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Yield Attributes and Yields of Sugarcane under Monoculturing

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Abstract: *All the cane yield attributes e.g. millable cane height, no. of canes per stool and no. of internodes per cane and cane weight had showed drastic reduction, which were corresponding to ratoon frequency. The cane juice quality parameters e.g. brix and pol percentage were reduced, but reverse was the trend in CCS and purity percentage. Present work deals the study of drastic reduction in yield parameters during monocropping, is in cane yield in both cultivars due to allelochemicals detected in sugarcane trash and old root system.*

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I. Introduction

Sugarcane is an important industrial crop cultivated in tropical and subtropical areas of more than 121 different countries in the world, mainly for sugar and biofuel production. This wonder cash crop is the most efficient solar energy harvester and highly stress tolerant, which is planted by stem cuttings (sugarcane setts) with one to three eye buds. These on germination develop in to millable stalks within 12 to 18 months.

Apart from *adsali*, pre-seasonal and *suru*, ratooning is the main practice for sugarcane cultivation throughout the world, including India, as it is highly economical and profitable to the farmers, as well as to the sugar factories, because of low cost of cultivation and higher recovery.

In ratoon crop, the decomposition of trash releases many phytotoxic secondary metabolites like p-hydroxybenzoic acid, p-courmaric acid, 2, 4, dihydroxybenzonazilone and benzonazinone, which affect root as well as shoot growth of new tillers and finally reduce the yield (Gupta, 1981). In general, the productivity of ratoon crops is very low as compared to plant cane (Mujumdar and Gangai, 2007). The major factor contributing to this phenomenon of yield reduction is soil sickness, caused by the allelochemicals released through sugarcane trash and exuded by root system of ratoon canes (Gupta, 1981, Chou, 1995, Wang *et al*., 1984). The perusal of information on monoculturing clearly indicated that soil sickness is the main culprit of multi-ratooning of sugarcane.

II. Material and Methods

Selection of sites: In high recovery zone the maximum frequency of ratooning was recorded up to six in a village Adur, Tal. Karvir, District Kolhapur. In medium recovery zone (Pune region) through extensive survey, a village Malegaon, from the area of Malegaon Sahakari Sakhar Karkhana, Limited, Malegaon Bk. (Shivnagar), Tal. Baramati, district Pune was selected.

Selection of sugarcane cultivars: The most popular sugarcane cultivars Co 86032 and CoC 671 preferred by farmers were selected for present study. These cultivars had good rationing ability and high yielding capacity.

Analysis of yield parameters:

1. **Height of millable cane:** The millable cane height (cm) was measured in harvested, detopped cane from the basal end up to the top end. The millable cane height was recorded from the randomly selected 25 canes and average values were recorded in the table.
2. **No. of internodes per cane:**The total numbers of internodes per cane were counted from randomly selected 25 canes and average values were recorded.
3. **Weight of cane:** Weight of randomly selected 25 millable canes was measured by using spring balance and mean values were recorded.
4. **Analysis of juice quality:** The randomly selected 25 millable canes after harvesting were crushed to obtain the juice. The juice was analyzed in laboratory for brix %, pol % (sucrose percent juice), CCS % and purity %, by using the method approved by the ICUMSA.

Brix percent and pol percent of juice were calculated by using the Schmitz's table and CCS percent was calculated with the help of corrected brix percent and pol percent values by using the following formula.

C.C.S. % = (S-(B-S) x 0.4) x 0.74

Where,

S = Sucrose percent juice

B = Brix percent juice (corrected)

0.4 = multiplication factor
0.74 = crusher factor
Juice purity percent was calculated by using the following formula,

$$\text{Juice purity \%} = \frac{\text{Sucrose percent juice}}{\text{Brix percent juice}} \times 100$$

III. Result

Table 1: Effect of monoculturing on yield parameters of sugarcane cultivars CoC 671 and Co 86032 from high recovery zone.

