

The average annual yield for the 2001 crop in the Tully district was 64 t cane/ha. On the other hand, July 2001 to June 2002 was characterised by relatively dry conditions (measured annual rainfall of 1847 mm) with the average annual yield for the 2002 crop reported as 98 t cane/ha. The 2005 crop produced an average yield of 97 t cane/ha. The measured annual rainfall was 2750 mm (July 2004 to June 2005).

In the following season (July 2005 to June 2006), the rainfall was relatively high (measured annual rainfall of 3173 mm). The average yield of the 2006 crop was 74 t cane/ha.

Sugarcane farms in the Tully district are divided into seven subdistricts to reflect differences in productivity viz. El Arish, Feluga, Riversdale, Syndicate, Murray, Lower Tully and Euramo (Anon., 2008b).

Figure 7 show the average annual yields for each of these sub-districts and the Tully district as a whole over the period 1990 to 2008. Figure 7a covers El Arish, Feluga, Riversdale and Syndicate.

These sub-districts are considered to be relatively wet, with yields having the potential to fluctuate quite markedly between seasons.

Figure 7b illustrates the average annual yields for the Murray, Lower Tully and Euramo.

These sub-districts are slightly drier than the other districts, yields are more consistent and commercial cane sugar (CCS) values are generally higher.

In considering the implications of the productivity and rainfall data on the EHAADY and DYP values within sub-districts, the average yields for individual farms within one sub-district each in the wetter areas (e.g. Riversdale) and drier areas (e.g. Murray) of the Tully district are shown in Figure 8.

To ensure anonymity and to illustrate trends more easily, farm numbers were allocated according to the level of production in 2001 (highest to lowest).

The 2001 sugarcane crop yield was generally low, with both the wetter (Figure 8a) and drier (Figure 8b) sub-districts under-performing.

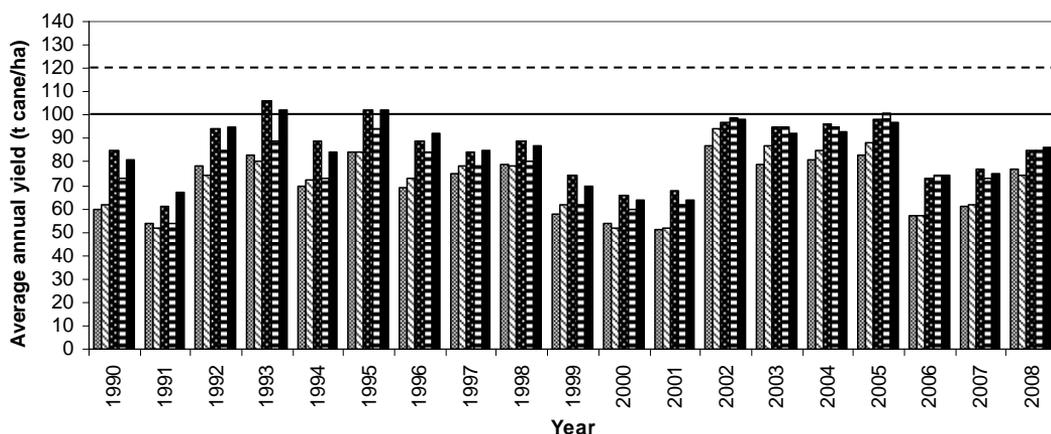
Yields improved substantially in 2002 with many farms producing in excess of the 100 t cane/ha level and some reaching or exceeding the DYP. In many instances the good yields attained in 2002 could not easily be predicted from the yield trend that occurred in 2001.

The year 2005 again produced high yields with similar trends as seen in 2002. However, the average yields for individual farms were not always in proportion to those recorded in 2002.

