IMPROVED YIELDS FROM RIDGING CANE IN THE SOUTH AFRICAN SUGAR INDUSTRY

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Abstract

Poor cane growth and low yields, with frequent need for crop re-establishment, are a feature of the majority of soils derived from Middle Ecca, Dwyka tillite and Beaufort sediments, which collectively comprise about 20 per cent of the area under cane. Results from five trials are presented to compare the yields from ratoon cane grown either on ridges or with flat cultivation. The trial sites were on soils of the Westleigh, Longlands and Katspruit forms. Yield responses to ridging in 13 crops varied from five to 20 tons cane per hectare, depending on cane variety and the amount of rainfall. The results of seven ratoon crops from a trial at Mtunzini showed that variety N12 responded best to being grown on a ridge, followed in decreasing order by varieties NCo376, N13 and N8. The monitoring of soil properties, root development and moisture distribution to depth indicated that the main advantages of ridging were improved drainage, less compaction damage on the ridge, and improved moisture conservation through an increase in effective rooting depth. Guidelines are given with regard to the use of ridges in the sugar industry.

Introduction

Soils derived from Middle Ecca, Dwyka tillite and Beaufort sediments include the Longlands, Westleigh, Kroonstad, Valsrivier and Katspruit forms. These belong to the Duplex family of soils, which comprise a sandy permeable topsoil lying abruptly on a slowly permeable subsoil. Factors which limit rainfall efficiency in these soils include low water intake rates, low total available moisture capacity, surface crusting, high erodibility hazard, slow internal drainage, low air-filled porosity, high compaction hazard and vulnerability to the development of saline/sodic conditions when irrigated (Meyer *et al.*, 1988). Cane frequently suffers from moisture stress on these soils and yields usually decline rapidly with successive crops. Difficulties in managing these soils led in 1979 to the initiation of a project to investigate practices that would alleviate the problems being experienced (Meyer *et al.*, 1988).

One such practice was planting on a ridge or creating a ridge on the cane row after the crop was established. Medium to fine textured soils are generally best suited to this practice and the key to its success is a well defined ridge (Randall, 1987). Ridges are meant to dispose of excess surface water and keep the roots above a water table or impervious layer (Meyer *et al.*, 1988).

Other advantages of growing cane on a ridge include a favourable water and temperature environment for the roots (Buchele *et al.*, 1985 and Burrows, 1963), increased root development (Bauder *et al.*, 1955) and erosion control (Radke, 1982). Ridging compels the manager to change to a controlled wheel traffic system that will reduce stool damage and confine soil compaction to the interrow (Bauder *et al.*, 1985). Disadvantages of this practice are: planting on the ridge will take longer than conventional planting, an improved level of management is necessary to weed the field (Selley and Eisenhauer, 1987) and the wheels of equipment must be set to the width of the ridges. Results of five ridging trials are reported and guidelines, based on soil criteria, are given on where ridging would be beneficial.

Experimental procedure

Description of trial sites

Five field trials to study the yield response of sugarcane to ridge tillage, and the influence of this practice on physical and chemical properties of soils, were conducted on grey hydromorphic soils. Selected characteristics and soil properties at the five sites are given in Table 1, and details of trial design are presented in Table 2.

Site 1, La Mercy: This trial was established in March 1985 on a Longlands form soil and terminated after the second ratoon was harvested in August 1988. There were three treatments: conventional tillage - control (T1), minimum tillage with ridging three months later (T2), and ridge planting (T3).

Site 2, Nkwaleni: This was the only trial located on a Katspruit form soil and conducted under irrigated conditions. It was established in April 1986 and treatments were

Table 1

Properties of the soils at the various field sites

Site No.	Location	Dominant soil form	Depth of impervious horizon (mm)	Top soil characteristics					
				Physical analysis			Chemical analysis		
				Clay (%)	Fine sand (%)	Medium + coarse sand (%)	pH	EC (mS/m)	SAR
1	La Mercy	Longlands	400–600	20	61	10	5,3	–	–
2	Nkwaleni	Katspruit	300–400	35	25	30	6,7	33	1,7
3	Mtunzini	Longlands	450–700	26	38	22	5,6	50	3,0
4	La Mercy (Winter plant)	Longlands/ Westleigh	400–600	13	56	23	5,0	80	2,4
5	La Mercy (Summer plant)	Longlands/ Westleigh	400–600	21	46	21	5,2	77	2,5

