Optimum Inter-Settling Spacing and Potential of Using Cane Tops in Spaced Transplanting Technique of Sugarcane in Sri Lanka

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ABSTRACT

The optimum inter-settling spacing and the possibility of producing settlings from sugarcane tops were studied in two field experiments to evolve an efficient planting technique and produce alternative planting materials to overcome the limitation of high planting costs and seed cane availability. In the spacing experiment, the effects of 40, 60, 80 and 100 cm inter-settling spacing on sugarcane yield traits were examined and compared with the conventional sett planting method. Germination and seedling survival of the nurseries established with the single-budded setts obtained from cane tops and mature stalks were compared in the other experiment.

Due to the better performance of crop in the settlings-planted plots and other advantages, the spaced transplanting (STP) could be considered as an efficient and effective technique to establish a commercial sugarcane plantation. The tested inter-settling spacing did not have a significant effect on average yields both in plant crop and ratoons. However, based on ratoon yields, the optimum inter-settlings spacing was 60 cm at 1.37 m inter rows spacing. The settlings requirement of approximately 12167 to plant a hectare at this spacing could be met from 1118 kg of unprocessed seed cane. This saves 85% of seed materials which is otherwise used to plant sugarcane by conventional sett planting technique. An estimated amount of 282600 single-bud sets available from about 94200 cane tops from a hectare of harvested sugarcane land is sufficient to plant 16.5 ha. Thus, the standard seed cane requirement could be eliminated by using the STP technique with the settling produced from cane tops.

Keywords: *settlings, single-budded setts, spaced transplanting, sugarcane*

INTRODUCTION

In sugarcane cultivation, high initial costs of land preparation and seed cane substantially reduce net income generated from plant crop. The present cost of seed cane per hectare, including transport cost, comes to about Rs.30,000. This is about 14% of the total production cost of sugarcane (Kodithuwakku, 2010). Moreover, non-availability of adequate good-quality seed cane at appropriate times and also at a reasonable price has been a major constraint for sugarcane production in Sri Lanka. For example, as has been observed in the Sevanagala Sugarcane plantations, about 7000 tonnes of seed cane harvested from about 100 hectares of 7-8 months old commercial sugarcane plantations is used annually to plant about 850 hectares of land.

Also, the average seed rate used to plant is high and is about 8-10 t ha^{-1}. The value of this amount of seed cane is about 17.5 million rupees. In addition, a large extent of commercial sugarcane lands which otherwise could be used to produce canes for sugar production is harvested for seed.

The introduction of efficient and effective propagation techniques, which have the potential of supplying planting material in abundance and also at a lesser cost while minimising seed cane requirement to plant a unit area became vital to increase productivity and profitability of commercial sugarcane production in Sri Lanka. With this in view, and based on physiological understanding of buds sprouting, tillering and inter-plant competition of sugarcane, new techniques such as lateral shoots multiplication (LSM) (Wijesuriya *et al.*, 2001), spaced planting of seed setts (Wijesuriya *et al.*, 2010) and spaced transplanting (STP) of sugarcane (Verma, 2004, Witharama, 2009) were introduced. However, LSM was not popular among sugarcane growers as it requires many skilled steps to produce planting materials though it has many economic benefits (Wijesuriya *et al.*, 2001, Wijesuriya *et al.*, 2010, Keerthipala *et al.*, 2001). The technique of spaced planting of seed setts was successful if the soil is adequately moist at the time of planting. It, however, requires only about two tonnes of conventional seed cane to plant a hectare (Wijesuriya *et al.*, 2010). Similarly, seed cane requirement for STP technique to plant a hectare is also about two tonnes. Thus, both of these techniques save 70% of the seed cane requirement when compared to the conventional planting technique.

An additional advantage of STP technique compared with spaced planting technique is that cane tops left behind after harvesting mature cane fields could be used to obtain single-budded setts to plant nurseries. Moreover, a farmer could produce his own planting material by the STP technique in the field or home garden a month before the expected date of planting the commercial field. Unlike in conventional sugarcane nurseries, this technique does not require a large extent of land to establish nurseries and management of a crop in a large extent of land during 7-9 months until the crop is harvested for seed. This technique lowers the cost of seed cane handling and transport. It is a simple, easy and low-cost propagation technique. Moreover, this technique gives better field establishment, weed control (Ishimine *et al.*, 1994), uniform plant population and higher yields (Pawar *et al.*, 2005) compared to the conventional sett planting method. However, the optimum spacing requirement for field transplanted settlings has not been worked out under local conditions. Therefore, experiments were conducted to study the optimum inter-settling spacing to obtain maximum yield. Further, studies were also carried out to determine the potential of producing settlings for the STP technique from the nurseries established by using single-budded setts which were separated from the cane tops left behind after harvesting sugarcane to reduce seed cane requirement and planting cost.