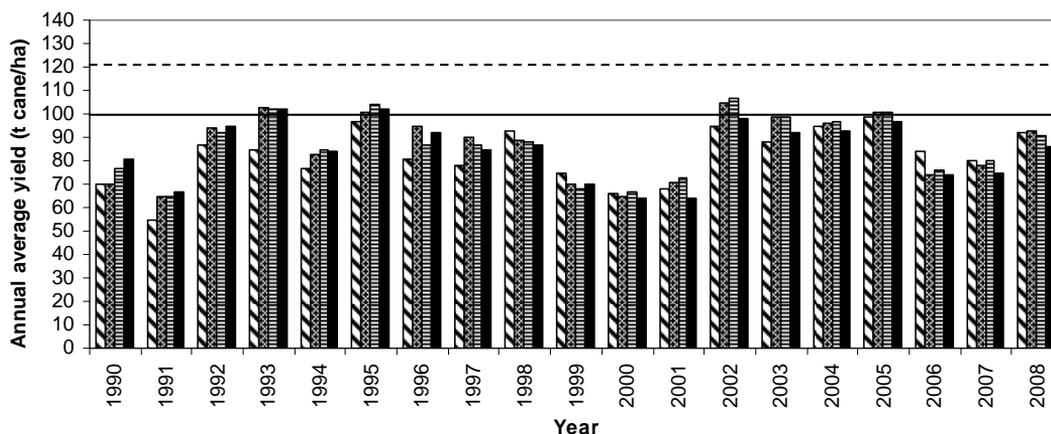
The relatively wet conditions of the 2005/2006 season produced a lower average crop but yields differed from those obtained in the relatively wet 2000/2001. Irrespective of whether farms are located in the 'wetter' or 'drier' areas, wet conditions (2001 and 2006) resulted in lower yields across farms.

Relatively dry conditions generally resulted in improved yields, but with the ‘wetter’ areas producing a greater proportion of farms with average yields above the EHAADY and reaching the DYP (Figure 8a) compared to farms in the usually ‘drier’ areas (Figure 8b).

It should be noted that many farms in the ‘drier’ areas still achieved average yields in excess of the EHAADY, with several reaching the DYP and one farm exceeding this level of production (Figure 8b).



(a) ■ El Arish □ Feluga ■ Riversdale ▨ Syndicate ■ Tully



(b) ▨ Murray ▩ Lower Tully ▨ Euramo ■ Tully

Fig. 7—Average annual district yields for sub-districts within the Tully district 1990–2008: (a) El Arish, Feluga, Riversdale and Syndicate, and (b) Murray, Lower Tully and Euramo.

The horizontal unbroken line indicates the 100 t cane/ha production level. The horizontal dotted line indicates the district yield potential (DYP) as identified within the SIX EASY STEPS program. The black bars indicate the average annual yield (t cane/ha) for the Tully district as a whole

