A breeder's perspective on the tiller dynamics in sugarcane

Raman Kapur, S. K. Duttamajumder and K. Krishna Rao*

Sugarcane is a vegetatively propagated crop grown for sugar. A sugarcane 'clump' comprises of several cane stalks arising from subsurface sprouting of the underground buds in the form of tillers which develop into millable canes, providing the sink for sucrose accumulation. Thus, the number of millable stalks and the individual stalk weight constitute the yield in sugarcane. The conventional sugarcane agriculture, wherein two or three-budded stalk pieces called 'setts' are used for planting, does not exercise strict control on the intra-row spacing and this often leads to sub- or supra-optimal tiller population. If it is suboptimal, it leads to poor yield. When in excess, it leads to competition and results in poor tiller survival. Although tillering ability is a genetically governed trait, a breeder tends to select the types which produce a near-optimal number of millable canes. What is overlooked in the process is the substantial tiller mortality. In our opinion, both these practices (breeding and agronomy) do not do justice to the very nature of the sugarcane plant and are rather wasteful. With this perspective, sugarcane planting and breeding are revisited to drive home the point that better selection of sugarcane variability and efficient planting system be adopted for reducing the cost of seed and increasing the profitability. Fortunately, it is being demonstrated at a few places in the country that better sugarcane agronomy is the route to enhanced productivity and juice quality. Further, the gains extend to ratoon crops as well, resulting in an overall win-win situation for the farmer and the factory.

Keywords: Intra-row competition, precision farming, sugarcane, tiller dynamics and mortality.

The problem

THE present-day cultivars of sugarcane are derivatives of inter-specific hybridization between mainly *Saccharum officinarum* and *Saccharum spontaneum*. The former is a cultivated species requiring careful nurture and is characterized by thick, juicy, colourful canes with good sugar content and moderate tillering. On the other hand, the latter is a wild species, very hardy and tolerant to biotic and abiotic stresses with profuse tillering[1]. The resulting thin, fibrous canes contain little extractable juice of low sugar content. Sugarcane varieties in vogue are an intermediate between the two, but the chromosomes of the two parental species are unequally represented in the hybrid, in favour of the cultivated species. *S. spontaneum* chromosomes comprise only about 10–15% in the 120–130 (2*n*) chromosomes of the commercial varieties. In the *Saccharum* species germplasm collection, the range of number of stalks per clump in *S. spontaneum* was 19–274, and the corresponding values for *S. officinarum* were 4–37 (ref. 2). Understandably, the typical segregating breeding populations show considerable variability for tillering ability, depending on the proportion of the chromosomes of the wild species, *S. spontaneum*. On account of the naturally stressful growing conditions, subtropical cane varieties have more of the *spontaneum* complement compared with that in the tropical varieties which are closer to *S. officinarum*[3]. For this reason, it would appear that tropical varieties would tiller less and retain most of the tillers to form millable canes. Breeders tend to select genotypes which produce acceptable number of millable canes, without much focus on the route (wasteful or spend-thrift) taken by a genotype to reach that number. A tiller mortality of 50–60% in sugarcane is considered acceptable. For this purpose, data of the All-India Coordinated Research Project (AICRP) on sugarcane for different agro-climatic zones were examined to see whether there are any regional differences in the kind of variability that gets selected with respect to tillering and their subsequent conversion to millable canes. Then the effect of intra-row competition in the conventional planting technique on tiller mortality was looked at for any opportunity for redressal. Fortunately, the solution is in sight and is being convincingly demonstrated at a few places in the country.

Raman Kapur and S. K. Duttamajumder are in the Indian Institute of Sugarcane Research (ICAR), Lucknow 226 002, India and K. Krishna Rao is in the KBD Sugars and Distilleries Ltd, Punganur 517 247, India.
*For correspondence. (e-mail: kapurraman2@gmail.com)

Methodology

The AICRP on sugarcane conducts multi-location varietal trials in five different sugarcane agro-climatic zones. The reports of the Principal Investigator (Plant Breeding) for recent years were used for working out the extent of shoot/tiller mortality[4–7]. The values for maximum shoot/tiller count and the millable canes towards maturity were used to compute percentage tiller survival. In addition, efforts of individual groups were sourced for information on the various possibilities and how the scenario can be turned to advantage. The two sites used for this purpose are Vapi in Gujarat and KBD Sugars, Andhra Pradesh. Apart from this, the experiments conducted at the Indian Institute of Sugarcane Research, Lucknow, on tiller dynamics and at the Sugarcane Breeding Institute, Coimbatore, on wide-row spacing have been taken into consideration to suggest possible solutions to this problem.

