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Challenges of Ripening of Sugarcane at Tendaho, Metahara and Wonji-Shoa Sugar Estates

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Abstract
Ripening in sugarcane refers to an increase in sugar content on a fresh weight basis before commercial harvest. In Ethiopian Sugar Industry ripening of cane especially at the early and late periods of crushing shows a decline against the mid periods of crushing. Thus, an effort was made to show the trend of ripening, associated losses by considering the problem of ripening at Tendaho, Metahara and Wonji-Shoa Sugar Estates. To have concrete information, cane plantation harvest result, meteorological and experimental data were used. From the trend analysis and experimental data it is concluded that the conventional ripening method by withholding water has draw back in exploiting the maximum attainable recovery potential at Metahara, Wonji-Shoa and Tendaho Sugar Factories. At Wonji-Shoa, the loss in sucrose percent cane from the peak value attained in the crushing months ranged from 0.02 to 0.95 %. Similarly, at Metahara, the deviation in sucrose percent cane from the peak in the crushing moths ranged from 0.32 to 1.10 %. In general, maximum loss in sucrose percent cane was observed in the early and late periods of crushing. Temperature and residual moisture plays an important role in the ripening of cane and the challenge also seems to occur at Finchaa and newly emerging sugar factories located in the lowlands of the country.

1. Introduction

Sugarcane (*Saccharum* spp.), a C_4 perennial grass, is a member of the Gramineae family and produces large quantities of disaccharide (sucrose) which is processed and refined into granulated sugar (Anon, ND). Sugarcane's value is determined by the amount of recoverable sugar per weight of cane (Orgeron, 2003). The economic success of sugarcane crops is determined by the accumulation of sucrose (Batta *et al.* 2002). On a weight basis, about three quarters of a sugarcane stem is water (Sundara, 2000). Out of the total weight transported to mill, the proportion of sucrose varies during the crushing period due to the fact that sugarcane is influenced by the soil fertility, irrigation, varieties, weed, pest and disease control, and many other factors including the length of the crushing season (Humbert, 1968). Conventionally, drying-off by withholding irrigation water few weeks before harvesting is exercised to facilitate cane burning and harvesting operation, and somehow improve sucrose content of cane (Singles *et al.,* 2000; James, 2004). However, this practice does not adequately induce sucrose accumulation (Gosnell and Lonsdale, 1974).

Sugarcane ripening refers to the accumulation of sucrose in the internodes. In Ethiopia, sugar content in cane is normally lowest in the start of the crushing period (lack of complete drying of the soil due to rain prior to cane crushing) and late period (due to the prevailing high temperature). The potentiality of the problem most probably will prevail in the lowland regions of the country where temperature is high in both the early and late periods (Tadesse, 2006).

Profit maximization is a must to be viable in the competitive global market. Thus, the sugar sector is making a remarkable effort to maximize profit through increasing sugar production per unit area. Among the less attention given challenges, low recovery of sucrose in the early and late periods of cane crushing is emerging to be the focus of the sector. Furthermore, the increase in temperature due to climate change (Srivastava and Rai, 2012) coupled with the high cost of production of sugar makes the industry incompetent in the world market. Thus, increasing sugar yield per unit area is identified as an opportunity. In Ethiopian sugar industry, attaining high sucrose content is the prime and critical objective of cane cultivation among others.

2. Methodology

2.1. Sugar Factories Considered

Three sugar factories located in the Rift Valley regions of Ethiopia were considered from which Wonji-Shoa and Metahara are currently producing sugar and have different physiographic set-up, while Tendaho Sugar Factory is a new sugar factory to commence crushing soon (Table 1). Furthermore, the remaining sugar factory Finchaa and newly emerging sugar factories. Their geographic location and meteorological information is described on Table 2.

2.2. Data Acquisition

Cane plantation production data from 2005/6-2009/10 were used to study the sucrose recovery trend of Wonji-Shoa and Metahara Sugar Estates to elucidate the sucrose recovery trend. From each month from all fields the sucrose percent cane was collected during the crushing period to determine the trend. For rainfall and temperature trend analysis, the meteorological data collected and documented for the respective years (2005/6-2009/10) were used. However, for Tendaho, since the factory is new, mean values for sucrose yield from two experiments and meteorological data were used. For Finchaa sugar factory and newly emerging sugar projects only geographic and climatic data were used from the respective stations and other sources (Table 2). Loss in sucrose percent cane (%) was calculated as the deviation from the peak value attained in the cane crushing months (February for Wonji-Shoa and December for Metahara). To substantiate the content, different publications were reviewed. Especially the South African research findings were used broadly in the review due to their rich experiences in relation to sugarcane ripeners' management. The data was analyzed using Excel-data sheet for plotting charts of sucrose yield and meteorological parameters (rainfall and temperatures).