Table 2

Details of trial design

Site No.	Trial start	Crops	Cane varieties	Treatments	Trial design	No. of replications	Row spacing (m)	Net plot size (m^2)	Water regime
1	March 1985	P-2R	NCo376	Minimum tillage (control) Ridged at 3 months after planting Ridge planting	Randomised block	8	1,5	108	Rainfed
2	April 1986	P	NCo376	Conventional plant (control) Ridged at 3 months after planting Ridge planting	Randomised block	6	1,5	36	Irrigation
3	Nov 1984	3R-8R	NCo376, N7, N8, N11, N12, N13, N14	Unridged (control) Ridged	Non-randomised	2	1,2	60	Rainfed
4	June 1989	P	NCo376 N12	Unridged (control) Ridged	Non-randomised	5	1,2	36	Rainfed
5	Nov 1988	P, 1R	NCo376, N12	Unridged (control) Ridged	Non-randomised	6	1,2	36	Rainfed

similar to those at site 1 above. The trial was terminated after harvesting in June 1987, because continual subsidence of the ridges necessitated re-ridging five times in 14 months.

Site 3, Mtunzini: This trial was superimposed on a mole drainage trial which had been terminated after the second ratoon. Seven cane varieties were already established on the site and, at the beginning of the third ratoon (October 1984), half the plots growing each variety were ridged (T2) and the remaining plots were not ridged (T1). The plots were re-ridged mechanically during the fourth, six and eighth ratoons when the cane was two to three months old. The eighth ratoon was harvested in September 1990.

Sites 4 and 5, La Mercy: These trials compared the effects of ridging and conventional tillage on two cane varieties (N12 and NCo376) planted in a summer cycle (November 1988) and in a winter cycle (June 1989).

Ridge construction

Following normal land preparation and before planting, ridges were constructed by a conventional two row ridge implement fitted with a small dividing furrower on the tool bar, which drew the planting furrows on top of the ridge (see Fig. 1). Once the cane setts had been placed in the furrows they were covered manually or mechanically with conventional implements.

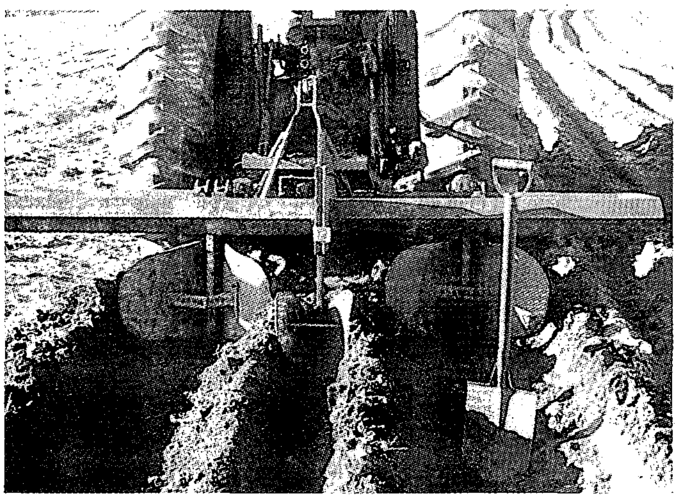

FIGURE 1 The modified two row ridger.

In the ratoon crops ridging was carried out two to three months after harvest using a conventional disc type ridger, which moved soil from the interrow onto the cane row. Where possible ridges were drawn to provide a minimum ridge depth of 200 mm, a ridge crown width of 400 mm and an interrow furrow width of 400 mm. In practise, a minimum row spacing of 1200 mm and topsoil depth of 100 mm is required to provide ridges of the above dimensions.

Root studies

Root development was studied at Mtunzini and La Mercy by opening pits across the cane rows of selected ridged plots and adjoining control plots, and exposing the roots by washing with water and painting them with lime wash. A 200 x 200 mm string grid was superimposed over the painted roots and the number of roots in each grid block were counted to estimate root density.

Soil measurements

Various field and laboratory measurements were made on soils at all trial sites. These included bulk density and soil moisture content using the Troxler neutron density gauge (Swinford and Meyer, 1985), particle size, porosity and ridge height.

Crop water use

Gypsum soil moisture blocks were installed at Mtunzini, in the control and ridged plots of varieties NCo376 and N12 at depths of 250, 500 and 750 mm. Weekly readings of moisture use were taken between May and October 1990.