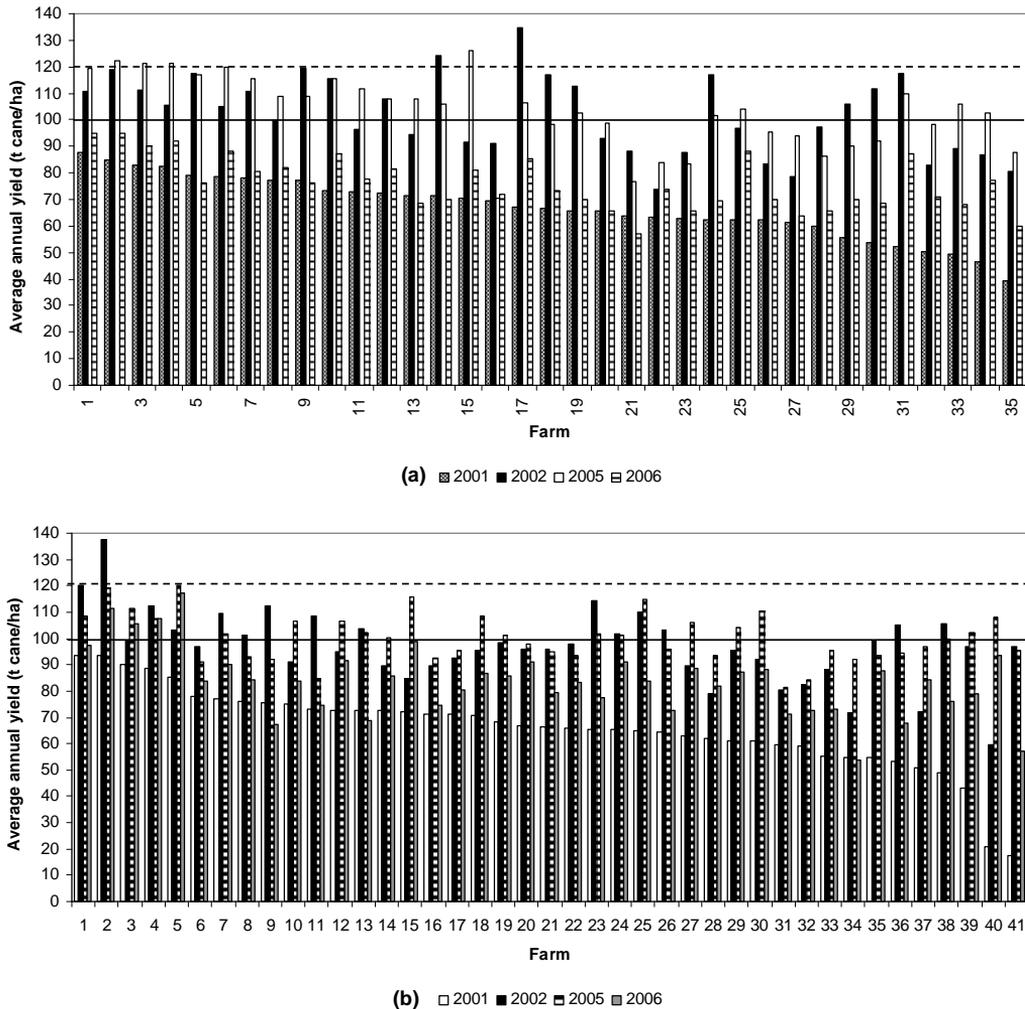


Fig. 8—Average yields for individual Tully farms (2001, 2002, 2005 and 2006) in: the Riversdale sub-district (which is considered to be a wetter area) the Murray sub-district (which is considered to be a drier area).

The horizontal unbroken line indicates the 100 t cane/ha production level. The horizontal dotted line indicates the district yield potential (DYP) as identified within the SIX EASY STEPS program. Farm numbers were allocated according to the level of production in 2001 (decreasing from left to right).

Herbert district

The Herbert district is situated in the so-called ‘moist’ tropics with an annual average rainfall for Ingham of 2026 mm. For sugarcane productivity purposes, the Herbert district is divided into 26 sub-districts (Table 2). These sub-districts can be grouped into three main areas. The sugarcane-growing area to the south and south west of Ingham is generally considered to be drier than the other areas of the district with an average annual rainfall of 1830 mm at Bambaroo. The remaining wetter areas are divided into an area to the west, north-west and north of Ingham, and an area consisting of sub-districts in the lower Herbert catchment closer to the coast. The

wetter areas tend to perform better when the rainfall in late spring and summer is lower than usual. The drier area tends to produce higher yields in relatively wet years. Average annual yields for some of the sub-districts within the drier (Figure 9a) and wetter (Figure 9b) areas of the Herbert district are indicated for the period 1991 to 2008. Four particular years were selected for greater scrutiny.

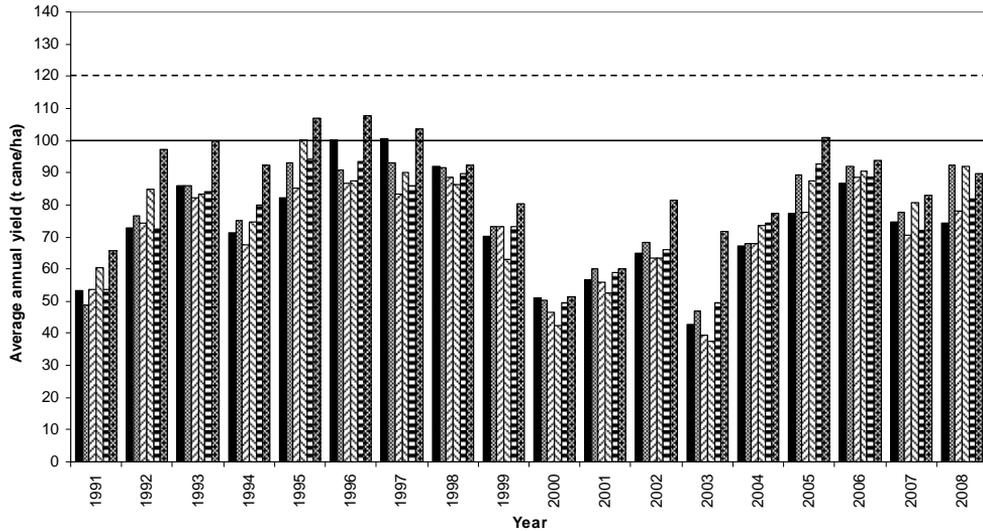
Generally good yields were produced in the two consecutive years: 1995 and 1996 (Figures 9a and 9b). Weather conditions during this period were drier than average (annual rainfall at Ingham of 1428 mm and 1313 mm respectively), but with just enough well-distributed rainfall to ensure adequate moisture for good sugarcane production especially in the usually wetter sub-districts.

