Research Article

Exploring the Ratooning Potential of Sugarcane (*Saccharum officinarum* L.) Genotypes under Varying Harvesting Times of Plant Crop

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Abstract | Ratoon keeping of sugarcane is very popular in Pakistan for its better economic benefits however harvesting schedule of plant crop is essential since low temperature severely effects the sprouting of subsequent ratoon in cane growing areas. A field study was conducted on loamy soil during 2011-2013 at Sugarcane Research Institute (SRI), Faisalabad to explore the ratooning ability of five sugarcane varieties/clones under varying harvesting dates of plant crop using randomized complete block design (RCBD) with split plot arrangements. The cane genotypes *viz.* S2003-US-704, S2006-SP-30, S2003-US-410, S2006-US-321 and HSF 240 (check) were kept in main plots whereas harvesting dates *viz.* 1st November, 1st December, 1st January, 1st February and 1st March of plant crop were placed in sub-plot in 2011-2012 and subsequent ratoon was harvested in January-2013. A highly significant differences were recorded among all the genotypes and harvesting dates for number of sprouts, millable ecane, striped cane yield and sugar yield. The HSF 240 exhibited better yield and qualitative characteristics than others. Whereas, subsequent ratoon of plant crop harvested on 1st February was found to be superior among all harvesting dates for most of traits and genetic potential of genotypes. It was also found that the ratoon crop yield was highly dependent on the number of sprouts which were significantly varied among harvesting dates and the genotypes tested as well (R^2=0.998 & 0.994, respectively).

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Introduction

The sugarcane is an important cash crop of Pakistan used for the production of refined sugar and jaggery *(Gur)*. Its value added share in agriculture and GDP is 3.4 and 0.7 percent, respectively (GOP, 2017). It was grown over 1,217 thousand hectares with production of 73.6 million tonnes of cane giving average stripped cane yield of 60.4 t ha^{-1} during 2016-17, however it is lower than world average production of 65.20 t ha^{-1} (FAO, 2014). Globally Pakistan ranked 5th largest in sugarcane area, production and cane sugar manufacturing (ISO, 2016 and FAO, 2014). It not only provides main stay to sugar industry but also raw material to many allied industries like chip board manufacturing and ethanol in addition to direct or indirect employment to more than four million peoples of Pakistan (Naqvi, 2005).

In Punjab province, more than 50% of total sugarcane cropped area is kept under ratoon crop but its production is 25-30% less than fresh crop (Rehman and Ullah, 2008). It is due to improper attention of sugarcane growers that leads to 35% loss in production

(Malik, 1997). The main reason of decline in yield of ratoon crop in sugarcane is different ratooning potential of cultivars and suboptimal crop management. Ratoon keeping is 25-30% economical than plant crop and get ready for harvest before plant crop with supplementary advantage of better juice quality and sugar recovery (Yadav, 1991). Similarly, spring harvested crop prove to be better ratoon than autumn because of moderate temperature conducive for stubble sprouting. Earlier studies showed that sugarcane cultivars with good ratoonig potential has the characteristics like rapid canopy development, early development of adequate number of stalks for more light interception at early growth stage and stability in cane weight at harvesting to maintain yield in ratoons (Gomathi et al., 2013; Sundara, 1996 and Sundara et al., 1992). In the sub-tropical regions, sugarcane is harvested under low temperature (early harvesting) and high temperature (late harvest) conditions. The yield of ratoon crop is affected and much influenced by environmental factors (Gomathi et al., 2013 and Shrivastava et al., 1992).

The major cane growing countries usually take two or more sugarcane ratoons (Yadav, 1991). Singh and Dey (2002) reported varying response of ratooning of different sugarcane genotypes for sprouting, millable canes and commercial cane sugar. The proper development of ratoon crop depends upon sprouting of underground buds those stay behind after harvesting of plant crop (Hunsigi and Krishna, 1998). The sugarcane clones differ in their ability to survive and produce profitable ratoon crop (Bhatnagar et al., 2003). The genetic variation among the genotypes for ratooning potential was also reported by Bhatnagar et al. (2003) and Rafiq et al. (2006) thus ratooning behavior of sugarcane cultivar is a function of genotype and environment interaction. Similarly, Shih and Gascho (1980) found declining trend in the yield of sugarcane ratoons with varying ratooning potential of genotypes. Saeed (1993) recorded bumper yields from first and second ratoon crops of sugarcane with proper crop management under Faisalabad conditions.