Results

Effect of ridging treatment on yield

Yield data for the ridging and control treatments covering 13 crops from the five trial sites are summarised in Table 3. In the plant crop at La Mercy, little response was obtained to either ridge planting or to ridging when the crop was three months old. Ridging had more effect in ratoon cane and there were significant yield responses in six out of nine crops. In general appreciable responses coincided with above-average rainfall periods. At site 1 (La Mercy), the first and second ratoon crops showed significant yield increases of 20

Table 3

Average yield results of the treatments

Site	1. La Mercy						2. Nkwaleni		4. La Mercy (Winter plant)		5. La Mercy (Summer plant)			
	Mar 85–Jun 86		Jun 86–Jul 87		Jul 87–Aug 88		Apr 86–Jun 87		Jun 89–Jul 90		Nov 88–Nov 89		Nov 89–Nov 90	
Treatment	Plant		1st ratoon		2nd ratoon		Plant		Plant		Plant		1st ratoon	
	tc/ha	ts/ha	tc/ha	ts/ha	tc/ha	ts/ha	tc/ha	ts/ha	tc/ha	ts/ha	tc/ha	ts/ha	tc/ha	ts/ha
T1 Control	54	6,3	69	9,0	44	5,9	92	10,0	65	8,5	41	4,2	70	8,2
T2 Ridge	56	6,9	75	9,3	50*	6,8*	102	11,2	68	9,0	42	4,3	70	8,3
T3 Ridge planting	53	6,2	82**	10,8**	52**	7,2**	99	9,8	—	—	—	—	—	—
Rainfall (mm)	923		1 074+		1 820+		990+		1 217+		1 327+		966	
Site	3. Mtunzini													
	Oct 84–Oct 85		Oct 85–Oct 86		Oct 86–Oct 87		Oct 87–Oct 88		Oct 88–Oct 89		Oct 89–Sep 90			
Treatment	3rd ratoon		4th ratoon		5th ratoon		6th ratoon		7th ratoon		8th ratoon			
	tc/ha	ts/ha	tc/ha	ts/ha	tc/ha	ts/ha	tc/ha	ts/ha	tc/ha	ts/ha	tc/ha	ts/ha		
T1 Control	56	7,1	64	8,5	51	6,2	42	5,6	55	7,1	52	6,4		
T2 Ridged	50	6,7	68	9,1	69**	9,0**	52**	7,1**	67**	8,9**	60*	7,6*		
Rainfall (mm)	1 117		1 032		2 225+		1 418+		1 224		1 207			
Long term mean (mm)	Mtunzini						1 339							

* Significant at 5% level ** Significant at 1% level + Above long term mean

Table 4

Responses to ridging in relation to variety (Mtunzini)

Variety	tc/ha														Mean response
	3rd ratoon		4th ratoon		5th ratoon		6th ratoon		7th ratoon		8th ratoon		Overall mean		
	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	
NCo376	55,2	57,0	56,7	57,8	42,0	60,8*	35,1	55,1**	45,0	72,3**	51,7	68,3*	47,1	61,4*	13,7
N7	51,7	51,5	57,8	65,0	48,0	61,4	43,8	47,8	54,2	71,9**	50,5	53,2*	51,1	58,4	7,3
N8	51,5	49,6	67,3	67,3	67,6	70,5	35,2	49,9**	46,7	65,7**	43,4	58,7*	52,2	60,2	8,0
N11	49,6	21,4	63,0	65,5	55,4	82,5**	42,2	44,3	53,8	35,3	49,6	39,3	52,3	49,0	−3,3
N12	64,4	68,0	69,3	78,3	50,3	75,4**	55,0	66,6**	63,3	89,7**	57,5	73,1*	59,9	75,2*	15,3
N13	52,3	47,2	61,6	70,4	48,9	66,2*	34,2	48,8**	53,3	61,0	50,8	67,8*	51,2	60,3	9,1
N14	65,1	60,3	70,6	78,5	45,6	58,2	50,8	52,7	62,3	85,0**	61,8	62,0	59,2	66,3	7,1

T1 Control * significant at 5% level
T2 Ridged ** significant at 1% level

and 22% respectively. At Site 3 (Mtunzini) no significant responses were obtained during the third and fourth ratoon crops under relatively dry conditions. However, highly significant increases were obtained in cane yield (35% and 23%), and in sucrose yield (45% and 27%) during the fifth and sixth ratoon crops when rainfall was relatively high. Although rainfall was below the long term mean during the seventh and eighth ratoons, significant responses to ridging were obtained, increases in sucrose yield being 25% and 19% respectively.