MATERIALS AND METHODS

Two field experiments, one was to study optimum inter-settling spacing of the STP technique and the other to determine the potential of producing settlings for the STP technique by raising nurseries from single-budded setts separated from sugarcane tops left behind after harvesting, were carried out at the research farm of the Sugarcane

Research Institute (SRI), Uda Walawe, Sri Lanka (6°21'N latitude, 80°48'E longitude and 76 m altitude). The area receives a mean annual rainfall of 1450 mm with a distinct bimodal distribution (Panabokke, 1996). The average annual minimum and maximum temperatures are $22 \pm 1.4\ ^0$C and $33 \pm 1.6\ ^0$C, respectively. Evaporation from a free water surface is approximately 5 mm per day (Sanmuganathan, 1992). The soil is classified as a Ranna series of Reddish Brown Earths (RBE), great group of Rhodustalfs (order Alfisols, suborder Ustalfa) soils and has a sandy clay loam texture (De Alwis and Panabokke, 1972; Anon, 1975).

Studies on inter-settling spacing of STP

This experiment was initiated in December 2004 and growth was observed in plant crop (PC), 1st and 2nd ratoon crops until May in 2008. A nursery of an about 1 m^2 in extent was established from single-budded setts separated from 7 – 9 months old stalks of the variety SL 88 116 to obtain settlings for field planting. A uniform land selected for field planting settlings was prepared as per recommendations for commercial sugarcane cultivation (Anon, 1991). The field was laid out to make three blocks, each having five treatment plots. The plot size was 9 m x 8.22 m, each of which consisted of 6 furrows spaced at 1.37 m. The treatments of four different intra-row inter-settling spacing (40, 60, 80 and 100 cm) and conventional planting of 3-budded setts of the same seed cane in the field as a control were allocated randomly to each treatment plot within a RCBD statistical design with three replicates.

After a four weeks period, the settlings from the established nurseries were planted in the furrows of the respective treatment plots according to the allocated treatment procedure. In the control plots, the seed setts were planted in the furrows as recommended by the SRI (Anon, 1991). The crop was irrigated sparsely to avoid the effect of severe drought on crop growth, particularly during the dry months of February, July and August. Thus, each of plant crop and two ratoons were irrigated 3 or 4 times during its cropping cycle. All other management practices were adopted as recommended by the SRI (Anon, 1991). After maturity, which was assured by examining brix values of top and bottom portion of cane standing in the field, the plant crop was harvested in February 2006. After stubble shaving, the 1st ratoon crop was raised in March 2006. The 2nd ratoon crop was established in March 2007 after harvesting the ratoon I in February 2007. The 2nd ratoon crop was harvested in May 2008.

Cane yield, sugar yield and juice quality parameters, *i.e.* % brix, % pol., % purity, pure obtainable cane sugar (% POCS) and % fibre (Varma, 1988), and yield traits, *i.e.*, number of millable stalks ha^{-1}, height (m) and diameter (mm) of stalks and number of internodes per stalk and weight of a stalk (kg), number of leaves per stalk, leaf length and width were recorded at harvesting plant crop and both ratoons. Leaf area calculated by length and width method based on a pre-calculated leaf area co-efficient was used to estimate LAI at harvest. Moreover, reductions in yields and yield traits from plant crop to ratoon 1 and 2 crops and reduction from ratoon 1 to ratoon 2 crop were estimated.

Potential of producing settlings for the STP technique from sugarcane tops

This experiment was conducted from 1st September to 1st November 2009. Four nursery beds of 1 m^2 were made, and each bed was divided into four identical plots of 0.25 m^2 to make total of 16 treatment plots. The four main nursery beds were used as four replicates, thus, there were 16 experimental plots. The four different types of single-budded setts were allocated randomly to each treatment plot in a nursery bed, and the same procedure was followed in the other three nursery beds to develop the experiment in a RCBD statistical design.