Table 1. *Meteorological and geographic information of Wonji-Shoa, Metahara and Tendaho sugar factories*

Factory	Geographic Location	Altitude (m.a.s.l)	RF (mm)	Temperature (0C)		
				Min.	Max.	Mean
Tendaho Sugar Factory	11^0 30'- 11^0 50' N and 40^0 45'- 41^0 03' E	365 to 340	222	21.9	37.2	29.6
Metahara Sugar Factory	$8^0$51'N and $39^0$52'E	950	554	17.5	32.6	25.1
Wonji-Shoa Sugar Factory	8°31'N and 39°12'E	1550	800	15.3	26.9	21.1

Note: RF=rainfall; m.a.s.l= meter above sea level; mm= millimeter; Min=minimum; Max=maximum.

Table 2. *Meteorological and geographic information of Finchaa Sugar Factory and newly emerging Sugar Factories (Kessem, Wolkait, Kuraz, Arjo-Dedessa and Beles)*

Factory	Geographic Location	Altitude (m.a.s.l)	Rainfall (mm)	Temperature (0C)		
				Min.	Max.	Mean
Finchaa Sugar Factory	8°31'N and 39°12'E	1350-1650	1300	15.0	31.0	23.0
Kessem Sugar Project	39° 54' E and 09° 09' N	800 to 850	569	18.9	34.2	26.6
Wolkait Sugar Project	13°50' N and 37°35' E	725**	910	19.5	35.5	27.5
Kuraz Sugar Project	5°8' to 6°16' N and 35°43'-36°13' E	400	991	20.2	34.9	27.6
Arjo-Dedessa Sugar Project	$8^0$30' to $8^0$40' N and $36^0$22' to $36^0$43' E	1350	1400	20.5	25.4	23.0
Beles Sugar Project	$11^0$30' N and $36^0$41' E	1110	1447	16.4	32.5	24.5

Note: RF=rainfall; m.a.s.l= meter above sea level; mm= millimeter; Min=minimum; Max=maximum.
**Source: Google earth.

3. Result and Discussion

3.1. Sucrose Percent Cane Pattern at Wonji-Shoa and Metahara Sugar Estates

Analysis result of five consecutive years (2005/06-2009/10) for sucrose percent cane across the crushing months at both sugar estates showed a sigmoid curve indicating a decline in sucrose content of cane at the start and end periods of cane crushing (Figure 1). The declining trend in sucrose value in the starting period of crushing (Figure 1) is conspicuously arises from the residual moisture in the soil from the main rainy season (June-September). However, in the late period of cane crushing principally, the prevailing high temperature combined with the intermittent rainfall plays a role in the decline of sucrose content of cane.

At both sugar estates (Figure 1), in the early cane crushing season the crop experiences low sucrose content. This is due to the presence of residual moisture from the previous months (June to September). The presence of enough moisture in the soil reduces sucrose content of cane (Donaldson and Bezuidenohout, 2000). At both Sugar Estates withholding irrigation (drying-off) is the conventional practice under use. This practice has limitations in enhancing the sucrose content of cane in the early period of crushing, due to the lack of complete drying of the soil prior to harvest. In contrary to this, in the late period of crushing, the relatively higher prevailing temperature reduces sucrose content of cane since cane growth is favoured (Gawander, 2007).

According to Glover (1973), the decrease in temperature reduces the rate of respiration as opposed to photosynthesis indicating that a greater portion of photosynthetic product is available for storage during reduced temperatures. The decrease in growth rate as age of cane increases, a lower amount of sugar is used in new tissue formation which results in storage of a greater amount of sucrose in the stalk (Cardozo and Sentelhas, 2013). In the process of ripening, the level of fructose and glucose reduces and sucrose storage maximized (Clements, 1962).

Gawander (2007) reported that lower temperatures during winter are very important for natural ripening of sugarcane and elevated temperatures reduce natural ripening and quality of sugarcane. In the presence of vigorous cane growth, the amount of sucrose accumulated is reduced. The rate of photosynthesis and respiration are influenced to large extent by the variations in temperature which has a direct effect on radiation use efficiency (Sinclair and Muchow, 1999; Donaldson, 2009).