Relative yield responses of the seven cane varieties to ridging at Mtunzini are summarized in Table 4. Results of the third to the eighth ratoon crops show a significant increase in yield for varieties N12 and NCo376. Variety N12 showed the highest average yield increase followed in decreasing order by NCo376, N13, N8, N7 and N14. Variety N11 showed little response to ridging.

In the winter cycle trial at La Mercy (site 1) growth measurements, taken when the crop was seven months old, showed an improvement in stalk population of between 15 to 20% in the ridged cane compared with the control, although there was no difference in stalk height. However, at the time of harvest, any advantage from ridging had almost disappeared. There was also little response to ridging in the plant crop in the summer cycle at La Mercy (site 5), and yields were poor. Inspection of the ridges in a number of plots showed signs of subsidence and these were manually reridged. However, no significant increase in yield was obtained from ridging when the first ratoon was harvested.

Effect of ridging on root development

Root distribution for variety NCo376 in ridged and unridged plots at Mtunzini is shown in Figure 2. In the unridged plot most roots (85-90%) were concentrated close to

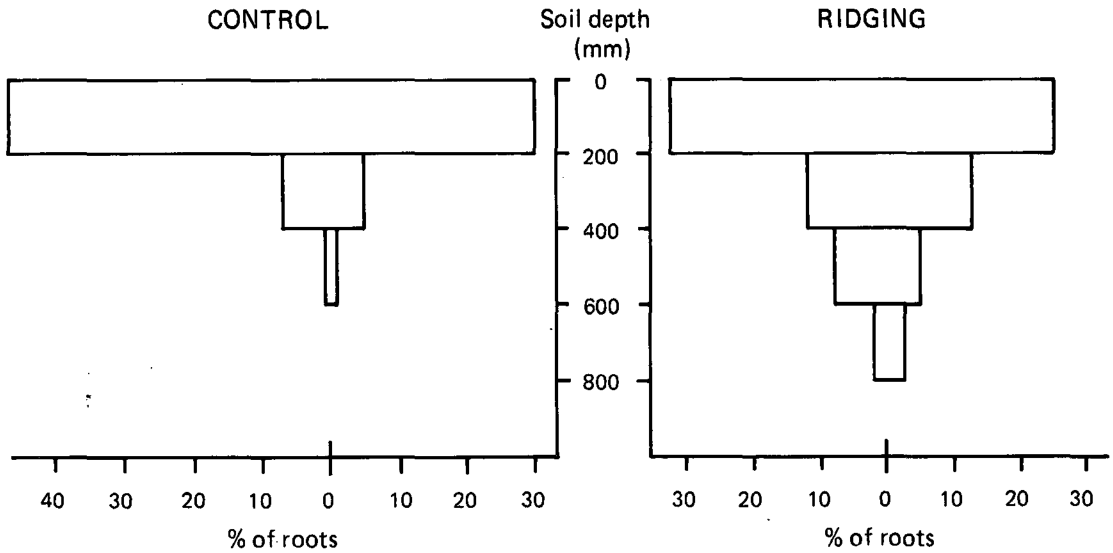

FIGURE 2 The effect of ridging compared with conventional tillage on root development under cane (variety NCo376) at Mtunzini.

the soil surface (0 to 200 mm depth) and only very few were found below 400 mm. Under the ridge, however, development was greatly improved with about 90% of roots well distributed to a depth of 600 mm. Similar patterns of root development were found under ridged and unridged treatments at the La Mercy trials. Variety N12 tended to have a deeper and more fibrous root system than NCo376.

Bulk density and soil moisture

Table 5 shows the bulk density values at the various trial sites. There was a small but consistent decrease in bulk density to a depth of 300 mm as a result of ridging. The lower bulk densities suggest reduced compaction due to loosening up of the soil when the ridges were constructed. Better drainage from the ridges was apparent from soil moisture measurements made during the rains at Mtunzini and La Mercy. Results showed that the ridged plots were up to 35% drier than the unridged controls at time of sampling.

Crop water use

Figure 3 shows the effect of ridging compared with no ridging on crop moisture use by variety NCo376 to a depth of 750 mm at Mtunzini. Each curve represents the mean of six gypsum block readings. Drying out of the soil profile to depth was greater and occurred more rapidly under the ridged treatment than under the unridged control. The moisture use patterns were consistent with the root distribution of NCo376 as determined by root washing (see Figure 2).