Cane tops left behind after harvesting 3rd ratoon crop of an irrigated crop (variety SL 83 06) were used to obtain single-budded setts to plant nursery. Three types of single-budded setts were separated from a cane top. The setts separated from the cane tops with 1st bud close to the detached end of the millable portion of a cane stalk were planted in the nursery as one treatment (T1). Similarly, the setts separated from the same cane tops with the 2nd or middle buds and with the 3rd or immature bud close to the epical bud were planted on separate treatment plots and named as T2 and T3, respectively. The treatment plots planted with matured single-budded setts obtained from the middle of millable portion of the same canes were named as T4.

Setts were cut just above the growth ring leaving 2-5 cm of the internode below the bud depending on the length of the internodes. They were soaked for 5 minutes in a fungicide (Folicur 0.5%). Nursery beds were irrigated adequately before planting setts, and the treated setts were established vertically, keeping the bud and root band zone just above the soil surface. The planted nursery beds were mulched with a layer of trash, and were irrigated daily. All shoots appeared at 10, 25, 40 and 60 days after planting (DAP) of setts were counted to estimate germination of buds and survival of shoots.

Significance of treatment differences of the variables in two experiments was tested by analysis of variance (ANOVA). Means were separated by using the least significant difference (LSD). Correlation between yield and yield traits were determined by correlation analysis. The SAS statistical computer package was used to analyse the data.

RESULTS AND DISCUSSION

Evaluation of inter-settling spacing for STP

Planting material requirement

In the STP technique of sugarcane planting, settlings requirement per hectare was 7300 and 18250 for 100 and 40 cm inter-settling spacing respectively when a field was planted in 1.37 m inter-row spacing (Table 1). The observed field survival rate after transplanting settlings was 97%. However, germination was approximately 70% in the plots planted with three-budded setts obtained from the same seed cane (T4). This may be due to increase of sprouting ability of the buds with the elimination of epical dominance when a cane stalk is cut into single-budded setts. This finding is agreeable with the observed higher germination and seedling survival rate (98%) due to settling transplanting compared to 63.5% germination and establishment percentage after planting two-budded setts obtained from the same seed cane (Pawar, 2005). Thus, STP technique gives higher field establishment when compared with conventional sett planting.

An average value of 80% germination was observed in the single-budded setts planted in nursery beds. Thus, the number of single-budded setts required to establish a nursery to get settlings to transplant one hectare of land ranged from 9125 to 22812 with 100 and 40 cm inter-settling spacing (Table 1).

Table 1. Planting material requirement for different inter-settling transplanting spacing levels and for conventional three-budded setts planting, both in 1.37 m inter-row spacing

Treatment	Planting material requirement per ha. of land			
	No. of settlings or setts	No. of single budded setts	Weight of prepared setts (kg)	Weight of raw seedcane (kg)
T1: Settlings in 40 cm	18250	22812	1140	1677 (78)
T2: Settlings in 60 cm	12167	15209	760	1118 (85)
T3: Settlings in 80 cm	9125	11406	570	839 (89)
T4: Settlings in 100 cm	7300	9125	456	671 (91)
T5: 3-budded sett -Control	36500	-	5214	7668

Germination % of the single-budded setts was 80%. Numerals in parentheses are seed cane saving % as compared to the conventional method.

In high density or 40 cm inter-settling spacing, maximum of 1677 kg of un-processed seed cane is required to plant a hectare. Thus, the seed cane requirement has reduced by about 80 to 90% in STP technique compared to the conventional three-budded setts planting, even with this high density settling transplanting (Table 1). Therefore, adoption of STP technique by using conventional seed cane to raise nurseries, there is a reduction of seed cane cost by about Rs.20,000 per hectare than conventional three-budded setts planting using the same seed cane. (Price of seed cane is Rs.3,000 t^{-1}; seed rate 8 t ha^{-1}) Moreover, it has been observed that the planting material requirement could be reduced further up to 6350 potted plants ha^{-1} using 90 cm intra-row spacing in 1.75 m wider inter rows without a significant yield reduction in irrigated sugarcane (Wijesuriya *et al.*, 2010).