For the same reason, sugarcane production on average was again good in 2005 (1344 mm rainfall at Ingham). However, 2006 was a wet year with above average rainfall in January, March and April (annual rainfall of 2397 mm at Ingham). As a result average yields in the wetter regions were lower than those attained in 2005 (Figure 9b).

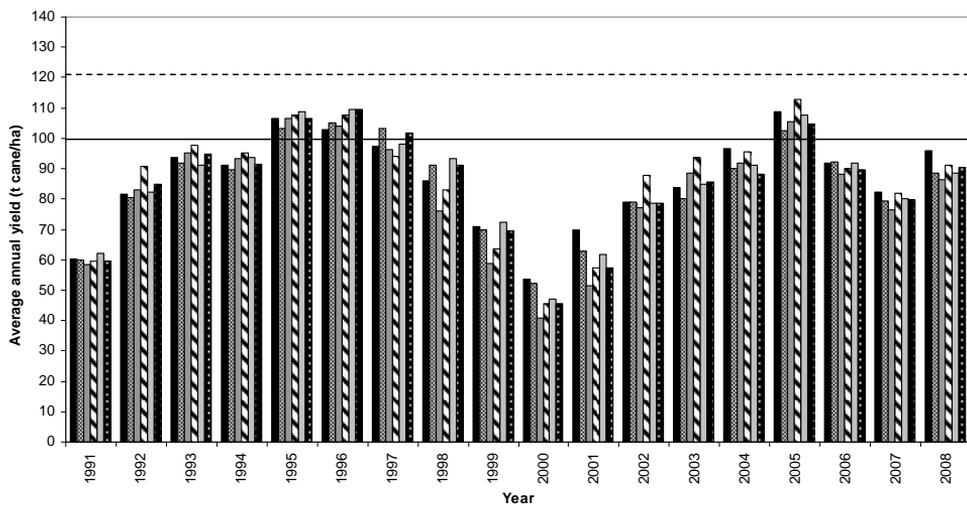
Table 2—Average annual yields for sub-districts within the Herbert district.

Areas within the Herbert sugarcane district	Sub-districts within the Herbert district	Average annual yields (t cane/ha) 1990–2008 (particular year shown in brackets)		
		Mean	Lowest	Highest
Southern drier area	Coolbie–Rollingstone*	74	43 (2003)	101 (1997)
	Bambaroo East	76	47 (2003)	93 (1997)
	Bambaroo West	71	39 (2003)	89 (1998)
	Yuruga	75	37 (2003)	100 (1995)
	Helens Hill	76	49 (2003)	94 (1995)
	Toobanna	83	47 (2000)	106 (1995)
	Upper Stone	75	53 (2003)	89 (1998)
	Mid Stone	75	54 (2000)	90 (1996, 1998)
Wetter area	Lower Stone	78	44 (2000)	105 (2005)
	Lannercost Extension	73	41 (2000)	97 (2005)
	Lannercost	76	45 (2000)	94 (2005)
	Long Pocket–Elphinstone	83	59 (2000)	99 (1995)
	Garrawalt	82	59 (2000)	98 (2005)
	Leach	79	61 (2001)	95 (1995)
	Hawkins Creek	78	45 (2000)	101 (1996)
	Tara–Seymour	73	34 (2000)	102 (1995)
Ripple Creek	77	37 (2000)	106 (2005)	
Higher yielding wetter area in the lower Herbert	Macknade	86	54 (2000)	109 (2005)
	Halifax	85	52 (2000)	105 (1996)
	Cordelia	82	41 (2000)	107 (1995)
	Foresthorne*	86	46 (2000)	113 (2005)
	Victoria Estate	86	47 (2000)	109 (1995, 1996)
	Sunnybank	85	46 (2000)	110 (1996)
	Hamleigh	84	46 (2000)	110 (1995)
	Fairford–Trebonne	84	46 (2000)	113 (2005)
Blackrock	86	51 (2000)	108 (1996)	

