

INTEGRATING AGRONOMIC AND ECONOMIC PRINCIPLES THROUGH APPLICATIONS OF VARIETY TRIAL DATA: THE ILLOVO CASE STUDY

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Abstract

Variety recommendations are conventionally based on agronomic principles, while the economic implications of such variety replacements are often overlooked. This case study describes the methodology and outcomes of an integrated agronomic and economic variety recommendation study in the South African sugar industry. The variety disposition of four miller-cum-planter estates belonging to Illovo Sugar Limited was evaluated, with the aim of limiting any single variety to a maximum of 30% of an estate's total area under cane. Field records describing topography, soil characteristics, and variety disposition were provided for each estate. A variety trial database at SASRI was restructured and aligned to field record spreadsheets from the estates (soil group, harvest age, region), and the RV yields of the existing varieties under specific conditions were estimated from trial data. Estate managers and Extension Specialists developed an alternate variety disposition based on individual field characteristics, agronomic suitability of varieties, and the 30% limitation. For each field, the economic implications (R/ha) of switching between existing and recommended varieties were calculated based on average RV yields from SASRI trials. Examples of differential varietal responses under different scenarios are illustrated and discussed. The results showed that conforming to the 30% limitation resulted in isolated economic losses associated with changing dispositions on some estates. Alternatively, when varieties producing only positive economic gains were chosen as replacements, the 30% limitation was exceeded on most estates. Also, new varieties gave greater economic returns in terms of average RV yields per hectare compared to existing commercial varieties. The practical implications of rapid variety shifts are outlined and discussed in the context of pest and disease risks and limited information on new varieties. The principles demonstrated in the study will be applied to other studies involving variety performance and recommendations.

Keywords: sugarcane, yields, variety, trial data, economic evaluation

Introduction

Variety selection is an important management decision that can affect the profitability of any farming enterprise, and it is often used as a tool to mitigate limitations imposed by biotic and abiotic stresses. In the South African sugar industry, yield variability of varieties have been attributed to regional characteristics (Parfitt, 2000), time of harvest (Donaldson *et al.*, 2008), age

of harvest (Ramburan and Sewpersad, 2009), soil type, and other management and pest and disease factors. In addition to the direct main effects of these factors on variety productivity, one must also consider their indirect associated effects as well as their interactions. This highlights the intricacies associated with variety selection and stresses the need for grower effort in this regard. Despite this, the current variety disposition of the South African sugar industry is dominated by two or three varieties on average, in each of the mill supply areas (MSA). In certain MSAs the area planted to the variety N12 is approximately 70%, posing a huge risk to production in the event of that variety succumbing to any new pest or disease. This lack of diversity of varieties is linked to a number of factors such as personal preference of growers and lack of technological information (Pillay, 1999). For example, in the South African industry the dominance of N12 is linked to this variety's perceived resistance to drought stress and damage caused by the borer *Eldana saccharina* Walker, Lepidoptera: Pyralidae, and changing to a wider spread of niche-specific varieties is considered risky. Growers therefore tend to wait until a new variety has been proven in the industry before adoption. A factor often overlooked in the industry, and which is conventionally superseded by agronomic considerations, is the profitability associated with different varieties.

In a global climate dominated by economic issues, profitability of different varieties is likely to be a dominant factor driving changes in variety dispositions. In addition to the effects of factors mentioned above, a comprehensive economic study of variety performance would have to take into consideration aspects such as relative weed control costs (canopy differences), harvesting and transport costs (cane yield differences), cane quality, and relative ratooning ability. Appropriate data that addresses all of these factors are often not available and, as a consequence, studies on the relative economic performance of varieties are rare. However, yield and quality data from variety trials conducted throughout the sugar industry are a valuable resource that can be utilised to provide indications of likely economic benefits associated with variety changes.