Yield and yield components in plant crop (PC) and ratoon crops

The effect of different inter-settling spacing and sett planting on different yield components, *i.e.*, mean stalk height (m) (2.1 ± 0.02 in PC, 2.0 ± 0.01 in ratoon 1 and 2.0 ± 0.01 in ratoon 2), mean stalk diameter (mm) (27.1 ± 3.7 in PC, 26.8 ± 3.4 in ratoon 1 and 25.6 ± 2.8 in ratoon 2) and mean number of inter nodes per stalks (24 ± 2.2 in PC, 24 ± 3.1 in ratoon 1 and 30 ± 3.3 in ratoon 2) was not significant (P>0.05). However, in plant crop, cane yield was reduced significantly in 100 cm inter-settling spaced plots than sett planted plots (Table 2). In ratoon 1, yield reduction appears in 100 cm inter-settling spacing than 40 cm inter-settling spacing treatment. In contrast, there was no significant effect of different inter-settling spacing or sett planting on ratoon 2 cane yield. This indicates that similar cane yield to conventional sett planning could be obtained by transplanting settlings in STP technique at 80 cm or at closer intervals along a cane row. Non-significant responses in ratoon 2 cane yield further indicates that planting in 80 cm or closer inter-settling spacing, the STP planting technique could be maintained to obtain cane yields similar to conventional sett planting technique in PC and several ratoons. In addition, effect of treatments on average cane yield (81.26 ± 2.47) of the plant crop and 2 ratoons was not significant (P>0.05). This further confirms that average performance of PC and two ratoons crops planted by the STP technique is similar to the conventional sett planting method.

Number of millable stalks recorded after harvesting was least in the plots planted in 100 cm inter-settling spacing but did not differ significantly from the value obtained under 80 cm inter-settling spacing (Table 2). However, these two values were significantly less than the stalk number recorded in plots planted in 40 cm inter-settling spacing. This indicates that millable stalks number was not reduced due to the STP planting technique compared to conventional sett planting in the plant crop if the settlings were planted at 80 cm or lower inter-settling spacing. However, more stalks could be obtained by planting at a high density or at a 40 cm inter-settling spacing. Since the number of millable stalks was not significantly different between 40 cm and 60 cm inter-settling spacing, a 60 cm could be considered as an optimum inter-settling spacing to transplant by STP technique. Non-significant effect of different treatments on number of millable stalks in ratoon 1 (mean 68992 ± 3425) further indicates that STP planting technique would not reduce this parameter in ratoon 1. In fact, significantly higher number of millable stalks appears in the plots transplanted in 40 cm inter-settling spacing than in the conventional sett planting technique in ratoon 2 indicates that this planting technique has contributed to increase the millable stalks number in late ratoon crops. The number of stalks per hectare was the highest correlated and contributed component to the cane yield (De Silva, 2008). Low cane yield observed in planting at a 100 cm inter-settling spacing thus may be associated with less number of millable stalks in the same plots. Therefore, the STP planting technique enhances the performance of ratoon crops when compared to the crops established with conventional sett planting technique.

Average weight of a harvested cane stalk in plant crop (1.25 kg) is highest in the plots transplanted at a 100 cm inter-settling spacing and that in the plots transplanted at 40 cm and 60 cm inter-settling spacing were significantly lower (Table 2). Average weight of a harvested cane stalk in the plots transplanted at 80 cm and 100 cm inter-settling spacing and sett planting were similar. The effect of different inter-settling spacing and sett planting on an average stalk weight (mean

Table 2. Effect of inter-settling spacing and setts planting on cane yield (t ha^{-1}) and yield components in plant and ratoon crops

Treatment	Plant crop				Ratoon 1	Ratoon 2		
	Cane yield	No. of stalks ha-1	Stalk Weight (kg)	LAI	Cane Yield	Cane Yield	No. of Stalks ha-1	Stalk Weight (kg)
T1: Settlings in 40 cm	94.53^{ab}	88762^{a}	1.06^{b}	5.13^{a}	74.71^{a}	95.34^{a}	92548^{a}	1.03^{b}
T2: Settlings in 60 cm	85.33^{ab}	80472^{ab}	1.05^{b}	3.92^{b}	67.77^{ab}	86.78^{a}	84617^{ab}	1.03^{b}
T3: Settlings in 80 cm	85.24^{ab}	74795^{bc}	1.11^{ab}	3.48^{b}	67.09^{ab}	83.99^{a}	78490^{b}	1.01^{b}
T4: Settlings in 100cm	82.81^{b}	68216^{c}	1.25^{a}	2.96^{b}	63.62^{b}	76.33^{a}	75336^{b}	1.07^{ab}
T5: 3budded setts-Control	99.75^{a}	84707^{ab}	1.17^{ab}	3.54^{b}	68.30^{ab}	87.32^{a}	76507^{b}	1.14^{a}
Mean	89.54	79391	1.13	3.81	68.30	85.95	81500	1.06
LSD (p=0.05)	15.41	10436	0.17	1.03	9.15	19.16	13465	0.10

LSD (p=0.05) for treatment comparisons within a respective variable. Means with the same letters within a variable are not significantly different at p=0.05.