Analysis

Shoot count at 120 days after planting, tiller count at 180 days and number of millable canes at 240 or 300 days for standard varieties, test varieties, early maturity group, mid-maturity group, plant crop and the ratoon crop data for different agro-climatic zones are presented in Tables 1 and 2. The values are given in terms of percentage survival and are an indication of the conversion efficiency of a genotype of turning tillers into millable canes or 'effective tillers'. Table 1 shows that the zones do not drastically differ in tiller mortality, except that in the East Coast Zone and North Central and Eastern zones, there is a higher tiller survival which could be on account of greater moisture availability. Secondly, early maturing and mid–late maturing varieties do not show much difference in tiller mortality.

An analysis of individual test varieties and standards in the NW Zone and the Peninsular Zone in two plant crops and one ratoon crop (Table 2) showed that varieties are not consistent in their tiller survival, suggesting a strong influence of the growing and cultural conditions. Mid–late varieties, in general, have a higher tiller survival, whereas ratoons due to higher tillering have higher tiller mortality. Further, ranks change from location to location (data not shown) and vary from crop to crop, which means tiller survival is highly influenced by the environment. Occasionally, in the test varieties, we encounter extreme types, i.e. shy tillering or high tillering genotypes. Yet, the fact remains that despite the innate capacity of a genotype, tillering is highly manipulatable culturally. Hoeing, intentional or accidental breaking of apical dominance and earthing-up are operations to encourage or discourage tillering. This can be further seen from the fact that apparently low tillering genotypes can be made to tiller profusely if their main shoot is smothered, injured or damaged by borers, etc. so much so that planking of young plants was a practice in some parts of western Uttar Pradesh/Haryana to enhance tiller production.

Experiments to study the role of time of planting on tiller production indicated that greater the maximum number of tillers in a particular treatment, greater is the mortality (Table 3)[8]. The earlier the planting time, higher is the tiller maxima and so is the tiller mortality, with ratoon showing the highest loss of tillers (72%). In another experiment with varieties differing in tillering

Table 1. Percentage survival of tillers in the standard varieties in different agro-climatic zones of sugarcane

Sugarcane zone	Early maturing variety	Tiller survival (%) Mean	Tiller survival (%) Range	Mid–late maturing variety	Tiller survival (%) Mean	Tiller survival (%) Range
Peninsular Zone	Co 85004	61.3	56.8–65.8	Co 7219	62.2	60.0–64.3
	CoC 671	63.5	58.2–68.7	Co 86032	62.7	58.6–66.7
	Mean	62.4		Mean	62.5	
East Coast Zone	Co 6907	70.2	64.4–76.0	Co 6304	80.7	78.4–83.0
	Co 7508	75.3	67.4–83.1	Co 7219	69.2	64.4–74.0
				Co 86249	75.2	65.3–91.3
	Mean	72.7		Mean	72.2	
North West Zone	CoJ 64	66.0	65.2–66.7	Co 1148	64.7	51.9–74.8
	CoPant 84211	61.8	60.2–63.5	CoS 767	63.9	50.4–76.7
				CoS 8436	63.7	50.4–76.5
	Mean	63.9		Mean	64.1	
North Central and North Eastern Zone	BO 120	75.7	74.8–76.6	BO 91	72.5	58.0–80.9
	CoS 687	77.5	76.4–78.7	BO 128	67.7	57.3–76.6
	CoSe 95422	71.9	66.9–77.0	CoSe 92423	77.3	66.4–83.0
	Mean	75.1		Mean	72.5	

Adapted from ref. 4.