The risks associated with over-reliance on a single variety were recently acknowledged by Illovo Sugar Limited, a multi-national miller-cum-planter with four large estates in the South African industry. The four Illovo estates consist of a total of 14 individual farms, with N12 as the dominant variety on all the hinterland/inland (50-99%) and coastal (14-69%) farms. This realisation of the dependence on N12 prompted an investigation into the variety disposition of each estate, as well as a mandate from company management to reduce the area planted to any single variety to a maximum of 30% of an estate. Additionally, it was also requested that the profitability of changing variety dispositions be investigated to provide an indication of the economic implications of any drastic variety shifts. Furthermore, Illovo Sugar management set a target for any new variety dispositions to be fully implemented within a period of five years. The objectives of this case study were therefore:

- To analyse existing, and develop new variety dispositions for four Illovo sugar estates without exceeding a threshold of 30% of any given variety.
- To evaluate the profitability of different variety dispositions by conducting an economic comparison of variety performance under specific field conditions.
- To identify opportunities and challenges associated with economic variety evaluation and highlight risks associated with rapid variety shifts.

Materials and Methods

Data collation and variety recommendations

Estate managers collated all farm and field data for their respective estates in appropriate spreadsheets. The spreadsheets consisted of data on field areas, soil type (depth and soil form), topography, aspect, altitude, current variety, haulage distance, and harvest age. Extension Specialists (ES) and estate managers calculated the current variety disposition for each farm within the estates, and used the above factors to recommend alternate varieties for each field. Their recommendations were initially based on the 30% threshold restriction, general agronomic knowledge of current and new varieties, and pest and disease considerations for each of the estate farms. These recommendations were subsequently referred to as the '1st choice disposition', and represented an ideal variety mix that conformed to the theoretical threshold of 30%.

A brief description of the strategy used for the Eston estate is given here. The farm was divided into three main categories for its potential to produce cane yield in a normal year, i.e. below average, average and above average potential. Fields were rated for their yield potential by using criteria such as soil form, clay%, actual rooting depth, aspect and rainfall (one area of the farm is known to be drier than the rest). The first step was to allocate as much of the below average potential fields to N31 (adapted to low potential conditions) without exceeding 30%. These fields were scheduled to be harvested in mid season, i.e. July to September each year in order to maximise the recoverable value (RV) potential of this variety (low RV% early in the season). The only other new variety available with a good track record from plant breeding and agronomy trials at the time of planning the planting programme was N50, and fields that had above average potential for sugarcane yield were selected for this variety. The balance of the farm (average potential) would remain with N12 as the first option. Similar methodology was applied to the other estates by taking into consideration specific production limitations.

Data analysis

Trial data was extracted from the variety trial database at the South African Sugarcane Research Institute (SASRI) (Bezuidenhout, 1998) and restructured to reflect similar factors displayed in the estate spreadsheets. Fields within farms on each estate were considered as individual units requiring their own analyses (1530 fields in total). Field characteristics could not be simulated exactly within the trial database (especially soil forms), so categories of factors had to be created (Table 1). This produced adequate datasets from which to calculate average variety performances under specified scenarios, e.g. more data was available on the performance of a variety under the category of 'grey lower slopes' as opposed to performance under a specific soil form falling into that category. The characteristics of individual fields on each of the estates (region, harvest age, season and soil type) were then simulated in the trial database, and the average RV yields of the current and recommended varieties were calculated (from trial data). The difference in RV yields between the varieties, the size of the individual fields, and an RV price of R2000/ton, was then used to calculate the expected change in gross margin/ha associated with changing from the current to the recommended variety. The expected change in gross margin associated with each field was then used to determine the total economic effect of switching to the new dispositions.

The analysis resulted in occasional economic losses on selected farms when the 30% threshold disposition was implemented. This prompted a second round of variety recommendations, where alternate varieties were selected based on their superior RV yielding ability demonstrated in variety trials conducted under the same field conditions. These recommendations were subsequently referred to as the '2nd choice disposition', and did not necessarily conform to the theoretical upper threshold of 30% of any given variety per estate. Depending on the outcomes of the economic analysis, individual estates implemented either the 1st or 2nd choice dispositions.