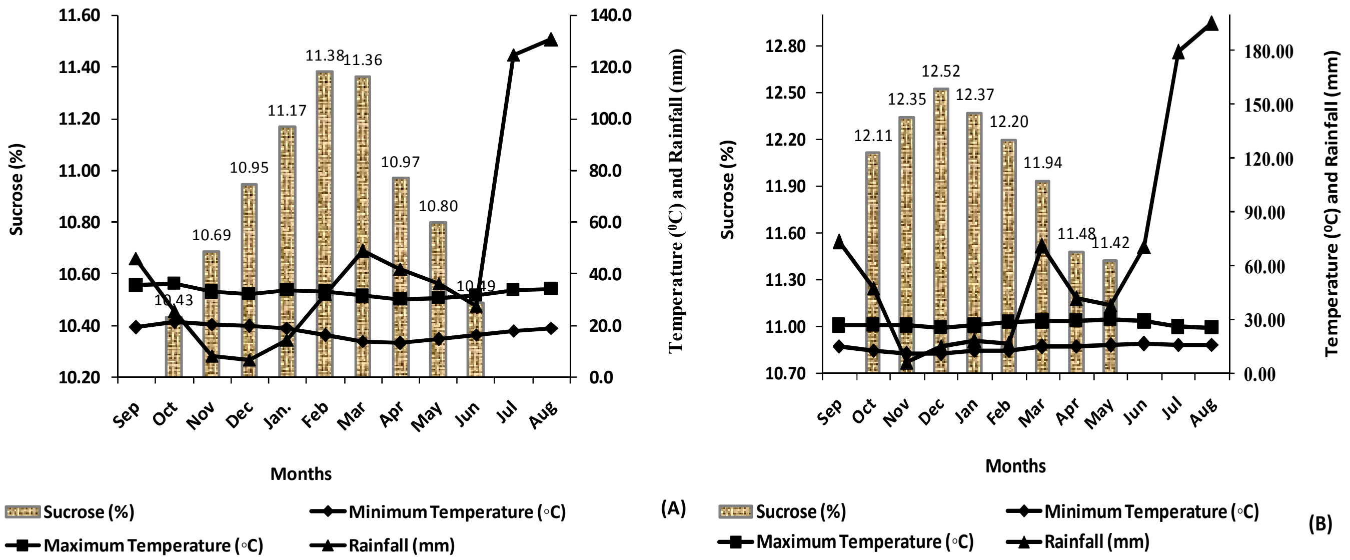

Figure 1. *Average sucrose yield (%) of harvested cane, temperature (maximum and minimum) and rainfall pattern from 2005/6-2009/10 and 2005/6-2009/10 cropping seasons at Metahara (A) and Wonji-Shoa (B) Sugar Estates, respectively.*

The highest mean sucrose percent canes were obtained in the months of February and December at Wonji-Shoa and Metahara; respectively (Figure 1). The decrease in sucrose percent cane in the early and late periods from the peak value attained in the cool period indicates the loss that occurs during the crushing months. In general a mean sucrose loss of 0.53 and 0.54 is observed at Wonji-Shoa and Metahara; respectively (Table 3).

Table 3. *Estimated loss in sucrose percent cane during the crushing months against the peak attained in February and December at Wonji-Shoa and Metahara Sugar Factories, respectively*

Wonji-Shoa				**Metahara**			
Months	**Sucrose (%)**	**Peak Sucrose (%)**	**Sucrose Loss (%)**	**Months**	**Sucrose (%)**	**Peak Sucrose (%)**	**Sucrose Loss (%)**
October	10.43	11.38	0.95	October	12.11	12.52	0.41
November	10.69	11.38	0.70	November	12.35	12.52	0.18
December	10.95	11.38	0.44	January	12.37	12.52	0.15
January	11.17	11.38	0.21	March	12.20	12.52	0.32
March	11.36	11.38	0.02	April	11.94	12.52	0.59
April	10.97	11.38	0.41	May	11.48	12.52	1.04
May	10.8	11.38	0.58	Jun	11.42	12.52	1.10
Jun	10.49	11.38	0.89				
Mean Loss			0.53	Mean Loss			0.54

The mean day temperatures of Wonji-Shoa and Metahara sugar estates are therefore 21.1 and 25.1 ^{0}C, respectively (Table 1 and Figure 1). In line with this Gururaj (2001) stated that a mean day temperature of 12-14 is desirable for proper ripening. Thus, the enhanced temperature at Wonji-Shoa and Metahara resulted in a lower sucrose recovery (Figure 1). Furthermore, the relatively higher mean daily temperature at Metahara (25.05 ^{0}C) has resulted in a lower sucrose recovery as compared to Wonji-Shoa (21.10 ^{0}C) (Figure 1).