Adaptation and success of a sugarcane variety depends upon its adaptability to agro-climatic conditions of the area. Selection of a proper variety to be planted in a particular agro-ecological zone is a primary requisite to explore its quantitative and qualitative characteristics. Ratoon keeping is very important in our cropping system for overall profitability of sugarcane cultivation as it save operational cost by 30%, mainly due to seed and reduced expenses for soil management (Sundara, et al., 1992). The genetic potential of a variety to give better yields in plant and ratoon crops is a focal point for sustaining high productivity and its acceptance by the farmers for good ratooning potential (Arain et al., 2011). The candidate sugarcane varieties in variety development program of Sugarcane Research Institute, Faisalabad are tested for ratoonability. Thus, sugarcane varieties with good performance in plant and ratoon crops should be promoted for commercial cultivation. As good ratooning in sugarcane is beneficial for the farming community as its production costs lower than the plant crop and also ratoon crop exists over more than half of cultivated area of sugarcane in Punjab, the prime objective of present study was to evaluate the ratooning potential of promising sugarcane genotypes by keeping ratoon at varying harvesting times of plant crop under the agro-climatic conditions of Faisalabad.

Materials and Methods

The study was conducted during 2011-2013 at the Sugarcane Research Institute, AARI, Faisalabad, situated at the Latitude of 31° 25' N and Longitude of 73° 09' E. The soil was loamy having pH of 7.6, EC of 0.36 dsm^{-1} and organic matter of 0.85%. The experiment was laid out in randomized complete block design (RCBD) with split plot arrangements having three replications. Five genotypes *viz.* S2003-US-704, S2006-SP-30, S2003-US-410, S2006-US-321 and HSF 240 (check) were kept under study with five harvesting dates: 1st November, 1st December, 1st January, 1st February and 1st March in 2011-2012. The genotypes were placed in main plot while harvesting dates in sub-plot. The experiment was planted in February-2011 and plant crop was harvested and kept as first ratoon on different dates, as mentioned. Planting was done in 120 cm apart dual row trenches with a net plot size of 4.8m × 4m at seeding rate of 50000 triple budded billets (setts) per hectare. Standard crop production technology needed for sugarcane crop was employed in the experiment in addition to the application of 30% more fertilizer for ratoon crop. All agronomic and plant protection measures were kept uniform for all the experimental units.

Meteorological observations

The data (Figure 1) showed that there were varied meteorological parameters during both years (plant and ratoon). The rainfall pattern during both years was more varied as during 1st year (2011) rainy season was extended (from July to September) which was squeezed only to September in 2nd year (2012).

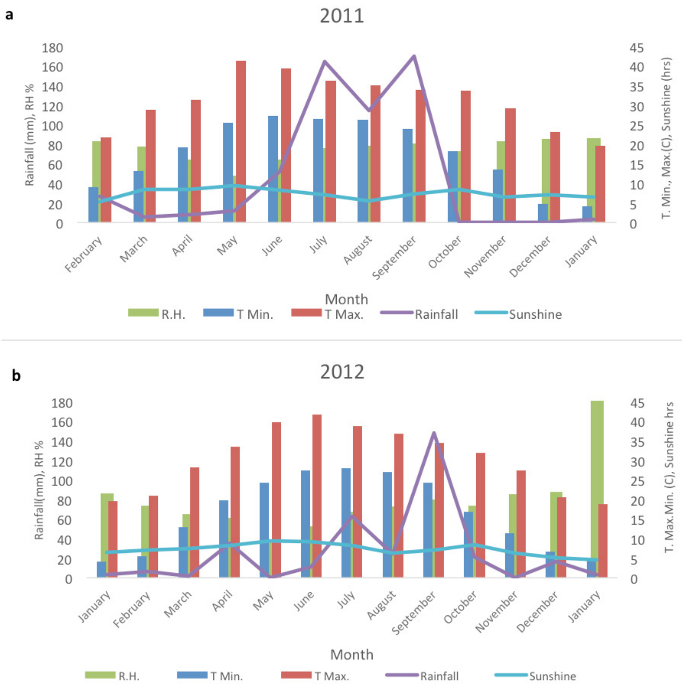


Figure 1: *Meteorological observations during plant (a) and ratoon (b) crop season.*