Table 1. Categorisation of soil type, age and season in the variety trial dataset.

<i>Soil type</i>	
<u>Form</u>	<u>Soil Group</u>
Dundee	Alluvial
Milkwood	
Mayo	Black structured
Bonheim	
Cartref	
Glenrosa	Grey crest to midslope
Longlands	
Oakleaf	
Sterkspruit	Grey lower slopes
Westleigh	
Katspruit	
Kroonstad	Grey poorly drained bottomland soils
Inanda	
Kranskop	Humic
Hutton	
Shortlands	Red
Valsrivier	Yellow
<i>Age</i>	
<u>Trial criteria</u>	<u>Categorisation</u>
Harvested at 10-15 months	12 month
Harvested at 15-20 months	18 month
Harvested at 20-25 months	24 month
<i>Season</i>	
<u>Trial criteria</u>	<u>Categorisation</u>
Harvested April-June	Early season
Harvested June-August	Mid season
Harvested August-December	Late season

Analysis of pest and disease reactions

It was acknowledged that one of the main objectives of changing the variety dispositions on the estates was to reduce the pest and disease (P&D) risks associated with over-reliance on a few varieties only. To this end, an analysis of the P&D risk profiles of the current, 1st, and 2nd variety dispositions was attempted. This was done by taking into consideration the probability of infection on a particular farm (P) as well as the potential impacts of the infection (I). ES's were asked to rate each of the farms on the estates according to their probability of infection by smut, mosaic, rust and eldana on a scale of 1 (low probability) to 5 (high probability). The impacts of infection were represented by SASRI's variety P&D ratings, which ranged from 1 (highly resistant) to 9 (highly susceptible). The risk index (RI) for each pest or disease of each variety was then calculated using the formula:

$$RI = (D \times P \times I)/CF$$

where

- D = disposition of the variety on a farm (%)
- P = probability of infection of variety by pest or disease (1-5)
- I = impact of infection of variety by pest or disease (1-9)
- CF¹ = re-scaling factor.

The RIs for each variety were then summed to calculate the total RI of a particular variety disposition. The risk index was only determined for the Sezela and Gledhow estates as pilot studies to determine if the equation was suitable for this type of study.

Results

Differential variety responses

Analysis of trial data revealed large differences in RV yields of varieties under different growing conditions. In particular, the harvest age and soil type associated with individual fields were very influential in determining RV yields. For example, Figure 1a illustrates the differential responses of varieties N12 and N37 to different soil groups in high altitude regions (>18 month harvest). The variety N12 produces higher RV yields (and economic benefits) than N37 on lower potential soils falling into the 'grey crest to midslope' and 'grey lower slopes' categories. In contrast, N37 shows higher average RV yields than N12 on soils falling into the 'humic' and 'red' categories. Furthermore, this RV yield advantage (and economic benefit) of N37 is much greater under humic than red soils. In some cases it was found that harvest age had an overriding effect compared to soil type. For example, Figure 1b shows that under both grey crest to midslope and grey lower slope soils, variety N12 produces higher RV yields than N41 when harvested at 24 months, while N41 yields better than N12 when harvested on a 12 month cycle. These analyses illustrate the need to calculate the average RV yielding ability of varieties under well-defined scenarios. In this study, individual field characteristics were defined in as much detail as possible before corresponding trial data was analysed, and the responses depicted in Figure 1 justify this field-based approach.