0.99 ± 0.01) was not significant in ratoon 1. However, significantly lower means of a stalk weight was observed due to transplanting at 40, 60 and 80 cm inter-settling spacing in ratoon 2 when compared to the control. Average weight of a stalk in the plots transplanted at 100 cm inter-settlings was similar to the settlings transplanted at 40, 80 and 60 cm inter-settling spacing and to that of sett planting. This indicates that transplanting at a close inter-settling spacing reduces average weight of a harvested stalk. However, reduced single stalk weight due to closer inter-settling transplanting had no impact on cane yield, and similarly, increased single cane weight by transplanting at a wider inter-settling spacing and also sett planting had not contributed to increase cane yields in the respective treatment plots. Thus, the weight of a stalk is lower in the plots with more millable stalk and *vice versa.* Millable stalks number is usually significantly ($p<0.05$) and negatively correlated with stalk weight and stalk diameter (De Silva, 2008).

Leaf area index at harvest (LAI) showed significant ($p<0.05$) differences between treatments in plant crop and the value is high in the plants of the 40 cm inter-settling spacing (Table 2). The effect of different planting treatments on the LAI in ratoon 1 and ratoon 2 was not significant ($P>0.05$). This finding indicates that the STP technique has not adversely affected canopy development, and it has contributed to enhance the potential to capture incident radiation by increasing LAI in plant crop, particularly by transplanting settlings at a high density (40 cm intervals).

The effect of different settling transplanting treatments and sett planting was not significant ($p>0.05$) on quality attributes of extracted cane juice after harvesting each crop, *i.e.*, means of percentages of brix (PC = 18.13 ± 0.23, ratoon 1 = 19.75 ± 0.25, ratoon 2 = 19.07 ± 0.19), pol (PC = 16.10 ± 0.25, ratoon 1 = 17.38 ± 0.27, ratoon 2 = 16.61±0.21), purity (PC = 88.76 ± 0.36, ratoon 1 = 87.96 ± 0.40, ratoon 2=87.18±0.48) and POCS (PC = 12.16 ± 0.21, ratoon 1 = 12.99 ± 0.23, ratoon 22 = 12.39 ± 0.18). This, together with the variations associated with cane yields under different treatments might have contributed to the observed non-significant differences in sugar yields (PC = 10.89 ± 0.50, ratoon 1 = 8.85 ± 0.19, ratoon 2 = 10.68 ± 0.44 t ha^{-1}), which was calculated by multiplying cane yields (t ha^{-1}) with POCS (%) values. This indicates that there is no reduction of either juice quality or sugar yield with STP technique. In contrast, transplanting at a closer inter-settling spacing (40 cm) had increased millable stalk number in ratoon 2, the most significant contributing factor to increase sugar yield as shown by the correlation analysis.

Cane yield showed a significant ($p<0.05$) positive correlation with number of millable stalks in PC, ratoon 1 and ratoon 2 crops ($r > 0.76$ with $p<0.001$), and LAI ($r = 0.69$ with $p = 0.004$) and stalk weight ($r = 0.53$ with $p = 0.04$) in plant crop. The correlation between cane yield and stalk number is more robust in the case of ratoon crops ($r = 0.87$ with $p = 0.0001$). Therefore, more tiller production and subsequent higher survival rate of shoots and stalks are important for higher ratoon yields. Number of millable stalks showed a positive correlation with stalk height ($r = 0.51$ with $p = 0.05$) and number of internodes ($r = 0.57$ with $p = 0.05$), and negative correlation with stalk diameter ($r = 0.49$ with $p = 0.05$) and stalk weight ($r = 0.50$ with $p = 0.05$). Therefore, it is important to maintain an optimum population density for increasing individual yield components to achieve a high cane yield. There was also a highly significant positive correlation (r = 0.94 and p = 0.0001) between sugar yield and cane yield indicating that sugar yield is mainly dependent on cane yield.

Millable stalks number plays a vital role in increasing yield. On the other hand, increase in the weight per stalk in low-density planting, which may be due to increase of girth, has compensated the reduction of yield caused by low number of millable stalks. Therefore, weight of an individual stalk and its diameter that are considered to contribute less to the final cane yield appears to have enhanced cane yield due to the low stalk population with low density planting.