Table 2. Mean values for number of tillers and millable canes and percentage of tiller survival in sugarcane varietal trials

a. North Western Zone (2007–2008 and 2008–2009) – Early

	AVT* I plant				AVT II plant				Ratoon (five locations)			
Variety	NMC[†] ‘000/ha	Tillers ‘000/ha	Survival (%)	Rank	NMC ‘000/ha	Tillers 180 d	Survival (%)	Rank	NMC ‘000/ha	Tillers 180 d	Survival (%)	Rank
Test variety												
CoH 127	101.2	150.1	**67.4**	1	100.3	142.5	**70.4**	1	108.2	191.5	56.5	3
CoJ 03191	**91.3**	143.1	63.8	4	**91.0**	136.6	66.6	4	**75.4**	**130.0**	58.0	2
CoJ 03192	**91.3**	**142.4**	64.1	3	93.9	**136.2**	68.9	2	75.8	136.1	55.7	4
CoLk 9902	**122.7**	**184.1**	66.6	2	**141.6**	**211.0**	67.1	3	**164.3**	**270.9**	**60.6**	1
CoPant 03219	110.6	179.8	61.5	5	112.3	173.8	64.6	5	105.3	204.2	**51.5**	6
CoS 03279	102.8	172.5	**59.6**	6	102.2	166.7	**61.3**	6	106.5	203.1	52.5	5
Standard												
CoJ 64	103.5	161.1	64.2	2	101.1	154.4	65.5	1	110.6	194.6	56.8	1
CoPant 84211	103.7	160.1	64.8	1	95.1	146.3	65.0	2	79.6	155.5	**51.2**	2

b. North Western Zone (2006–2007 and 2007–2008) – Mid-late

	AVT I plant				AVT II plant				Ratoon			
Variety	NMC ‘000/ha	Tillers 120 d	Survival (%)	Rank	NMC ‘000/ha	Tillers 120 d	Survival (%)	Rank	NMC ‘000/ha	Tillers 120 d	Survival (%)	Rank
Test variety												
Co 0121	94.0	141.0	66.7	6	82.3	128.4	**64.1**	7	79.8	126.7	63.0	3
Co 0240	90.0	**113.0**	**79.6**	1	**73.8**	**105.5**	69.9	2	79.4	**109.0**	**72.8**	1
CoLk 9710	**121.1**	**188.0**	**64.4**	7	**103.4**	**150.5**	68.7	3	**115.6**	**177.1**	65.3	2
CoPk 59	94.2	137.0	68.8	3	77.7	120.8	64.3	6	77.7	138.4	**56.1**	7
CoPk 112	106.2	155.0	68.5	4	**73.8**	113.9	64.8	5	**72.1**	115.4	62.5	4
CoS 98259	95.3	138.0	69.1	2	91.9	127.8	**71.9**	1	101.2	163.0	62.1	5
CoS 01268	**84.1**	125.0	67.3	5	81.6	124.8	65.3	4	98.1	158.1	62.0	6
Standard												
Co 1148	114.4	171.0	66.9	1	100.5	**154.8**	64.9	2	98.9	168.2	58.8	2
CoS 767	103.7	164.0	**63.2**	3	87.4	141.3	**61.9**	3	94.9	161.9	58.6	3
CoS 8436	97.6	149.0	65.5	2	85.9	122.3	70.3	1	84.6	122.7	68.9	1

c. Peninsular zone (2007–2008 and 2008–2009) – Early

	AVT I plant				AVT II plant				Ratoon			
Variety	NMC ‘000/ha	Tillers 120 d	Survival (%)	Rank	NMC ‘000/ha	Tillers 180 d	Survival (%)	Rank	NMC ‘000/ha	Tillers 90 d	Survival (%)	Rank
Test variety												
Co 0205	93.1	151.6	**61.4**	9	92.6	167.8	55.2	4	80.5	141.3	57.0	4
Co 0209	90.4	136.6	66.2	4	93.5	**135.6**	**69.0**	1	84.6	136.7	61.9	2
Co 0310	88.6	128.8	68.8	3	83.7	180.7	46.3	8	76.2	167.2	**45.6**	9
Co 0312	**109.8**	**171.5**	64.0	6	**102.2**	**219.0**	46.7	7	**98.4**	**200.5**	49.1	7
Co 0315	89.8	**113.2**	**79.3**	1	84.5	145.4	58.1	3	78.1	133.4	58.5	3
CoM 0254	95.8	150.3	63.7	7	93.2	198.3	47.0	6	86.8	183.1	47.4	8
CoM 9902	99.6	141.8	70.2	2	88.4	164.4	53.8	5	80.4	**123.6**	**65.0**	1
CoM 9903	88.6	134.1	66.1	5	**80.4**	175.3	**45.9**	9	**72.4**	140.4	51.6	6
CoVC 9982	**82.4**	131.5	62.7	8	91.0	152.9	59.5	2	76.9	142.7	53.9	5
Standard												
Co 85004	101.1	157.8	64.1	3	99.0	174.7	56.7	2	94.5	164.7	57.4	2
Co 94008	88.2	119.7	73.7	1	89.4	105.5	**84.7**	1	82.3	137.1	60.0	1
CoC 671	84.5	130.0	65.0	2	82.3	154.8	53.2	3	76.1	134.1	56.7	3