¹CF was used to re-scale the range of RI to [0.10]

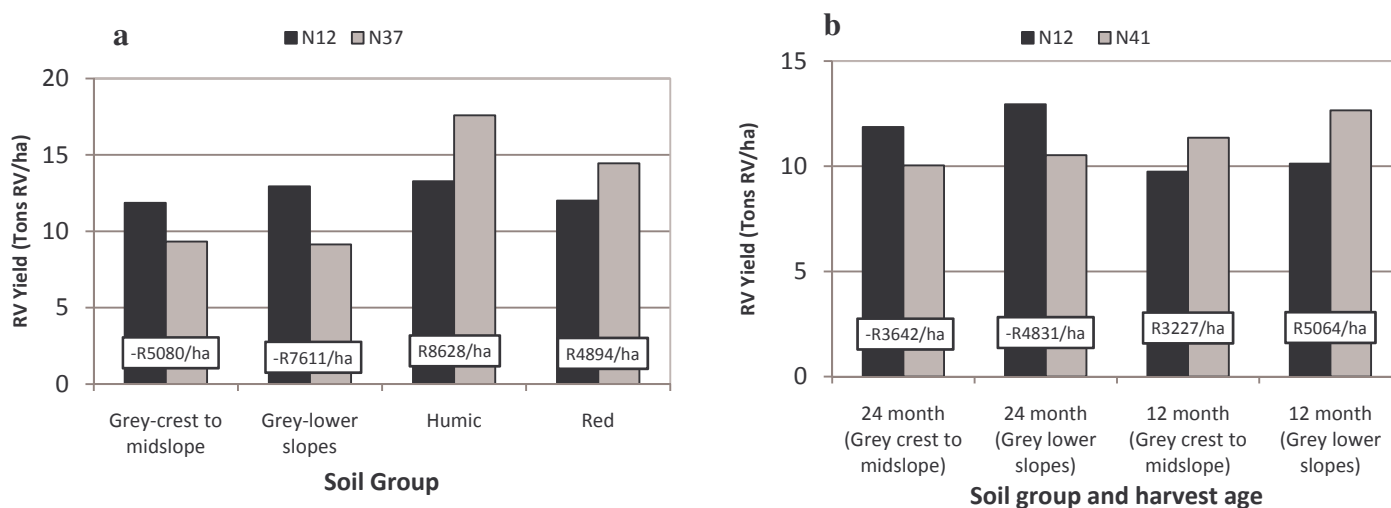


Figure 1. Effects of soil type on average RV yields of N12 and N37 (a), and effects of harvest age and soil type on RV yields of N12 and N41 (b). Economic benefit/loss expected from replacing N12 with N37 or N41 under the different conditions are indicated in boxes.

Variety disposition analyses

Figure 2 illustrates the current and recommended variety dispositions for each of the four estates. At Sezela (Figure 2a), the current variety disposition was dominated by N12 (73%), with very little contribution from other varieties. The 1st choice disposition resulted in a significant drop in the area planted to N12 (37%), with corresponding increases in varieties N39 and N41. The 30% threshold was not adhered to at Sezela due to the lack of suitable replacement varieties under the specific environmental conditions. When the 2nd disposition was considered, the area of N39 increased to 38%. This is due to the significantly better performance of this variety in trials under a range of conditions (particularly sandy soils) along the coast. The area of N41 declined, reflecting general poor trial performance under these conditions on the coast. At Eston (Figure 2b) the area planted to N12 (85%) once again dominated the current disposition, as relatively few alternate varieties are available for planting in this region. Only a 1st choice disposition was analysed at Eston as all the alternatives produced positive economic benefits (see later). Large areas of N31, N47 and N50 would have to be planted out, and the strategy to implement this change will be discussed later. The variety disposition at Gledhow (Figure 2c) seemed much more balanced, with a range of varieties contributing to production. This was mainly due to the diversity of farms making up the estate and the existence of irrigated areas as well. Nevertheless, the recommendations point towards a large reduction in the area under N12, with corresponding increases in the areas planted to N31 and N39 in both the 1st and 2nd dispositions. Recent production concerns with the variety N27 (apparent poor ratooning and susceptibility to damage by sugarcane thrips) also led to significant reductions in the areas recommended for this variety. The Umzimkulu estate (Figure 2d) showed a trend similar to Sezela and Eston, with N12 dominating in the current disposition and N39 replacing that variety in the 1st and 2nd recommended dispositions.