The study shows that STP technique, particularly transplanting at low inter-settling spacing increases millable stalks number and cane yield. The optimum inter-settling spacing found was 60 cm. Moreover, transplanting of settlings significantly reduces the cost of planting material, without affecting cane and sugar yields. Pawar (2005) also observed significantly greater cane and sugar yields while increasing individual yield components under settlings transplanting at 45, 60, 75 and 90 cm wide inter-settling spacing compared to the two-budded setts planting. Moreover, Anon (2010) recorded that transplanted C_4 type crops, such as, sorghum, pearl millet and maize, had uniform plant populations and higher yields compared to the direct sowing under water stress conditions.

Reduction of yield and yield components from plant crop to ratoon crops

Cane yield, sugar yields and stalks number have declined from plant crop to ratoon 1 (Table 3). Reduction of cane yield from plant to ratoon 1 was greater than that from plant to ratoon 2. In the case of plots transplanted at 60 cm and 100 cm inter-settling spacing, cane yield reduction from plant to ratoon 1 was significantly lower when compared to the control. However, in ratoon 2, a reduction of cane yield from PC to ratoon 2 was significantly less under all treatments of settlings transplanting except in the 100 cm inter-settling spacing when compared to sett planting. This indicates that transplanting at 80 cm or closer inter-settling spacing is preferred for getting a high ratoon crop yield. Field transplanting settlings at inter-settling spacing of 60 cm was found to be the best for high cane yield. The lack of significant treatment effect observed in the other parameters, *i.e.,* millable stalk numbers and sugar yield under each crop category indicates that the contribution of these components to ratoon yield is similar in STP technique and sett planting. Therefore, the lower reduction of cane yield from PC to ratoon 2, particularly transplanting settling at 80 cm inter-settling spacing or closer, is an added advantage of the STP technique when compared to sett planting. Thus, the STP technique enhances ratoon crop performance and closer inter-settling spacing was seen to be beneficial.

Cane yield reduction from plant crop to ratoon 1 crop had a significant positive correlation with the reduction of number of millable stalks (r = 0.48 with p = 0.06). Sugar yield reduction between these two crops also showed significant positive correlations with the reduction of cane yield (r = 0.84 with p = 0.0001) and the reduction of number of millable stalks (r = 0.57 with p = 0.02). When the reduction in yield and yield components from plant crop to the 2nd ratoon crop were considered for correlation analysis, cane yield reduction showed significant positive correlations with the reduction of number of millable stalks (r = 0.78 with p = 0.0005) and reduction of stalk weight (r = 0.49 with p = 0.06).

Table 3. Effect of inter-settling spacing and setts planting on reductions of cane and sugar yields (t ha^{-1}) and stalk number ha^{-1} from plant to 1st ratoon and from plant to 2nd ratoon crops

Treatment	Reduction from plant crop to the 1st ratoon crop			Reduction from plant crop to the 2nd ratoon crop		
	Cane Yield	No. of Stalks	Sugar Yield	Cane Yield	No. of Stalks	Sugar Yield (t)
T1: Settlings in 40 cm	19.82	13878	1.84	-0.81	-3785	-0.31
T2: Settlings in 60 cm	17.57	12887	1.93	-1.44	-4145	-0.96
T3: Settlings in 80 cm	19.20	10634	1.76	-1.17	-3695	0.19
T4: Settlings in 100 cm	18.16	901	1.53	8.92	-7119	0.79
T5: 3 budded setts -Control	31.45	13697	3.17	12.44	8201	1.37
Mean	21.24	10399	2.05	3.59	-2109	0.22
LSD (p=0.05)	13.08	15078	1.62	10.55	14574	3.38

LSD (p=0.05) for treatment comparisons within a respective variable. Negative values indicate that the respective values in the ratoon crops were higher than in the plant crop.

Sugar yield reduction showed significant positive correlations with the reduction of cane yield ($r = 0.89$ with $p = 0.0001$) and the reduction of number of millable stalks ($r = 0.72$ with $p = 0.002$).