* Individual farm data used to explore distribution of yields within sub-districts in the various areas indicated—see Figures 10 and 11.



(a) ■ Coolbie-Rollingstone ▨ Bambaroo East ▩ Bambaroo West ▪ Yuruga ▮ Helens Hill ▭ Blackrock



(b) ■ Macknade ▨ Halifax-Four Mile ▩ Cordelia ▪ Foresthome ▮ Victoria Estate ▭ Sunnybank

Fig. 9—Average annual district yields for certain Herbert sub-districts (1991–2008) in the: (a) southern drier area, (b) higher-yielding wetter area in the lower Herbert district.

The horizontal unbroken line indicates the 100 t cane/ha production level. The horizontal dotted line indicates the district yield potential (DYP) as identified within the SIX EASY STEPS program.

Individual farm data from representative sub-districts within each of the ‘drier’ (e.g. Coolbie-Rollingstone—Figure 10) and ‘wetter’ (e.g. Foresthome—Figure 11) areas show the yield distributions within the four years mentioned above. To ensure anonymity and to illustrate trends more easily, farm numbers were allocated according to the level of production in 1995 (highest to lowest).

Coolbie-Rollingstone

The drier conditions in 1995 resulted in generally lower yields on Coolbie-Rollingstone farms (Figure 10).

However, the well-distributed rainfall pattern in 1996 caused average yields to improve, with some farms reaching or even going above the 100 t cane/ha level. In 2005 yields were again reduced by drier conditions. The wetter conditions in 2006 resulted in good yields in this drier area of the Herbert district.

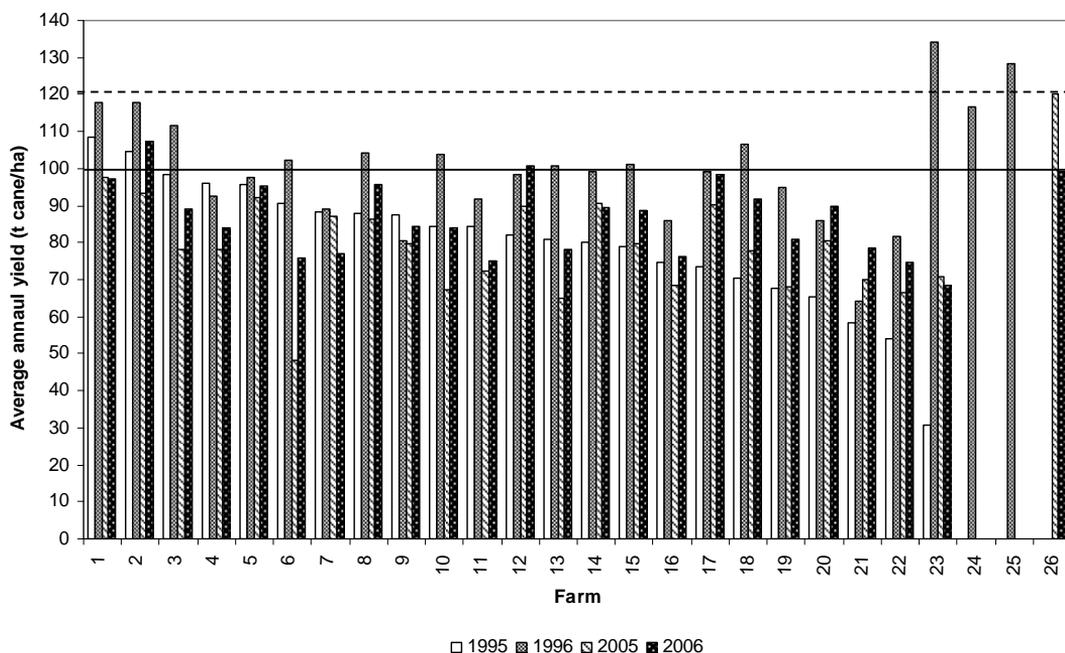


Fig. 10—Average yields for individual farms in the Coolbie-Rollingstone sub-district in the southern drier area of the Herbert district (1995, 1996, 2005 and 2006).