The standard procedure was followed while recording the observations on number of sprouts, millable canes, striped cane yield (t ha^{-1}), sugar content (CCS%) and sugar yield (CCS t ha^{-1}). Data on number of sprouts were recorded by counting all the tillers in plot and number of millable canes per plot was recorded at harvest and both were converted into thousand/hectare. Cane yield was recorded by harvesting the whole plots and stalks were stripped, topped ad weighed with the help of floor balance. The cane yield (kg) of each plot was expressed as tonnes/ha. Ten canes were randomly selected from cane stool in the field for qualitative juice analysis. The juice was extracted by cane crusher having 60% extraction. While brix were recorded by brix hydrometer standardized at 20°C and pol percent were determined by Horn's dry lead sub-acetate method of sucrose analysis (Anonymous, 1970). The commercial cane sugar (CCS%) was calculated by using following formula:

$$CCS\% = 3P/2\,[1 - (F + 5)/100] - B/2\,[1 - (F + 3)/100]$$

(P stands for pol%, F for fibre% and B for Brix% (Anonymous, 1970)).

Sugar yield was calculated by using the formula:

Sugar yield (tonnes/ha) = CCS% / 100 × stripped cane yield

The data collected were statistically analyzed employing MSTATC; version 1.3 (Freed, 1990) and least significant difference test (LSD) was applied to compare the treatment means (Steel et al., 1997).

Results and Discussion

Number of sprouts

Results obtained from the ratoon crop of sugarcane revealed that number of sprouts varied significantly among the genotypes and harvesting dates (Table 1). On an average, the check variety (HSF 240) produced highest number of sprouts but it was at par with S2006-SP-30 as against the lowest in case of S2003-US-410. The variation in number of sprouts was due to different genetic potential of genotypes. Similar results were reported by Bashir et al. (2012), Shah et al. (2008) and Jamro et al. (2000) who found significant variation among the ratoons of different sugarcane genotypes for number of sprouts. As regards harvesting dates, the highest numbers of sprouts were recorded in ratoon crop kept on 1st February. It was due to upcoming spring season conducive for stubble sprouting. It is also depicted from the data that the lowest sprouting was observed when the plant crop was harvested on 1st December, mainly due to low temperature effect on it which normally prevails at this time in semi arid tropics and sub tropics.

Number of millable canes

The data shown in Table 2 indicated that highest number of millable canes were produced by HSF 240 but stands at par with S2006-SP-30 as against the lowest for S2003-US-410. The variation in number of millable canes was attributed to varied genetic potential under the prevailing agro-ecological conditions. These results are in line with those of Bhatnagar et al. (2003) who found significant variation in number of millable canes for ratoon of different sugarcane genotypes. Conversely, the 1st February kept ratoon crop exhibited the highest number of millable canes and it was closely followed by ratoon kept on 1st March. The maximum number of millable canes produced in 1st February kept ratoon crop were due to frost free period that had been over before the start of the month which is the a prevailing environmental scenario in

Table 1: *Effect of harvesting dates on number of sprouts (000 ha^{-1}) of different sugarcane genotypes in subsequent ratoon crop.*

Genotypes	Harvesting dates of plant crop					Average
	1st Nov	1st Dec	1st Jan	1st Feb	1st Mar	
S2003-US-704	77	50	83	101	96	82 b
S2006-SP-30	106	91	108	138	134	116 a
S2003-US-410	37	30	41	49	44	40 c
S2006-US-321	67	45	73	89	86	72 b
HSF-240	122	104	126	138	134	125 a
Average	82 d	64 e	86 c	103 a	99 b	

Any two means not sharing a letter in common differ significantly at $p \leq 0.05$; -LSD values for Genotypes = 19.3; Harvesting dates = 4

Table 2: *Effect of harvesting dates on number of millable canes (000 ha^{-1}) of different sugarcane genotypes in subsequent ratoon crop*

Genotypes	Harvesting dates of plant crop					Average
	1st Nov	1st Dec	1st Jan	1st Feb	1st Mar	
S2003-US-704	68	45	73	87	85	71 b
S2006-SP-30	91	77	99	111	108	97 a
S2003-US-410	33	27	35	44	38	35 c
S2006-US-321	61	37	60	79	79	63 b
HSF-240	104	88	108	115	113	106 a
Average	71 b	55 c	75 b	87 a	84 a	

Any two means not sharing a letter in common differ significantly at $p \leq 0.05$; -LSD values for Genotypes = 15.6; Harvesting dates = 4.20

Table 3: *Effect of harvesting dates on striped cane yield (t ha^{-1}) of different sugarcane genotypes in subsequent ratoon crop*