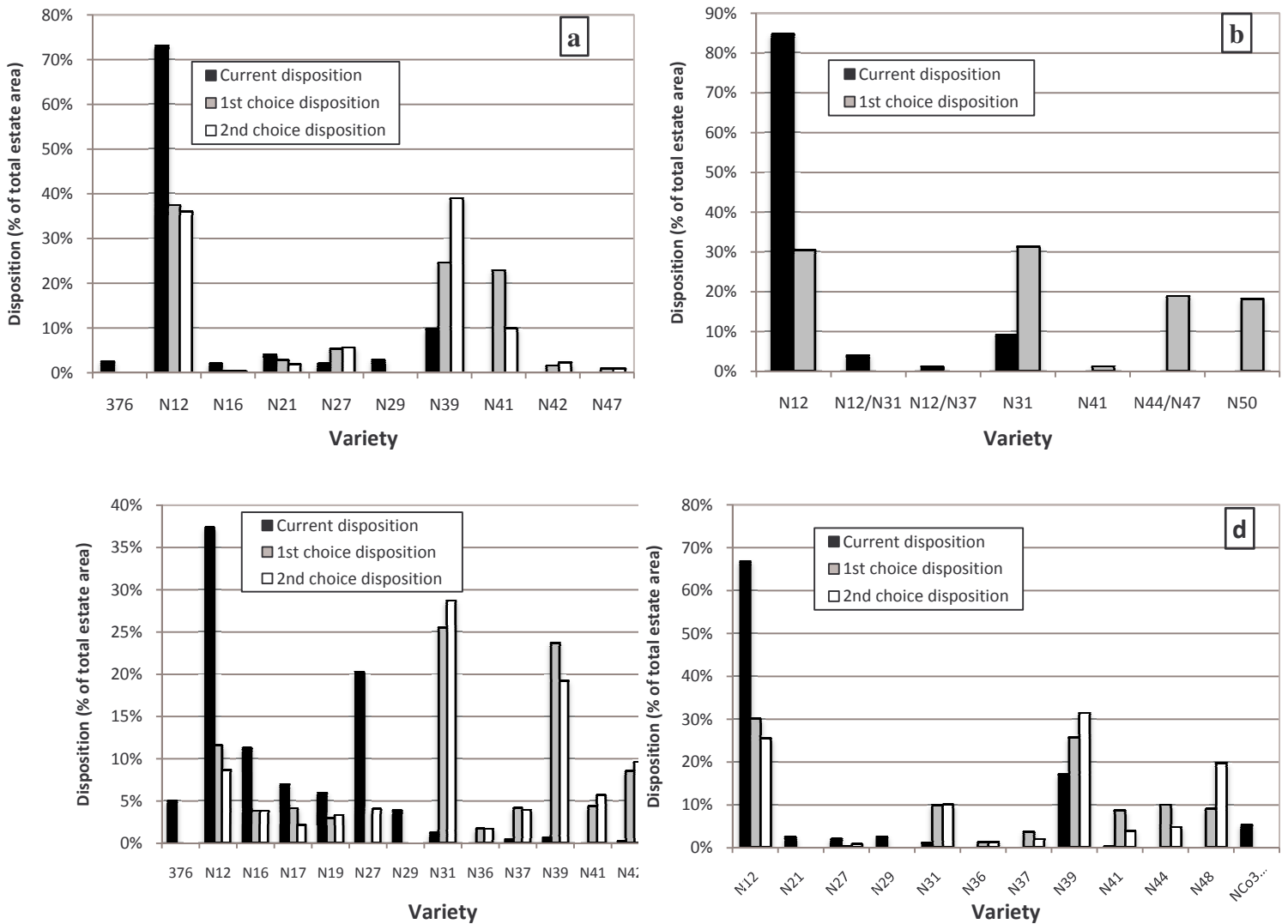


Figure 2. Current, first and second choice variety dispositions for the Sezela (a), Eston (b), Gledhow (c) and Umzimkulu (d) estates.