The horizontal unbroken line indicates the 100 t cane/ha production level. The horizontal dotted line indicates the district yield potential (DYP) as identified within the SIX EASY STEPS program. Farm numbers were allocated according to the level of production in 1995 (decreasing from left to right).

Foresthome

The well-distributed rainfall experienced in the wetter areas of the Herbert district in 1995, 1996 and 2005 resulted in average yields being in excess of the EHAADY on many farms (Figure 11).

A relatively large proportion of these reached, and sometimes exceeded, the DYP. The wetter conditions in 2006 were probably the primary cause of the lower average farm yields, but the negative effect was less apparent than in some of the other sub-districts e.g. the low-lying Tara-Seymour area (not shown here).

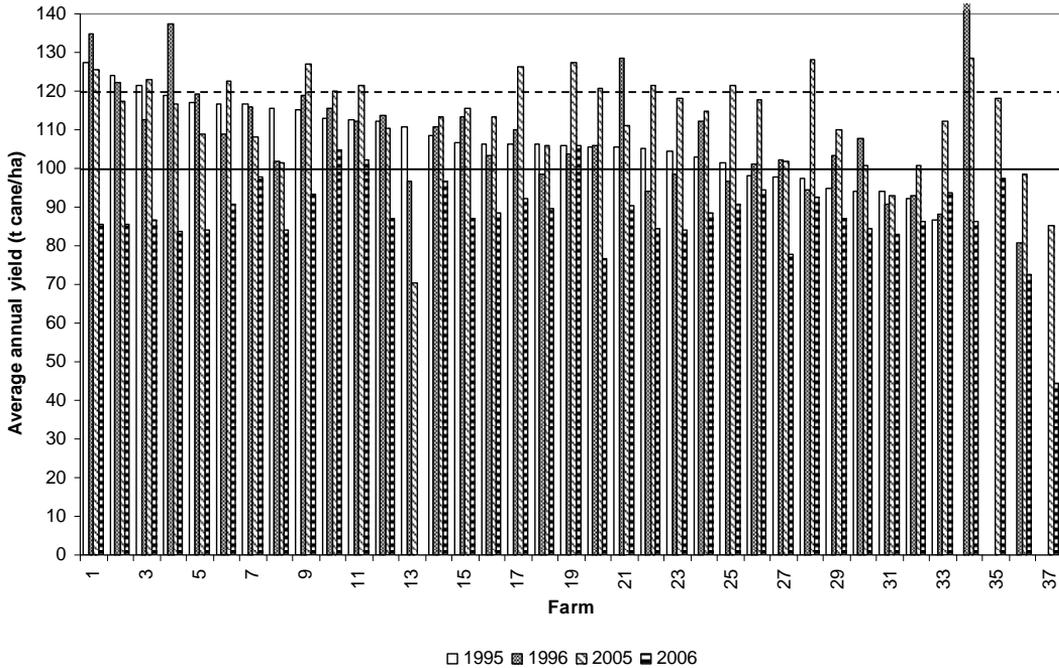


Fig. 11—Average yields for individual farms in the Foresthome sub-district in the higher-yielding wetter area (1995, 1996, 2005 and 2006).

The horizontal unbroken line indicates the 100 t cane/ha production level. The horizontal dotted line indicates the district yield potential (DYP) as identified within the SIX EASY STEPS program. Farm numbers were allocated according to the level of production in 1995 (decreasing from left to right).