Genotypes	Harvesting dates of plant crop					Average
	1st Nov	1st Dec	1st Jan	1st Feb	1st Mar	
S2003-US-704	52.60	35.67	58.00	71.92	69.67	57.57 b
S2006-US-30	76.58	62.57	84.17	96.00	92.67	82.40 a
S2003-US-410	23.33	18.00	24.33	32.00	26.33	24.80 c
S2006-US-321	54.67	32.49	47.92	68.67	66.25	54 b
HSF 240	87.22	73.51	95	102	99	91.34 a
Average	58.88 b	44.45 c	61.88 b	74.12 a	70.78 a	

Any two means not sharing a letter in common differ significantly at $p \leq 0.05$; -LSD values for Genotypes = 16.4; Harvesting dates = .094

most of the semi-arid regions. Frost suppresses the growth of sprouts. Bashir et al. (2012) also reported similar results and recorded maximum number of millable canes in February kept ratoon crop.

Striped cane yield

The perusal of the data in Table 3 shown that the genotypes and harvesting times differ significantly for cane yield. On an average, maximum yield of 91.35 t ha^{-1} was recorded in plots of HSF 240 but it was at par with S2006-SP-30 (82.4 t ha^{-1}). Whereas, the minimum cane yield (24.8 t ha^{-1}) was obtained in case of S2003-US-410. The difference in cane yield of ratoon of sugarcane genotypes was due to their varied genetic potential which exploit edaphic and aerial factors of crop production. These results are in accordance with those of Bashir et al. (2012), Ongin et al. (2011) and Shah et. al. (2008) who reported significant difference among the ratoon of sugarcane genotypes for cane tonnage. As regards the harvesting time, the maximum stripped cane yield (74.12 t ha^{-1}) was obtained when the plant crop was harvested on 1st February but it was closely followed by 1st March harvest (70.78 t ha^{-1}). The lowest production (44.45 t ha^{-1}) was recorded in ratoon of plant crop harvested on 1st December. Similar trend was observed in case of number of millable canes. These results are in accordance with those of Bashir et al. (2012).

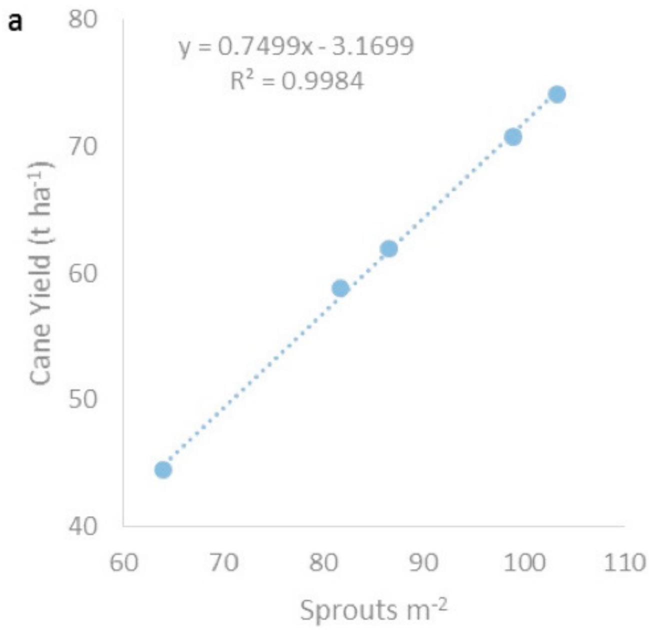
It is also evident from the data that stripped cane yield of the ratoon crop was highly dependent on the sprouting potential of the genotypes which was further affected by the harvesting time of the plant crop also (Figure 2).

Sugar content (%)

The results presented in Table 4 indicated that highest commercial cane sugar (%) were recorded in plots of S2003-US-704 (13.55%) but it was at par with S2006-SP-30(13.13%). The results are in line with the findings of Shah et al. (2008) and Gowda et al. (2000). As regards the harvesting dates the sugar contents were found to be non-significant.

Sugar yield

It is evident from data (Table 5) that there was significant difference among the genotypes and harvesting dates for sugar yield. The variety HSF 240 was found to be superior to all tested genotypes giving maximum sugar yield (11.80 t ha^{-1}) which was followed by S2006-SP-30 (10.74 t ha^{-1}). However, the minimum sugar yield was given by S2003-US-410(3.01 t ha^{-1}). Genetic variation among sugarcane genotypes for this trait has previously been reported by Sundra et al. (1992) and Das et al. (1996). Whereas, ratoon kept on 1st Februaryyielded highest sugar tonnage(9.39 t ha^{-1}) but it was at par with 1st March (9.12 t ha^{-1}) as against lowest in case of ratoon kept on 1st December (5.74 t ha^{-1}). The increase in sugar yield was attributed to highest cane tonnage and sugar content of particular genotypes. Bashir et al. (2012) reported the similar variation among the genotypes and harvesting times for sugar yield of ratoon crop.