Economic analysis

Table 2 shows the economic benefits (R/ha/crop harvested) of switching from the current to the 1st and 2nd variety dispositions for each of the estates. In general, the 1st choice disposition produced lower economic benefits than the second, and on farms such as Esperanza (Sezela), Ravenhill (Umzimkulu), and Beach (Gledhow), the change from the current variety disposition resulted in economic loss. As expected, when varieties showing better average RV yields in trials compared to the current varieties were chosen (2nd choice), the economic benefits were substantial on all farms. At Eston, the 1st recommended disposition produced positive economic returns, and consequently, no 2nd choice disposition was analysed. It must be noted that the economic benefits indicated represent a straightforward calculation of R/ha income, and does not take into consideration other variety dependent costs such as harvesting and transport.

Table 2. Economic benefit/loss (R/ha) associated with switches from the current to the first and second disposition on a farm and estate level.

<u>Average economic benefit (R/ha)</u>		
<u>Farm</u>	<u>1st disposition</u>	<u>2nd disposition</u>
	<u>Sezela</u>	
Glenroy	189	845
Sezela	470	1149
Esperanza	-77	603
Isonti	1749	1990
Illovo	74	1117
Estate average	481	1141
	<u>Umzimkulu</u>	
Paddock	1479	1545
Ravenhill	-427	385
Seafield	1185	1685
Estate average	746	1205
	<u>Gledhow</u>	
Beach	-611	1258
Blythdale	755	1711
Hillbrow	1395	2410
Glendale	616	2220
Kranskop	1026	1601
Estate average	636	1840
	<u>Eston</u>	
Eston	1996	–

Pest and disease risks

The risk index (RI) associated with each variety disposition on the Sezela and Gledhow estates are indicated in Table 3. At Sezela, a change in the variety disposition from the current to the 1st and 2nd dispositions didn't produce any drastic changes in the P&D risk indices for any of the diseases or *E. saccharina*. Similarly, at Gledhow, the results showed that changing variety dispositions did not affect the P&D indices that much. Based on knowledge of the P&D susceptibility of current varieties which made up large proportions of the current dispositions, large differences in the P&D risk profiles were anticipated. However, this was not the case, as changes in dispositions only produced minor integral changes in the RIs on a scale of 1 to 10. This lack of response may be due to the nature of the formula used to calculate the index. It is likely that the formula employed was not sensitive enough to changes in the actual P&D risks associated with the variety dispositions, and further attempts should be made to develop a suitable formula, or modify the existing formula for such a calculation.

Table 3. Pest and disease risk indices associated with different variety dispositions at the Sezela and Gledhow sugar estates.

	Disease or pest risk index (1-10)			
	Smut	Mosaic	Rust	<i>Eldana saccharina</i>
	<i>Sezela</i>			
Current	1.44	1.20	1.49	2.59
1st disposition	1.53	1.05	1.72	2.48
2nd disposition	1.54	1.04	1.73	2.50
	<i>Gledhow</i>			
Current	3.12	3.35	3.02	4.20
1st disposition	3.29	3.17	3.26	4.39
2nd disposition	3.24	3.17	3.32	4.40

Discussion

The results have demonstrated that diverse variety dispositions could theoretically produce higher economic returns compared to dispositions dominated by single varieties. This phenomenon is due to the greater exploitation of growing conditions by niche varieties, as opposed to the general performance of a more stable variety (e.g. N12) over a wide range of conditions. Many of the varieties recommended in the 1st and 2nd dispositions were niche varieties that are adapted to specific soil types and harvest ages, as illustrated in Figure 1. Results from trials demonstrated that such varieties produced higher RV yields than N12 when the specific regional conditions, harvest age and soil conditions were taken into consideration. This highlights the importance of correct variety placement, and illustrates the benefits of SASRI's recommendation strategy for niche specific varieties.