The data from HCPSL enabled sugarcane yield to be plotted against specific block numbers (allocated in an arbitrary manner) for particular soil types in the Herbert district. For illustrative purposes, sugarcane yields associated with ‘alluvial-type’ soil were considered for plant cane (Figure 12a) and ratoon cane (Figure 12b) for 2005 (dry year with well-distributed rainfall) and 2006 (wet year). Individual block yields range vary markedly around both the EHAADY (100 t cane/ha) and DYP (120 t cane/ha) for both plant and ratoon cane. Although this is probably due to a number of factors (including on-farm management), seasonal variation is a major contributor due mainly to the differing rainfall patterns

Conclusions

The SIX EASY STEPS program, with its sound scientific principles, extensive R&D and an appropriate extension and delivery mechanism, is an important development because it provides a firm basis for the Queensland sugarcane industry to meet the challenges set by the State Government’s decision to implement their Reef Protection Package. Importantly, the SIX EASY STEPS program is aimed at a combination of maintained or improved sugarcane productivity and profitability, together with ongoing environmental responsibility.

Although the overall basis for the SIX EASY STEPS N guidelines (a combination of DYP and a soil mineralisation index) is well documented, supporting information relating to the concept of DYP and EHAADY has not previously been presented in detail.

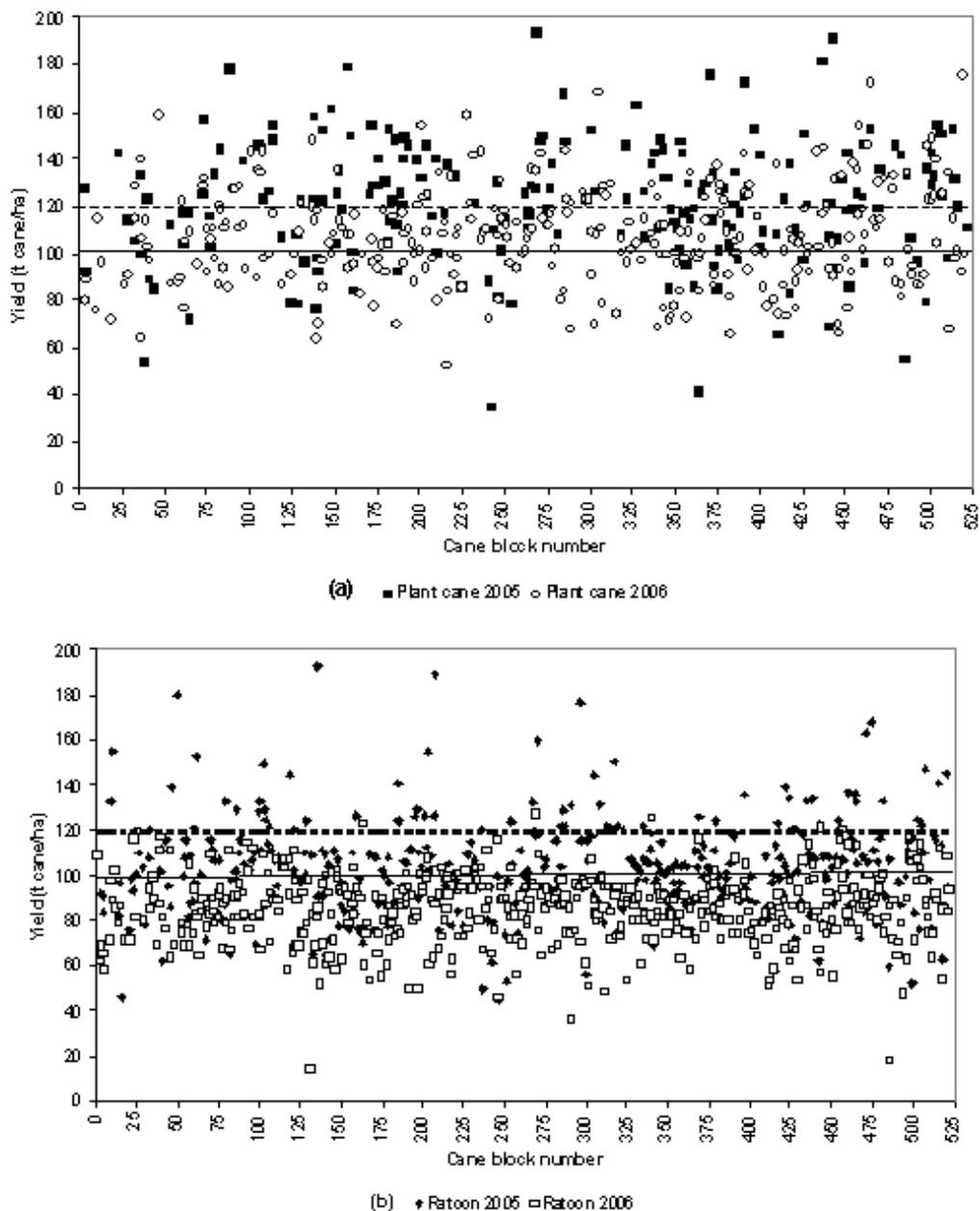


Fig. 12—Sugarcane yield on 'alluvial soils' plotted against arbitrarily allocated cane block number: (a) plant cane 2005 and 2006, (b) ratoon cane 2005 and 2006.

While 2005 was characterised by well-distributed rainfall, 2006 was relatively wet. The horizontal unbroken line indicates the 100 t cane/ha production level. The horizontal dotted line indicates the district yield potential (DYP) as identified within the SIX EASY STEPS program.

Examination of mill statistics data indicated that the established EHAADY values used within the SIX EASY STEPS program are appropriate for the various districts within the Queensland sugarcane industry. Importantly, they also take into account conditions that may influence particular districts' abilities to produce higher average annual yields than the standard 100 t cane/ha.

Examples of data from sub-districts indicated that DYP values, determined as EHAADY multiplied by a factor of 1.2, are realistic, particularly when individual farm data are considered. It was found that the average sugarcane yields on a substantial number of farms reached or exceeded the DYP value of 120 t cane/ha in both the Herbert and Tully districts. This occurred during seasons that were characterised by rainfall