(*Contd.*)

Table 2. (*Contd.*)

d. Peninsular Zone (2007–08 and 2008–2009) – Mid-late

	AVT I plant				AVT II plant				Ratoon			
Variety	NMC '000/ha	Tillers 120 d	Survival (%)	Rank	NMC '000/ha	Tillers 120 d	Survival (%)	Rank	NMC '000/ha	Tillers 90 d	Survival (%)	Rank
Test variety												
Co 0218	85.4	145.8	58.6	6	83.9	158.8	52.8	7	73.3	**156.4**	**46.9**	8
Co 0211	**97.3**	**158.4**	61.4	4	**112.4**	**176.1**	63.8	2,3	**90.6**	136.6	66.3	2
Co 0317	83.2	123.5	67.4	2	80.4	125.4	**64.1**	1	73.4	112.3	65.4	3
Co 0325	**70.8**	**108.2**	65.4	3	**69.4**	**110.9**	62.6	4	64.4	**99.2**	64.9	4
Co 0328	86.2	118.8	**72.6**	1	77.9	122.1	63.8	2,3	72.2	105.9	**68.2**	1
CoM 0265	83.2	150.6	**55.2**	8	70.6	119.4	59.1	5	72.0	126.0	57.1	6
MS 0217	74.0	122.2	60.6	5	83.7	164.0	**51.0**	8	68.0	133.8	50.8	7
CoVC 03301	75.5	134.3	56.2	7	82.6	151.1	54.7	6	**63.7**	106.4	59.9	5
Standard												
Co 7219	91.4	124.2	**73.6**	1	89.9	132.8	**67.7**	1	82.0	140.0	58.6	2
Co 86032	93.5	139.9	66.8	2	90.4	151.5	59.7	2	82.7	133.3	62.0	1

*AVT, Advance Varietal Trial, †NMC, Number of millable canes. In Table 2 *a*, values for NMC and tillers are mean of 8 locations, adapted from refs 5 and 6. In Table 2 *b*, *c*, *d*, values for NMC and tillers are mean of 10 locations, adapted from refs 6 and 7. Extreme values are given in bold.

Table 3. Pattern of tiller (× 1000/ha) production in sugarcane crop (cv. Co 1148)

Month	Autumn planting	Spring planting	Late (April) planting	First year ratoon
March	160	50	–	160
April	**400**	120	200	380
May	380	**320**	200	**500**
June	280	310	**260**	350
July	140	180	240	220
August	140	170	180	140
September	130	140	150	140
October (millable cane)	120	100	95	140
Percentage of survival*	30.0	31.3	36.5	28.0

*No. of millable canes in October/maximum no. of tillers (in bold) × 100.
Adapted from Dwivedi and Srivastava[8].

ability (CoLk 8102 and CoJ 64), again the one with lower tiller number (CoJ 64) had higher tiller survival, irrespective of the planting time (Table 4)[9]. This may have resulted from the competition for nutrition, moisture and space.

The effect of planting methods on growth and yield attributes[10] is presented in Table 5. Least tiller survival (62%) was observed at 60 cm row spacing compared with 90 cm row spacing (68%) and trench planting (66%). The highest tiller survival was obtained with pit planting (73%), which got translated into higher cane yield. Maximum sun during the crop maturity phase is more conducive to maturity of sugarcane. Space planting allows an individual clump to trap more light with minimal shading. Therefore, in the pit method of planting, the sucrose content is significantly higher than that in the other treatments where planting is continuous within a row. Further, tiller mortality is the lowest in the pit method.