Although this study has demonstrated the economic benefits of diversifying variety disposition, these results must be interpreted with caution. A more complete economic analysis should take into consideration differential harvesting and transport costs associated with different varieties as well as differences in canopy architecture. High biomass varieties with low sucrose content, like N31 (which made up a substantial proportion of the 1st and 2nd dispositions on the Eston, Gledhow and Umzimkulu estates) would definitely have an effect on transport and harvesting costs, thereby influencing the net economic benefits calculated. Another essential factor overlooked in this study, and which plays an extremely important role in the South African sugar industry, is the differential ratooning ability of varieties. The ratooning ability of many new recommended varieties is currently unknown and, as a result, such an analysis could not be conducted. Isolated studies demonstrating ratooning ability of new varieties are available (Ramburan *et al.*, 2009); however, a generalised characterisation of all released varieties in terms of their ratooning ability is lacking in the industry. Nevertheless, this study has provided insight into the likely economic benefits associated with diversifying variety dispositions, and further analyses that consider the above factors are recommended.

Another concept frequently questioned during this study was the 30% threshold that was implemented. The objective of limiting any single variety to 30% of the total farm area is to

protect against losses that could be incurred from sudden pest or disease outbreaks. This makes sense intuitively and biologically; however, the methods employed to identify the 30% threshold are not well documented. Recently, Millard *et al.* (2009) quoted a 30-40% threshold of any single variety for the Australian sugar industry. It would seem that a 30% threshold is recommended in South Africa, yet the means used to arrive at this figure are unclear. What is needed is an integrated simulation study using yield loss estimates and economic principles. Such a model should calculate the P&D yield loss associated with various dispositions and use an economic threshold (break-even point) to calculate a generalised variety threshold. It is likely, however, that the optimal threshold will vary for different farm conditions. In this study it was found that there was a tradeoff between reaching the optimal variety disposition (according to the 30% threshold) and economic benefits. Adhering to the 30% threshold (1st recommended disposition) resulted in lower economic benefits compared to situations where the threshold was occasionally exceeded (2nd recommended disposition). This suggests that the 30% threshold should be re-evaluated within the South African industry to include both P&D and economic considerations.

A further limitation of the study was that most calculations used simplistic data-averaging principles and sound statistical methodology was not employed. The differences in yielding ability, the economic differences between the dispositions, and the differences in P&D risk indices were not determined using statistical methods. This was mainly due to time and resource limitations experienced during the study. A follow-up study should employ a more scientific approach to validate many of the results observed.

The implementation strategies for the recommended dispositions will vary between estates; however, the timelines planned for the implementation are the same (five years). SASRI advocates a 10% or less annual replant strategy. In order to implement the rapid varietal shifts suggested in this study, the SASRI recommendation would have to be exceeded, raising several concerns. Firstly, the difficulties associated with sourcing good quality seedcane (especially of new varieties) within such short time frames, must be acknowledged. The consequences of planting large areas of land and not conforming fully to soil conservation and environmental legislation are also a cause for concern. The cost effectiveness, as well as the resource capacity of estates to replant large areas must also be considered. Finally, the cane cycle replant programme in subsequent years may also be affected, as the strategy may require approximately 20% of the area to be replanted again in 7-8 years.

Conclusions

The study has shown that diversification of variety dispositions can theoretically produce higher economic returns compared to a single variety strategy. This highlights the advantages of planting high RV yielding, niche-specific varieties in their correct production conditions, as opposed to planting stable varieties across a range of conditions (although stable varieties will be beneficial with high seasonal variability). The economic benefits of changing dispositions were greater when the variety threshold of 30% was exceeded. Although economically superior, the P&D risks associated with exceeding the 30% threshold are likely to be greater. The P&D risk index determined in this study does not reflect these risks, and further refinement of the formula is necessary to increase its sensitivity.

The study has demonstrated the value of accurate grower records and farm characterisations, and how these can be used to develop tailor-made variety recommendations. A proper characterisation of a farm allows for improved placement of niche-specific varieties which will produce better economic returns. Furthermore, the study has shown how trial data can be applied to commercial studies through collaboration between industry, extension and scientists. The use of trial data for such purposes is an untapped resource, and other areas of research could also benefit by applying this approach.

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