Frequency of ratooning	Millable cane height (cm)		No. of internodes		No. of millable canes/stool		Weight of millable cane (kg)	
	CoC 671	Co 86032	CoC 671	Co 86032	CoC 671	Co 86032	CoC 671	Co 86032
Plant cane	255.00±35.79	265.12±18.74	22.10±3.32	23.00±2.54	12.00±1.68	13.00±0.91	2.15±0.32	2.25±0.24
2nd	210.12±16.94	245.35±19.78	21.00±2.73	21.30±1.29	10.10±0.81	11.20±0.90	1.95±0.25	2.00±0.12
3rd	160.24±17.69	180.43±27.12	19.70±2.76	20.30±2.64	8.50±0.93	9.35±1.40	1.35±0.18	1.50±0.19
5th	150.41±19.61	160.37±22.50	18.40±1.30	18.20±1.64	6.30±0.82	8.50±1.19	1.18±0.08	1.20±0.10
6th	145.74±20.45	148.65±13.46	16.65±1.50	17.21±1.55	6.00±0.84	7.15±0.64	1.05±0.09	1.10±0.09
$LSD_{0.05}$	30.57	27.46	3.24	2.66	1.42	1.38	0.28	0.22
Significance	**	**	*	**	**	**	**	**

Table 2: Effect of monoculturing on yield parameters of sugarcane cultivars CoC 671 and Co 86032 from medium recovery zone.

Frequency of ratooning	Millable cane height (cm)		No. of internodes		No. of millable canes/stool		Weight of millable cane (kg)	
	CoC 671	Co 86032	CoC 671	Co 86032	CoC 671	Co 86032	CoC 671	Co 86032
Plant cane	235.05±32.99	242.14±17.12	29.00±4.35	31.00± 3.42	14.00±1.96	16.25±1.14	2.00±0.30	2.15±0.23
2nd	202.32±16.31	234.67±18.91	21.20±2.76	22.40±1.36	11.50±0.92	14.50±1.16	1.75±0.22	1.85±0.11
3rd	155.14±17.13	158.28±23.79	19.15±2.68	20.15±2.62	9.50±1.04	10.00±1.50	1.45±0.20	1.50±0.19
5th	148.23±19.32	149.55±20.99	18.50±1.30	19.74±1.78	9.12±1.18	9.75±1.36	1.50±0.10	0.90±0.08
6th	132.15±18.54	140.26±12.70	16.15±1.46	17.00±1.53	8.15±1.14	8.95±0.81	1.10±0.099	1.15±0.10
$LSD_{0.05}$	28.70	25.27	3.62	3.01	1.73	1.61	0.27	0.21
Significance	**	**	**	**	**	**	**	**

[#] Data are mean values (n=5) followed by ±standard deviation. '*', '**' and 'ns' represent significance at $p<0.05$, $p<0.01$ and non-significance, respectively.

Effect of monoculturing on yield parameters of sugarcane ratoon:

In highly profitable cash crop like sugar cane, the cane yield and juice quality as well as sugar recovery etc. are most important for growers as well as sugar factories. Various factors such as irrigation, fertilizers, soil, climate and frequency of ratooning had influence on almost all the yield attributes like millable cane height, no. of internodes, no. of millable canes per stool and weight of millable cane. All these finally contribute to cane yield per hectare, which is adversely affected by multi-ratooning practice. It is the major drawback in multi- ratooning of sugarcane. The analysis of all such parameters will help to predict the loss/decline in cane yield with every ratoon. The level of autotoxicity, degree of soil sickness, desertification of soil microflora, exhaustation of soil nutrients will be under stood through these studies.

1. Millable cane height :

The results recorded in table 1.revealed that millable cane height was significantly reduced in CoC 671 and Co 86032 in high recovery zone. The degree of reduction was increased with increasing frequency of ratooning as compared to plant cane. The range of reduction in millable cane height was from 255.00 and 265.12 cm (plant cane) to 145.74 and 148.65 cm (sixth ratoon) in CoC 671 and Co 86032 respectively.

The results recorded in table 2. had indicated quite similar trend in reduction of millable cane height, no. of internodes, no of millable canes and weight of millable cane in CoC 671 and Co 86032 from medium recovery zone. The values of reduction in millable cane height were ranging from 235.05 and 140.26 cm (sixth ratoon) in CoC 671 and Co 86032 respectively.

Similar was the range of reduction in both the cultivars in yield parameters like number of internodes and number of millable canes per stool. All the results were highly significant.

Highly significant reduction was observed in most reliable yield parameter i.e. weight of millable cane in both the cultivars (table 1). The decrease in cane weight was from 2.00 and 2.15 kg (plant cane) up to 1.10 and 1.15 kg (sixth ratoon) in CoC 671 and Co 86032.All the result shown highly significance.

2.Internodes:

Exactly same trend was seen in no. of internodes percent in both the cultivars in high recovery zone. The reduction was from 22.10 and 23.00 (plant cane) to 16.65 and 17.21 (sixth ratoon) in CoC 671 and Co 86032. All the results are highly significant in Co 86032 and less significant in CoC 671 (Table 1).