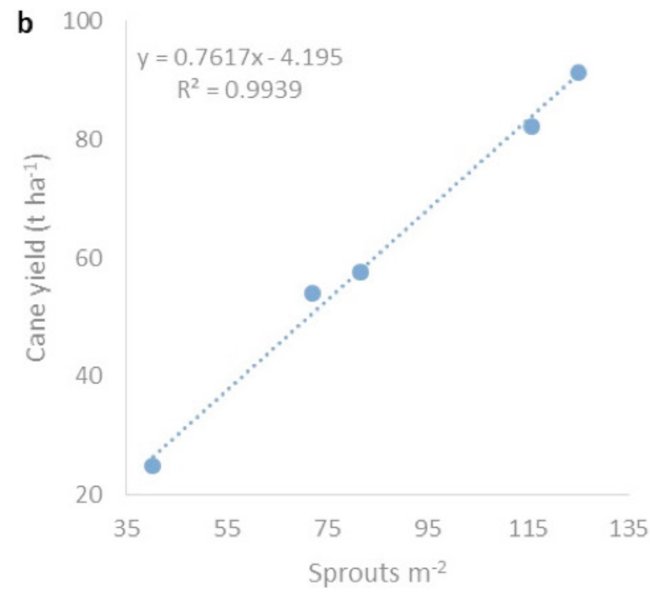


Figure 2: *Cane yield dependent on sprouts m^{-2} as influenced by harvesting time (a) and genotypes (b)*

Table 4: *Effect of harvesting dates on commercial cane sugar (%) of different sugarcane genotypes in subsequent ratoon crop*

Genotypes	Harvesting dates of plant crop					Average
	1st Nov	1st Dec	1st Jan	1st Feb	1st Mar	
S2003-US-704	13.63	13.18	13.60	13.54	13.79	13.55 a
S2006-SP-30	12.50	13.82	13.41	13.07	12.12	13.13 a
S2003-US-410	12.50	12.01	12.24	11.77	12.65	12.13 b
S2006-US-321	12.65	12.54	12.15	11.81	11.53	12.14 b
HSF-240	13.45	12.37	12.91	12.62	13.17	12.90 ab
Average	12.87	12.88	12.82	12.62	12.67	

Any two means not sharing a letter in common differ significantly at $p \leq 0.05$; -LSD values for Genotypes = 0.89; Harvesting dates = 0.68

Table 5: *Effect of harvesting dates on commercial cane sugar (t ha^{-1}) of different sugarcane genotypes in ratoon crop*

Genotypes	Harvesting dates of plant crop					Average
	1st Nov	1st Dec	1st Jan	1st Feb	1st Mar	
S2003-US-704	7.16	4.69	7.90	9.79	9.65	7.82 b
S2006-SP-30	9.43	8.63	11.24	12.26	12.13	10.74 a
S2003-US-410	2.83	2.23	2.93	3.93	3.15	3.01 c
S2006-US-321	6.94	4.01	5.83	8.11	7.65	6.51 b
HSF-240	11.70	9.12	12.29	12.87	13.04	11.80 a
Average	7.61 b	5.74 c	8.04 b	9.39 a	9.12 a	

Any two means not sharing a letter in common differ significantly at p ≤0.05; -LSD values for Genotypes = 2.03; Harvesting dates = 0.73

Conclusion

It can be concluded from the study that sugarcane genotypes differ in ratooning ability for cane and sugar yield and for good ratoon, plant crop should be harvested from 1st February to 1st March to attain better productivity in semi-arid areas of the country as the cane yield of the ratoon crop is highly affected by the sprouting behavior of the genotypes which is influenced by the harvesting time of the plant crop.

Author's Contribution

MUH conducted field trial, collected data, entry and statistical analysis of data, conceived idea, wrote article and did overall management of the article. NF helped in collection of data, proof reading of article and technical inputs at every step. MAM did proof reading, incorporated meteorological data and did regression analysis and technical input at each step. MY provided technical input at each step.

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