Results of wide row spacing with respect to cane productivity and other yield contributing traits are summarized in Table 6 (ref. 11). It is obvious that tiller survival (39% as opposed to 29%), cane weight and cane yield are higher in wide row spacing in var. Co 86032. Less number of initial tillers and higher conversion of tillers into millable canes in wide row planting led to greater weight of individual canes. The discrepancy in the percentage tiller survival in the data presented, particularly in the AICRP varietal trials, is possibly because the tiller maxima were not taken into account. Significant differences in varietal response to wide row spacing (150 cm) were observed with high tillering varieties (Co 6304, Co 8021, Co 86032, Co 62175 and Co 8506) giving higher yields than the low tillering varieties (Co 87025, CoC 671 and Co 8014). Some of the varietal characters suiting wide row spacing are high tillering, fan-shaped growth habit, longer duration, high-yielding nature and non-lodging[12].

Table 4. Mean number of tillers/row in relation to time of planting

Variety	Autumn planting	Spring planting	Late (summer) planting
CoJ 64	87.2	49.8	60.1
Survival %	**38.3**	**48.9**	**45.0**
CoLk 8102	123.9	76.6	85.5
Survival %	**29.8**	**38.2**	**35.6**

Adapted from Shrivastava and Misra[9].

Table 5. Effect of planting methods on growth and yield attributes of sugarcane

Planting method	Germination (%)		No. of tillers ('000 ha^{-1})			No. of millable canes ('000 ha^{-1})	Tiller survival (%)	Cane length (cm)	Cane girth (cm)	Weight per cane (kg)	Brix (%)	Pol % juice	CCS %	Cane yield (t ha^{-1})	CCS (t ha^{-1})
	30 DAP	45 DAP	June	August	October										
60 cm row spacing	29.9	42.5	190	210	162	130.1	61.9	221	2.30	0.79	18.2	15.03	10.1	70.1	7.07
90 cm row spacing	31.2	41.9	167	166	125	112.7	67.5	231	2.36	0.90	18.3	15.20	10.2	63.9	6.57
Trench planting	38.7	48.5	176	183	151	121.9	66.5	236	2.38	1.09	18.2	15.21	10.2	75.6	7.74
Pit planting	42.5	49.5	169.0	148	144	122.7	72.6	252	2.61	1.30	18.7	15.54	10.4	86.3	9.02
CD (P = 0.05)	2.26	3.2	8.3	11.7	9.7	12.3	–	12.2	0.35	0.44	0.21	0.2	0.19	4.86	1.10

DAP, Days after planting; Adapted from ref. 10.

Table 6. Quantitative parameters of cane under wide row spacing in var. Co 86032

Quantitative character	Wide rows (1.5 m)	Conventional spacing (0.75 m)
Seed rate (no. of two-budded setts/ha)	50,000	100,000
No. of tillers/ha at 90 days	270,000	414,000
No. of millable canes at harvest/ha	105,000	120,000
Tiller survival (%)	38.9	29.0
Cane height (cm)	430	322
Cane diameter (cm)	2.64	2.35
No. of internodes per cane	31	29
Single cane weight (kg)	1.98	1.52
Cane yield (t/ha)	208	182

Adapted from Nagendran[11].

It may be argued that the above experiments may not apply to the stressful growing conditions existing in the subtropical region. In fact, similar advantage is derived in the spaced transplanting (STP) technique[13] developed at the Indian Institute of Sugarcane Research (IISR), Lucknow with respect to cane yield and maturity. Herein, single bud nursery was raised and settlings transplanted in the field at a distance of 75–90 cm between the rows and 45–60 cm within the row, depending on the tillering ability of the variety in question. The STP technique was developed as a result of the special attention paid to tillering that lays the foundation of the dominant yield-determining attribute, i.e. stalk population. Through this technique the researchers achieved the long-awaited corrections in spacing and geometry for a fuller utilization of incoming radiation[14]. The added advantages are that the seed rate is one-third of the conventional and seed selection is of the highest order, which results in nearly 90% germination from the single bud setts.