3.Number of millable canes/stool:

The results recorded in same table (Table 1) had indicated drastic reduction in no. of millable canes per stool in both the cultivars. The degree of reduction was increased with the increasing frequency of ratooning. The rage of reduction observed was from 12.00 and 13.00 (plant cane) to 6.00 to 7.15 (sixth ratoon).

4.Weight of millable cane:

Drastic reduction in weight of millable cane was noted in CoC 671 and Co 86032 as compared to plant cane. The level of reduction was increased from plant cane (2.15 and 2.25 kg) to sixth ratoon, which showed the highest reduction (1.05 and 1.10 kg).

5.Millable cane height (Medium Recovery zone):

The results recorded in table 2 had indicated quite similar trend in reduction of millable cane height, no. of internodes, no of millable canes and weight of millable cane in CoC 671 and Co 86032 from medium recovery zone.

The values of reduction in millable cane height were ranging from 235.05 and 140.26 cm (sixth ratoon) in CoC 671 and Co 86032 respectively.

Similar was the range of reduction in both the cultivars in yield parameters like number of internodes and number of millable canes per stool. All the results were highly significant (Table 2).

Highly significant reduction was observed in most reliable yield parameter i.e. weight of millable cane in both the cultivars (table 2). The decrease in cane weight was from 2.00 and 2.15 kg (plant cane) up to 1.10 and 1.15 kg (sixth ratoon) in CoC 671 and Co 86032.All the result shown highly significance.

Effect of monoculturing on juice quality:

Table 3: Effect of monoculturing on juice quality parameters of sugarcane cultivars CoC 671 and Co 86032 from high recovery zone.

Frequency of ratooning	Brix (%)		Pol (%)		CCS (%)		Purity (%)	
	CoC 671	Co 86032	CoC 671	Co 86032	CoC 671	Co 86032	CoC 671	Co 86032
Plant cane	22.16±1.57	22.46±1.81	20.41±1.24	21.56±0.89	14.58±1.03	15.69±1.26	92.25±5.61	95.31±3.93
2nd	21.20±1.08	20.05±1.42	20.05±1.62	20.59±1.25	15.15±0.77	16.15±1.14	93.79±7.56	95.99±5.84
3rd	20.50±0.65	20.00±1.02	18.57±1.31	19.32±1.56	16.50±0.52	18.05±0.92	93.90±6.64	92.10±7.43
5th	19.45±0.80	19.12±0.60	18.48±0.94	19.21±1.36	17.34±0.71	19.08±0.60	94.23±4.80	93.25±6.59
6th	19.04±1.16	19.03±0.78	18.32±0.58	18.67±0.95	18.65±1.13	20.21±0.83	94.45±2.99	93.54±4.77
$LSD_{0.05}$	1.45	1.60	1.57	1.62	1.14	1.29	-	-
Significance	**	**	*	**	**	**	ns	ns

Table 4: Effect of monoculturing on juice quality parameters of sugarcane cultivars CoC 671 and Co 86032 from medium recovery zone.

Frequency of ratooning	Brix (%)		Pol (%)		CCS (%)		Purity (%)	
	CoC 671	Co 86032	CoC 671	Co 86032	CoC 671	Co 86032	CoC 671	Co 86032
Plant cane	22.10±1.56	22.40±1.81	20.40±1.24	21.55±0.89	14.60±1.03	15.65±1.26	92.27±5.61	95.30±3.93
2nd	21.30±1.09	20.15±1.42	20.20±1.63	20.50±1.25	15.20±0.78	16.10±1.14	93.75±7.56	96.00±5.84
3rd	20.40±0.65	20.05±1.02	18.45±1.30	19.25±1.55	16.55±0.52	18.15±0.93	93.91±6.64	92.05±7.42
5th	19.35±0.80	19.10±0.60	18.40±0.94	19.20±1.36	17.33±0.71	19.10±0.60	94.25±4.81	93.22±6.60
6th	19.10±1.16	19.10±0.79	18.35±0.58	18.65±0.95	18.70±1.14	20.25±0.83	94.40±2.99	93.60±4.77
$LSD_{0.05}$	1.45	1.60	1.57	1.62	1.14	1.29	-	-
Significance	**	**	*	**	**	**	ns	ns

[#] Data are mean values (n=5) followed by ±standard deviation. '*', '**' and 'ns' represent significance at $p<0.05$, $p<0.01$ and non-significance, respe

The juice quality parameters like brix, pol and CCS and purity percent are involved in sugar yield. The analysis of influence on all above parameters, due to multi- ratooning will predicted the status of synthesis and accumulation of sugar, its yield and productivity level.