Ridge height

At each trial site ridges were inspected and assessed for such attributes as ridge height, shape and stability. Ridging proved to be most successful at Mtunzini. Ridge heights for the seventh and eighth ratoon crops varied between 200 and 300 mm and re-ridging was necessary only every alternate year. The largest individual plot responses to ridging were generally associated with the best-shaped and highest ridges. The rate of ridge subsidence was calculated for two periods: 22/10/87 to 19/10/89 and 23/01/90 to 25/09/90. For the first period the average rate of ridge subsidence was one millimetre every 9,3 days and for the second period it was one millimetre every 15,2 days. These rates correlated well with the higher average rainfall of 3,7 mm/day during the first period than the 2,7 mm/day during the second period.

Discussion

Improved surface drainage, better root distribution and greater effective rooting depth are the main reasons for the superior performance of cane growing on ridges. Evidence from root washing showed that ridges increased soil depth and gave roots more room to grow. This is particularly important where a water table or a root restrictive layer is within 500 mm below the soil surface. Because ridges increase depth above the limiting soil layer they will also increase the total available moisture, which reduces the risk of moisture stress during dry conditions. Gypsum block measurements have proved useful in demonstrating the increased use of soil moisture to depth under a ridge system.

Table 5

Average bulk densities (BD, kg/m³) at the various trial sites (0–300 mm)

Site	1. La Mercy (8 plots)		2. Nkwaleni (2 plots)	3. Mtunzini (14 plots)	4. La Mercy Winter plant (12 plots)		5. La Mercy Summer plant (12 plots)		
Treatment	17.07.86	01.09.87	14.11.86	20.04.89	14.09.89	12.06.90	14.02.89	07.06.90	28.11.90
T1 Control	1 761	1 853	1 403	1 807 *(10,6%)	1 585 *(13,2%)	1 637	1 755 *(20,4%)	1 657	1 692 *(12,9%)
T2 Ridged	1 729	1 795	1 537	1 754 *(8,4%)	—	—	—	—	—
T3 Ridge planting	1 769	1 777	1 369	—	*1 469 *(8,5%)	1 575	1 610 *(17,2%)	1 570	1 649 *(10,7%)