The exposition

The above facts point to two things. One is regarding the breeding of sugarcane. Seedlings do get enough space and time to have most of the tillers turning into millable canes. But the actual growing environment in subsequent clonal generations is akin to the conventional method with no control over intra-row spacing. This is where the genetic variation in tillering ability and the effective tillers (those resulting into millable canes) are selected in favour of only high tillering genotypes. It can be said that the otherwise good genotypes with a 'shy' tillering habit do not go very far. Such clones score low on cane productivity. No special effort is made by agronomists to come out with a package of cultural practices to capitalize on the potential of such genotypes and thus these are beaten by higher tillering and better-yielding clones. Nevertheless, it is possible for a breeder to score his elite selections for lower tiller mortality and promotion of the efficient ones. It is hoped that this exposition shall help breeders look at their selections from a new perspective. Indirectly, such genotypes would not have their tillering phase spread out too much temporally, and shall lead to more synchronous tillers, the benefit of which will be reflected in uniform ripening and better cane quality.

The second aspect is more manageable and feasible, but calls for a drastic change in the way we cultivate sugarcane. Rather than being dubbed as a hardy crop which can take a lot of abuse and neglect, we have to turn cane agriculture into a modern precise farming system. This is another stunning fact of conventional cane agriculture in subtropical India, that 30–40% germination is the norm. Nearly two-thirds of the viable buds are supposed to provide a buffer, just as the excess tillering is considered an insurance against crop failure. To begin with, the very preparation of seed cane, preparation of seed bed, ensuring a good tilth and high germination of single bud setts (either in nursery or directly in the field) and subsequently nurturing the young crop (direct planting or transplanted settlings) for a high survival call for a change in our approach. It is not that options have not been provided, but these have lacked a strong conviction and adequate efforts to convince the scientific community and the research administrators. The technologies in question are sett transplanting (STP) or modifications thereof, such as polybag method, single pre-sprouted bud planting, bud-chip method, etc. The benefits of these have been demonstrated, but the required follow-up by extension workers to popularize these has not been done sufficiently.

There have been many studies which have focused on sugarcane tillering and support the concept of intra-row spacing. As early as in 1956, it was reported that as the canes per clump increased, the stalk length, cane weight and percentage in juice declined[15]. A study carried out with the cultivar Co 453 at Shahjahanpur showed that with increase of seed rate in the autumn and the spring-planted crops, tillers per plant decreased, millable canes per hectare increased, tiller mortality and yield increased, but the average cane weight decreased[16]. Similarly, experiments conducted in Punjab showed that with increase in inter-row spacing, there was a significant reduction in tiller mortality, which was 57.0, 37.5, 34.1, 26.1 and 18.9% at spacings of 60, 90, 120, 150 and 180 cm respectively[17].

Experiments carried out in Australia on row configurations and cane productivity showed that high density planting (81,000 setts/ha in 0.5 m rows) did not produce more cane or sugar yield at harvest than low-density planting (27,000 setts/ha in 1.5 m rows) regardless of location, crop duration, water supply or soil health[18]. Results also showed that sugarcane possesses the capacity to compensate for different row configurations and planting densities through variation in stalk number and individual stalk weight[19,20]. Further, there was evidence of different growth patterns between cultivars in response to different row spacings. It was argued that there is a need to evaluate potential cultivars under a wider range of row distances[21].

Closer home, the results of several experiments at the Sugarcane Breeding Institute and elsewhere with wide row spacing were reviewed[22]. Stressful conditions, more prevalent in subtropical India, warrant narrower row spacing as an insurance against poor individual cane weight, wherein greater tillering provides the buffer. Nevertheless, several studies have proved 90 cm row spacing as the optimum. However, changing varietal spectrum, labour shortages forcing mechanization of cane agriculture, especially of the planting and the harvesting operations, require that crop geometry be revisited[22].

The solution

Interestingly, sporadic but dedicated efforts are nevertheless, being made to grow sugarcane differently. The better known example is the Vapi experiment at Vikram Farm, Gujarat by Channaraj[23]. The system primarily uses single bud setts planted in rows 120 cm apart and bud-to-bud distance of 30 cm. The seed is drawn from a 7-month-old crop. Organic and inorganic nutrition is spread out and split in monthly dozes up to 120 days. Irrigation is provided through a sub-surface porous pipe, which saves a lot of water. The aim is to obtain 25,000 plants per hectare, each with 10 tillers which become individual millable canes of 1 kg each. The ratoon crop is equally well-managed and productive. The Madhi Sugar Factory area where the technology is being adopted is reporting enhanced cane yields (nearly 50%) and better sugar recovery (0.5% points). A visit to the place rather than looking for published results would be more rewarding.