From the results shown in table 3 on juice quality of sugarcane cultivars CoC 671 and Co 86032 from high recovery zone it was screen that there was significant decrease in brix percent in both the cultivars as compared to plant cane. The reduction in brix percent ranged from 22.16 to 22.46 % (plant cane) to 19.04 and 19.03 % (sixth ratoon).

The reduction in pol % in both the cultivars in high recovery zone showed decrease with increasing frequency of ratoon. The level of reduction from plant cane to sixth ratoon was ranged from 20.41 and 21.56 (plant cane) to (6th ratoon).

The results shown in the same table revealed that the CCS percent was increased with increasing frequency of monoculturing. Which is the most common feature of ratoon. The increase in CCS % is always coupled with reduction in cane yield.

The results on purity percentage (Table 3) in both the cultivars influenced by monoculturing revealed that in CoC 671, it showed slight increase over plant cane in 2^{nd} to 6^{th} ratoon. But in Co 86032 there was reduction in purity% in all the ratoons studied as compared to plant cane. However the changes were non significant.

The impact of monoculturing on all juice quality parameters of both the cultivars from medium recovery zone had shown similar pattern and range of reduction in brix, pol, CCS and purity % (Table 4). Amongst all juice quality parameters the results on purity% in both recovery zones and cultivars were non significant.

The present investigation had very clearly indicated that both the yield and juice quality parameters were adversely affected under multi-ratooning in both cultivars.

IV. Discussion

Effect of monoculturing on yield parameters of sugarcane:

The results tabulated in Table 1 and 2 indicated that in both the recovery zones during multi-ratooning, the yield parameters like millable cane height, no. of internodes, no. of millable canes per stool and weight of millable cane were negatively influenced in both cultivars under monoculturing.

Kadam *et al*. (2007) indicated that millable cane height and no. of millable canes were more in Co 86032,while cane weight was more in CoC 671 at Kolhapur region (high recovery zone). Hooda *et al*. (1988) indicated the contribution of millable canes, cane height, internodes and cane thickness towards cane yield.

Singh *et al*. (2002) showed that number of millable canes per stool, single cane weight and stalk diameter reflected highly positive direct effect on ratoon yield at genotypic level. Similarly Neeraj and Singh (2005) showed that the single cane weight, cane diameter and no. of tillers per stool are important characters contributing towards cane yield. Therefore improvement in these characters should be given due consideration for getting higher yield in sugarcane under ratoon cultivation. Pawar (1974) noted that increased potassium causes profuse tillering in sugarcane.

The reports of Mengel and Kirkby (1982), Agarwal (1994), Vyas *et al.* (1999), Katiyar *et al.* (1999) indicated that nitrogen content in soil governs the growth, canopy development, productivity and yield in crop plants. In present investigation the nitrogen content was decreased in ratoon crop with increasing frequency of ratooning. It might be the reason for declined cane population and yield in sugarcane.

According to Shrivastava *et al*. (2000) the tiller mortality was lower in plant cane as compared to ratoon, hence the maximum number of millable canes gradually reduced in subsequent ratoon. The average cane weight was also relatively decreased in ratoon crops during ratoons.

According to Sundara (1999) and Pawar *et al*. (2007) cane yield declined drastically, while CCS% and sugar yield increased in the successive ratooning than plant cane. Similar was the trend in both cultivars during monoculturing. The 5^{th} and 6^{th} ratoon showed drastic reduction in cane yield but CCS % was higher than plant cane.

Mujumdar and Gangai (2007) reported reduced yield in 2^{nd} ratoon as compared to 1^{st} ratoon. They also observed higher yield in Co 86032 than CoC 671.But the cane yield was declined in successive ratoons, which is a prominent feature in state of Maharashtra. Similarly Shrivastava *et al*. (1992) reported that sugar yield of ratoon was comparatively lower than the plant crop and it declined in successive ratoons. Naidu and Venkataramana (1988) also recorded reduced cane yield during ratooning. Sinha and Swaminathan (1984) claimed that some abiotic factors were responsible for the gaps in potential cane yield. Verma (1995) noted gradual decline in cane yield with the increasing number of ratoons. The rate of decline in yield was depending upon many other factors such as soil, climatic conditions, variety, intensity of insects, pests and diseases as well as crop management methods.