Pawar (2005) has reported that a significant increase of tillering ability and thus tiller ratio under settling transplanting could contribute to increasing ratoon yields. The results of this study reveal that millable stalks number under settlings transplanting was more than that was found in setts planting, particularly in the late ratoon crops. In the correlation analysis, millable stalks number was found to be the most significantly contributing factor to cane yield. Therefore, the performance of ratoon crops in settling transplanting was found to be better than in conventional sett planting. High tiller density during early growth of ratoon crop leads to reduce weight of a cane stalk and death of some tillers. This phenomenon is responsible for lowering cane yields in ratoon crops (Sundara, 1997). However, ratooning eliminates land preparation and seed cane requirements, and, thus significantly reduces planting cost, which is the largest proportion of cost of sugarcane production, apart from harvesting cost (Verma, 2002). Therefore, 60 cm intra-row spacing was identified as the optimum inter-settling spacing when transplanting settling in 1.37 m spaced furrows. Adoption of this planting technique requires only 1118 kg of the conventional seedcane per hectare, thus saving 85% of the seed materials required for planting with conventional sett planting technique.

Possibility of using sugarcane tops to produce settlings for the STP technique

On an average, 1213 single-budded setts were planted in 1 m^{-2} nurseries (Table 4). A significantly ($p<0.05$) higher number of single-budded setts was obtained from the cane tops (T1, T2 and T3) which were planted in a unit nursery area, when compared to the single-budded setts obtained from the millable portion of the same cane stalk (T4). Number of shoots per square metre at 10, 25, 40 and 60 DAP showed significant ($p = 0.009$) differences between different types of setts (T1-T4) planted in the nursery. Setts type T1 recorded a significantly higher number of shoots up to the 60 DAP. The sett type T2 recorded significantly higher numbers of shoots up to 40 DAP. All the types of setts obtained from the cane top (T1, T2 and T3) recorded significantly higher number of shoots at 10 DAP and average number of shoots up to the 60 DAP when compared to the single-budded setts obtained from the matured portion of a stalk (T4). However, at the stage of field transplanting the shoots, *i.e.,* 4-6 weeks after nursery planting, the sett types T1 and T2 showed significantly greater number of shoots than the sett type T3 and T4. Even-though, transplanting was delayed up to 60 DAP, setts taken from the cane tops provided a higher number of shoots to transplant than the setts taken from matured cane. Thus, sugarcane tops left behind after planting are preferred to mature stalks for establishing nurseries to obtain settlings for STP. Significantly higher average numbers of settlings were obtained after planting with the setts separated from cane tops than from mature stalks further confirms the above fact.

Bud germination and subsequent shoots survival percentages were estimated on the basis of live settlings at 10, 25, 40 and 60 DAP setts in the nursery. The sett type T2 had significantly ($p<0.05$) higher germination and shoot survival percentage at 10 and 25 DAP and their average up to 60 DAP than the control (Table 5). The sett type T3 showed significantly ($p<0.05$) higher number of shoots only at 10 DAP than the control (T4). But the percentage germination and shoot survival values were significantly less at 25 and 40 DAP when compared to the control (Table 5). Moreover, germination and shoot survival of the matured setts (T4) in the nursery increased up to 80% at 25 DAP, but this value was significantly lower than the percentage value recorded against T2, the second sett separated from the cane tops.

This further confirms that the single-budded setts obtained from cane tops are preferred to establish nursery for STP technique. Out of different types of setts separated from the cane tops, the sett type T3 showed a significantly lower germination and shoot survival rates at 25 and 40 DAP, but the sett types T1 and T2 maintained over 80 % germination and shoot survival rate until 40 DAP. Therefore, the sett types T1 and T2, separated from the cane tops, are more suitable to plant single-budded sett nursery for STP as they provide the highest number of transplantable shoots from unit nursery area at the time of planting, usually about 4 – 6 weeks after nursery establishment (Verma, 2004).

Table 4. Number of different types (T1, T2, T3 and T4) of single-budded sugarcane setts planted and number of shoots emerged per square metre of nursery

Treatment	No. of setts planted m^{-2}	Number of shoots emerged per m^2 nursery				
		10 DAP	25 DAP	40 DAP	60 DAP	Mean value of shoots
T1: 1st sett of cane top	1391*	1038*	1226*	1120*	773*	1039*
T2: 2nd sett of cane top	1278*	1156*	1184*	1037*	737	1029*
T3: 3rd sett of cane top	1367*	944*	813	720	647	781*
T4: Matured sett-control	816	563	650	640	528	595
Mean	1213	925	968	879	671	861
LSD (p=0.05)	203	259	209	189	218	162

LSD (p=0.05) for treatment comparisons within a respective variable. * Significantly greater than the control treatment at p=0.05.