Another example of a successful application of this concept is from Andhra Pradesh. At Sree Vaani Sugars, Chittoor District, a system of renewed intensification (SRI) of sugarcane cultivation, called Krishna’s sugarcane SRI cultivation, has been developed[24]. Herein, single bud nursery is raised in plastic trays (each with a capacity to hold 50 buds). The sprouting and healthy growth of settlings is ensured in a net-house for 4–5 weeks. The transplanting in the field is done at the rate of 12,500–13,750 settlings per hectare. The row-to-row and plant-to-plant distance is 120 and 60 cm respectively. This spacing is designed to allow growing of an intercrop like tomato to augment return to the farmer and reduce his waiting period from a long-duration crop like sugarcane. The germination is more than 85% and establishment more than 90%, with appropriate care. Nine tillers per clump are attained by 120 days of transplanting. This tiller count of 100,000–125,000/ha does not reduce, as hardly any tiller mortality is observed. Individual canes acquire a weight of up to 1.5 kg. This results in a cane yield of 150–180 t/ha, which is a huge gain. The quality also is in no way less than the conventional method. In fact, it is better on account of uniform maturity. The system not only ensures more return to the farmer from sugarcane, but adds to his profit through an intercrop. It also means substantial water-saving due to wide row spacing. Again, such innovations have to be seen *in situ* to generate the confidence for repeating them at other places.

Thus, by judicious modification of the method of planting which takes care of the intra-row spacing, the tillering attribute of sugarcane is allowed to have its full expression. Also, the cultural practices ensure that the tillers produced are nurtured to develop into millable canes and harvested to bumper yields. This methodology not only ensures that all the energy of the plant is utilized in producing harvestable biomass, but that canes get full term to acquire impressive girth and weight. The advantage spills over to the ratoon because ratoons suffer much more due to excessive tillering, tiller mortality and the resultant gaps. Better management of ratoon in the spaced-out sugarcane crop either in wide row planting or controlled intra-row spacing, ensures higher ratoon productivity and uniform maturity. When tillers are not allowed to form after a particular stage (implying that secondary and tertiary tillers contribute minimally to the total count), all the millable canes are physiologically closer in maturity leading to better cane quality. This leads to more profits for the grower and miller alike. The underlying synchronous tillering, for which adequate variability does exist in segregating populations, could be a selectable trait. As a matter of fact, all the successful examples addressing the problem of tiller mortality can be conceptually traced back to the STP technique of IISR.

Therefore, suggestion is made to all those involved with sugarcane development to help rewrite sugarcane agronomy in the long-term interest of sugarcane farmers, industry and the nation. Not only the required technology is in place, but it has been practically demonstrated and found feasible and profitable. It is no more a matter of choice, but imperative that if we want to meet the future targets for sugarcane and sugar, precision farming is the answer. This shall prolong the commercial life of sugarcane varieties and better realize their genetic potential with a mere reorientation of the same resources. The greatest spin-off will be a better control on the quantity and quality of sugarcane seed with a significant reduction in the quantity of seed required. The attention of breeders is also sought to be drawn on the possibility of breeding more efficient genotypes with a higher tiller to millable cane conversion ratio.