The shallow root system of ratoon declined cane yield and tillers. The other factors responsible for originate at a higher level than those of preceding ones. Consequently, the root system of ratoon plants became shallower and shallower, with the increase in number of ratoons. This shallow root system is unable to supply adequate water and nutrients for the growth of new tillers leading to declined cane growth, height and yield under multi-ratooning.

Wang *et al.* (1967a) while studying the yield decline of sugarcane in Taiwan, reported that it was due to phytotoxic substances released from the decomposition of sugarcane residues in the soil. They had recorded five different phenolic acids and six short-chain acids in decomposing sugarcane leaves in waterlogged soils. Studies by

Lovett and Hurry (1992) in Australia also indicated that allelopathy was involved in yield decline in sugarcane. Similar may also be the reasons for yield decline in both cultivars studied in present investigation.

Usually the cane yield in ratoon is poor and hence the yield gap between plant and ratoon crops is by 10 to 20% in tropical belt. But Sundara (2003) indicated that it can be improved over the plant crop by proper management practices.

Bell *et al*. (2001) also reported that the cane yield in 2^{nd} and 3^{rd} ratoon was highly reduced than 1^{st} ratoon, due to substantial decline in the productive capacity of soils under sugarcane monoculture, which was due to the reduction in stalk number and weight. Poor ratoon yield was one of the main reasons for low average cane yield of the country (Sundara, 1987).

Major role in severe ratoon yield reduction is played by different allelochemicals existing in sugarcane trash and its decomposing residues. Many workers like Rice (1984), Korner and Nicklisch, (2002), Leu *et al.* (2002), Inderjit and Duck (2003) claimed that different allelochemicals significantly reduce the growth and yield of different crop plants.

Effect of monoculturing on juice quality:

Similar to cane yield, the juice quality is also important in sugar yield, recovery etc. The juice quality attributes like pol, brix, purity, CCS % are given due importance, which also changed due to impact of various biotic and abiotic factors.

In high recovery zone and all frequencies of ratooning the juice quality in terms of brix and purity % was better in CoC 671, while pol and CCS % was better in Co 86032. Similar trend was also noted in medium recovery zone for both cultivars under monoculturing (Table 3 and 4). Kadam *et al*. (2007) reported that purity and CCS % was better in ratoon crop than plant cane in Co 86032 and CoC 671 in Kolhapur region. The findings of Singh *et al*. (2003) clearly indicated that the brix, purity and CCS % were positively correlated with sugar yield. As suggested by Sharma and Katiyar (1986) brix percent, number of internodes, millable cane height and girth were found to be highly important characters associated with sugar yield. In present study it was noted that these parameters were negatively influenced by successive ratooning of Co 86032 and CoC 671, which may be due allelochemicals accumulated in ratoon soil, released from trash and decomposing residues.

These allelochemicals had adverse impact on juice quality, cane yield and growth also. Patel *et al*. (1990), Rao *et al*. (1997) and Lonsdale and Gosnell (1975) noted that time of harvesting has a considerable effect on cane yield and juice quality in 1^{st}, 2^{nd} and 3^{rd} ratoon.

It may also be true for both cultivars, which showed higher sugar yield inspite of all negative influence. Thus the results of almost all parameters studied in both cultivars grown in high and medium recovery zones under multi-ratooning, revealed that allelochemicals, soil sickness, autotoxicity, nutrient deficiencies, soil enzymes, soil microflora etc. are playing crucial role and affect ratoon cane growth, tillers, cane population, cane yield as well as juice quality by acting synergistically through changes in cane metabolism.

V. Conclusion

All yield parameters such as height and weight of millable cane, no. of canes per stool and no. of internodes per cane were significantly reduced with the increasing frequency of ratooning as compared to plant cane in both cultivars. Higher reduction was recorded in Co 86032 than CoC 671. Under multi-ratooning growth parameters, physiological and enzymological parameters were affected, which had shown negative influence on yield parameters and finally resulted in reduction of yield.

In both cultivars the juice quality parameters such as brix and pol percentage was decreased with increasing frequency of ratooning. However CCS and purity percentage were increased.

The negative influence recorded in every aspect investigated in both the cultivars and recovery zones might be attributed to the presence of different organic and inorganic constituents as well as allelochemicals like terpenoids, flavonoids and bitter principles existing in the leaves, trash and old root systems. These organic and inorganic constituents as well as different allelochemicals might have caused synergistic impact on various metabolic processes, growth and yield of sugarcane under ratooning. The overall findings of the present investigation are in agreement with several allelopathy workers.

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