Table 5. Percentage of bud germination and shoot survival at 10, 25, 40 and 60 DAP and average germination % from 10 to 60 DAP in different types (T1, T2, T3 and T4) of single-budded setts planted in the nursery

Treatment	Germination and survival percentage (%)				
	10 DAP	25 DAP	40 DAP	60 DAP	%Average shoots
T1: 1st sett of cane top	74.28	87.69	80.26	55.48	74.43
T2: 2nd sett of cane top	91.19*	92.94*	81.34	57.67	80.78*
T3: 3rd sett of cane top	68.86	59.47+	52.36+	48.75	57.36+
T4: Matured sett-control	68.97	80.18	78.77	64.44	73.09
Mean	75.83	80.07	73.18	56.58	71.41
LSD (p=0.05)	12.70	9.96	12.60	16.62	6.31

LSD (p=0.05) for treatment comparisons within a respective variable. * Significantly greater than the control treatment at p=0.05. + Significantly lower than the control treatment at p=0.05.

There is an apparent reduction of shoot survival beyond 25 DAP with all four types of setts, which may be due inter-shoot competition as a result of higher shoot density (Table 4). Therefore, similar to the observation recorded by Verma (2004), the shoots obtained from a 4 weeks old nursery are the best for transplanting. At this stage, one square metre nursery planted with types T1 and T2 setts produces an average of 1000 shoots with 80% average shoot survival rate.

Benefits of using cane tops for producing settlings

In this experiment, single-budded setts were obtained from the cane tops left behind after harvesting the 3rd ratoon crop of the variety SL 83 06 grown under irrigation. It was estimated that the crop produced about 94200 millable stalks ha^{-1}, and thus the same amount of cane tops. Each cane top gave an average of three single-budded setts with a 71% average germination. Thus, total estimated number of single-budded setts available from the cane tops after harvesting a hectare of cane is about 282600. The estimated average planting density was about 1213 single-budded setts per 1 m^2 of the nursery. Therefore, a nursery area of about 233 m^2 is required to plant single-budded setts taken from cane tops of one hectare of land. With an average germination of approximately 71%, 233 m^2 of a nursery provides about 200646 transplantable settlings. This amount is sufficient to transplant about 16.5 ha. of sugarcane field under an optimum inter-settling spacing of 60 cm in 1.37 m spaced furrows. Therefore, in the STP technique of sugarcane propagation the Field:Nursery ratio increased up to 1:700. It significantly reduces the land requirement for sugarcane nurseries compared to conventional and LSM nursery techniques of sugarcane propagation (Wijesuriya *et al.*, 2001, Keerthipala *et al.*, 2001). Moreover, this planting technique reduces seed cane handling cost and labour involved in planting field apart from low material cost compared to conventional planting technique. Conventional method requires about 148.5 t (9 t ha^{-1}) of good-quality seed cane which costs approximately Rs.371,250 (Rs.2,500 t^{-1}) to cultivate 16.5 ha. of sugarcane. However, unskilled labour intensive STP technique requires about 200 labour units to prepare nurseries and produce settlings to cultivate 16.5 ha. of sugarcane field which costs some Rs.100,000 (Rs.500 per labour unit). Thus, the financial benefit of the STP technique is about Rs.271,000 if settlings produced from nurseries established from single-budded setts are taken from 94,200 cane tops collected from a hectare of harvested sugarcane land.

CONCLUSIONS

There exists a great potential to adopt the STP technique to establish sugarcane crop as this technique reduces seed cane requirement by about 80 to 90% without reducing yield, which is a significant saving to the farmers, particularly under prevailing high seed cane prices. Moreover, enhancement of performance of crops, particularly ratoons, planted using this technique further confirms its appropriateness. The optimum inter-settling spacing to transplant settling in 1.37 m spaced furrows was found to be 60 cm.

Sugarcane tops left behind after harvesting a mature crop could be successfully used to obtain single-budded setts to establish nurseries for the STP technique. Three single-budded setts with an average germination and shoot survival rate of about 71% are available in an average cane top to plant the nurseries. However, germination and shoots survival rate vary among different buds, and depend on the physical maturity of each bud. Shoots emerged from the most immature buds, which were separated from a region close to the apical buds had lower germination and shoot survival rate. However, a higher germination and shoot survival rate when compared to setts obtained from conventional seed cane was observed in the setts separated from mature region of the cane tops after planting them in a single-budded nursery. One or two setts separated from mature end of cane tops are recommended to establish a nursery for the STP planting technique. Thus, the use of cane tops to produce settlings for STP planting technique totally eliminates conventional seed cane requirement and reduces sugarcane planting cost substantially.

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