1. Barber, C. A., Studies on Indian sugarcane. No. 4. Tillering or underground branching. *Mem. Dep. Agric. India Bot. Ser.*, 1918, **10**(2), 39–153.
2. Sreenivasan, T. V., Sugarcane genetic resources activities in India and *in vitro* germplasm conservation. In *Sugarcane Varietal Improvement* (eds Naidu, K. M., Sreenivasan, T. V. and Premchandran, M. N.), Sugarcane Breeding Institute, Coimbatore, 1989, pp. 177–194.
3. Selvi, A. *et al.*, Genomic constitution and genetic relationship among the tropical and sub tropical Indian sugarcane cultivars revealed by AFLP. *Crop Sci.*, 2005, **45**, 1750–1757.
4. Anon., All India Coordinated Research Project on Sugarcane, Principal Investigator's Report for Varietal Improvement Programme 2005–2006, Sugarcane Breeding Institute, Coimbatore, 2006.
5. Anon., All India Coordinated Research Project on Sugarcane, Principal Investigator's Report for Varietal Improvement Programme 2006–2007, Sugarcane Breeding Institute, Coimbatore, 2007.
6. Anon., All India Coordinated Research Project on Sugarcane, Principal Investigator's Report for Varietal Improvement Programme 2007–2008, Sugarcane Breeding Institute, Coimbatore, 2008.
7. Anon., All India Coordinated Research Project on Sugarcane, Principal Investigator's Report for Varietal Improvement Programme 2008–2009, Sugarcane Breeding Institute, Coimbatore, 2009.
8. Dwivedi, R. S. and Srivastava, K. K., A scenario of research on physiology and biochemistry of sugarcane. In *Sugarcane Research and Development in Subtropical India* (eds Singh, G. B. and Sinha, O. K.), IISR, Lucknow, 1993, pp. 143–190.
9. Shrivastava, A. K. and Misra, S. R., Tillering in sugarcane. Technical Bulletin No 35, Indian Institute of Sugarcane Research, Lucknow, Appendix (Tables), 1996, p. 10.
10. Anon., Annual Report 2007–2008, Indian Institute of Sugarcane Research, Lucknow, 2008, pp. 13–14.
11. Nagendran, K., Mechanization programme in Sakthi Sugars. In National Workshop on Mechanization of Sugarcane Cultivation. Sakthi Nagar, Erode, 1999, pp. 45–51.
12. Sundra, B., Influence of varieties, seed and fertilizer rates and planting pattern on sugarcane (*Saccharum officinarum*) grown under wide row spacing. *Indian Sugar*, 2002, **LII**(5), 341–347.
13. Srivastava, K. K., Narasimhan, R. and Shukla, R. K., A new technique for sugarcane planting. *Indian Farming*, 1981, **31**, 15–17.
14. Anon., Physiology of tillering, In: Twenty-five Years' Research Results, IISR Silver Jubilee 1977, IISR, Lucknow, 1977, p. 17.
15. Raheja, P. C., Physiological researches in relation to agronomy in India. *Proc. ISSCT*, 1956, **9**(1), 400–418.
16. Singh, U. S. and Singh, Lallan, Optimum requirement of three-budded setts under normal spacing of cane planting during autumn and spring seasons. *Indian Sugar*, 1967, **27**(3), 275–281.
17. Kanwar, R. S. and Sharma, K. K., Effect of interrow spacing on tiller mortality, stalk population and yield of sugarcane. *Proc. ISSCT*, 1974, **15**(2), 751–755.
18. Garside, A. L. and Bell, M. J., Row spacing and planting density effects on the growth and yield of sugarcane. 1. Responses in fumigated and non-fumigated soil. *Crop Pasture Sci.*, 2009, **60**(6), 532–543.
19. Bell, M. J. and Garside, A. L., Shoot and stalk dynamics and the yield of sugarcane crops in tropical and subtropical Queensland, Australia. *Field Crops Res.*, 2005, **92**(2&3), 231–248.
20. Garside, A. L., Bell, M. J. and Robotham, B. G., Row spacing and planting density effects on the growth and yield of sugarcane. 2. Strategies for the adoption of controlled traffic. *Crop Pasture Sci.*, 2009, **60**(6), 544–554.
21. Garside, A. L. and Bell, M. J., Row spacing and planting density effects on the growth and yield of sugarcane. 3. Responses with different cultivars. *Crop Pasture Sci.*, 2009, **60**(6), 555–565.
22. Sundra, B., Wide row spacing planting in sugarcane. In *Sugarcane Planting Techniques and Crop Management* (eds Yadav, R. L. and Yadav, D. V.), Indian Institute of Sugarcane Research, Lucknow, 2007, pp. 29–36.
23. Channaraj Ars, M. C., Precision farming in Indian agriculture. In Paper presented at IISR in collaboration with United Phosphorous Ltd and Jay Research Foundation, 2008, pp. 1–14.
24. Rao Krishna, K., Krishna's sugarcane SRI (system of renewed intensification) cultivation. In Paper prepared for Gayatri Sugar Complex, Prabhagiripatnam, Andhra Pradesh, 2007, pp. 1–15.

ACKNOWLEDGEMENTS. We thank the Director, IISR, Lucknow; Project Coordinator, AICRP on Sugarcane; Principal Investigator (Plant Breeding) AICRP(S) and Sh. M. C. Channaraj Ars, Vapi, Gujarat.

Received 16 July 2010; accepted 15 October 2010