conditions that were conducive to good sugarcane growth (2002 and 2005 in Tully, and 1996 and 2006 in the Coolbie-Rollingstone area of the Herbert district). Unfortunately, the DYP was not reached on many farms during seasons with unfavourable rainfall patterns. This included the occurrence of either excessive rainfall (in the Tully district in 2001 and 2006, and in the Foresthome area of the Herbert district in 2006) or relatively dry conditions (such as those experienced in the Coolbie-Rollingstone area in 1995 and 2005).

Sugarcane yield plotted against block numbers for particular soil types showed that sugarcane yields vary markedly around both the EHAADY and DYP values due to several factors including weather conditions.

As a result, N fertiliser inputs based on actual sugarcane yields could fluctuate markedly from year to year and be substantially higher or lower than those based on a standard DYP.

Higher N application rates than those recommended within the SIX EASY STEPS guidelines on soils close to waterways (such as the alluvial soils included in Figure 12) would be regrettable from an environmental perspective.

Nitrogen applied at rates lower than those contained in the SIX EASY STEPS guidelines could restrict sugarcane yield. This would occur particularly if such lower N inputs (based on lower yield obtained in one year due to adverse weather conditions) were applied and the subsequent growing season was characterised by a well-distributed rainfall pattern that favoured good sugarcane production.

The difficulty of predicting weather conditions curtails our ability to formulate N input strategies prior to a particular growing season.

This means that the only appropriate management option is to apply fertiliser with the aim of producing the best crop and assume that the forthcoming season will be characterised by favourable weather conditions (particularly rainfall).

At present, the SIX EASY STEPS guidelines provide the best possible option in terms of achieving these aims. However, this approach could be further enhanced by the inclusion of accurate seasonal forecasting to assist in guiding N inputs. Further R&D is required to determine whether such developments would be possible and reliable enough to ensure a sustainable sugarcane production system within Australia.

Acknowledgements

The majority of figures presented in this paper are based on data obtained from: BSES Limited Annual Mill Area Statistics Reports; Tully District Comprehensive Area Productivity Analysis (CAPA) compiled by Tully Sugar Limited, Tully Cane Productivity Services Limited, BSES Limited and Tully Cane Growers Ltd; Herbert Cane Productivity Services Ltd (HCPSL); and CSR Sugar Productivity Data Cube.

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