* Mean soil moisture percentage

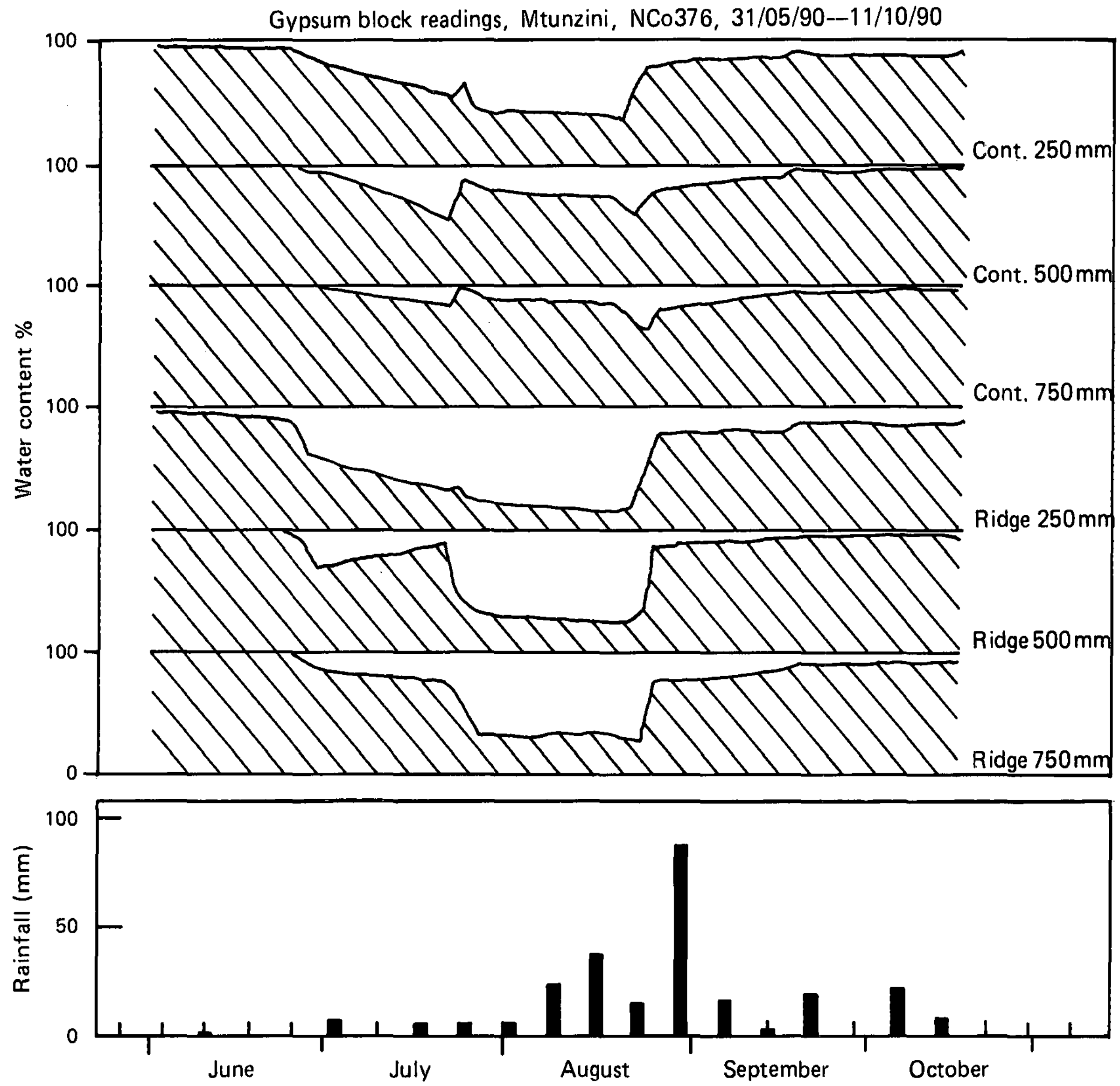

FIGURE 3 The effect of ridging compared with conventional tillage on water use of cane (variety NCo376) to a depth of 750 mm (shaded areas indicate crop available moisture).

Table 6

Interim suitability guide for ridge tillage in sugarcane

Criteria	Response to ridging	
	Most likely	Unlikely
Rainfall	Above long term mean	Below long term mean
Toposequence	Lower footslope and bottomland	Upland
Slope	Less than 5%	More than 5%
Soil form	Longlands, Westleigh, Estcourt, Kroonstad, Katspruit, Valsrivier, Sterkspruit Possible: Willowbrook, Bonheim, Tambankulu, Rensburg	
Crop	Ratoon	Plant
Variety	NCo376, N7, N8, N12, N13, N14	Unknown for other varieties except for N11 (no response)
Topsoil: Texture	20 to 35% clay	Unknown
Sodium adsorption ratio (SAR)	Less than 6	More than 6
Depth of A horizon to underlying impervious horizon	Less than 700 mm	More than 700 mm

Medium to fine textured grey hydromorphic soils in flat or low-lying areas appear to be best suited to ridge tillage. Slopes in excess of five percent should be avoided because of the potential erosion hazard and frequent need for ridge maintenance. However, where ridging is practised the cane rows must be on an adequate gradient to allow drainage of surplus surface water from the fields to avoid ponding. Ideally, at planting, ridges should be drawn to a height of at least 200 mm between the planting furrow on the ridge and the bottom of the furrow in the interrow. Depth of planting rows on the ridge can be varied in relation to the depth of the interrow depending on the necessity for good drainage (Edwards, 1973). However, ridge height should not exceed 300 mm as this will restrict mechanical operations in the field.

Some of the factors that will determine the success of ridge tillage are soil form, rainfall, cane variety, topsoil texture, depth of topsoil to the underlying impervious horizon, bulk density, and air-filled porosity. Interim guidelines for ridge tillage based on these criteria are given in Table 6. Other factors requiring consideration are the systems of planting, harvesting, loading and cane haulage used, as ridges may create practical difficulties in the field.

Conclusions

Ridge tillage is an inexpensive technique which can be used to increase the productivity of sugarcane growing on grey hydromorphic soils. The economics of ridging in ratoon cane is most attractive because improved yields can be expected, and so can an increase in the number of ratoon crops before re-establishment. In the trial at Mtunzini the ninth ratoon crop is growing on a site that was previously abandoned because of poor cane growth. The cumulative response to ridging over three crops was about six tons sucrose per hectare for an input cost equivalent to about half a ton of sucrose. As grey hydromorphic soils comprise about 20% of the sugar industry there is considerable scope for increasing cane yields on these soils.

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