3.2. Sucrose Percent Cane at Tendaho Sugar Factory

Though there has been no data on commercial harvesting at Tendaho Sugar Factory, from the experiments conducted, the presence of ripening problem can be deduced (Table 4). The first experiment entitled with effect of age of seed cane on yield and yield components of sugarcane at Tendaho sugar factory (Experiment 1) was harvested in the month of December at 12 months of age, while the second experiment was effect of number of buds per sett and intra-row spacing of setts on yield and yield components of sugarcane (Experiment 2) was harvested in the month of September at age of 12 months. The temperature and rainfall patterns experienced during the study periods are illustrated on Figures 3. The mean sucrose percent cane obtained averaged for the main effects of the varieties was 7.85 and 6.78; for experiment 1 and 2 respectively.

Table 4. *Mean values of sucrose percent cane of sugarcane varieties obtained from two experiments conducted at Tendaho Sugar Factory at 12 months of age*

December Harvesting (Experiment 1)		**August Harvesting (Experiment 2)**	
Varieties	Sucrose (%)	Varieties	Sucrose (%)
B52298	8.86	Co680	6.60
NCo334	7.36	N14	6.85
Mex 45/245	7.33	Co740	6.89
Mean	7.85	Mean	6.78

Note: Experiment 1 = Netsanet *et.al* (2014); Experiment 2 = Netsanet (2009).

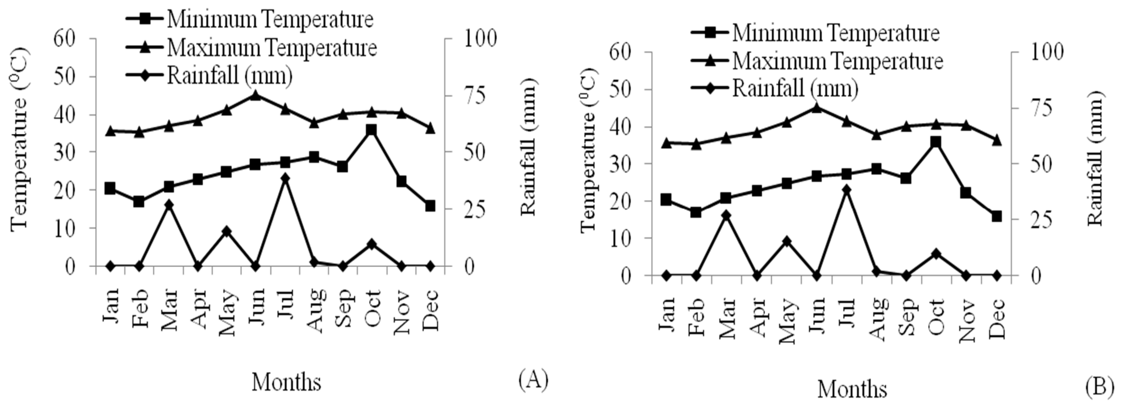

Figure 2. *Average minimum and maximum temperatures and rainfall pattern of Tendaho on the studies of effect of age of seed cane on yield and yield components of sugarcane from January, 2012-December, 2013 (A) and effect of number of buds per sett and intra-row spacing from September 2007 to August 2008 (B).*

In both experiments percent recoverable sucrose was poor (Table 5). The mean sucrose percent cane from the three varieties in experiment 1, in general, ranged from 7.33 to 8.86% and was higher than that of experiment 2 which ranged from 6 to 6.89%. The relatively higher percent sucrose cane in experiment 1 was due to the relatively low temperature and absence of rainfall during the months of October and November (Figure 3A). The mean day temperatures recorded during the ripening period prior to harvest in October and November were 38.4 and 31.5 °C, respectively; however, in the second experiment the mean day temperatures for July and August was 32.75 °C. In contrary to this, Legendre (1975) asserts that temperatures of 17-18 °C appear to be favorable for the partition of photosynthates into the internodes and the accumulation of sucrose. On the other hand Gururaj (2001) states that for proper ripening a mean day temperature of 12-14 °C is desirable, since at higher temperature during ripening, inversion takes place with considerably reduced sugar recoveries.

The feasibility study of the Tendaho Sugar Project forecasted the possibility of obtaining 10.2 % recoverable sucrose (TDSP, 2005). However, the result of the two experiments showed lower values (Table 4).

3.3. Possible Challenges at Finchaa and Newly Emerging Sugar Factories

The climatic condition prevailing at Finchaa sugar factory and the newly emerging sugar projects (Belese, Kuraz, Wolkait, Arjo-Dedessa and Kessem) indicates the possibility of challenges in ripening as it can be judged from the mean daily temperature data (Table 2). The mean temperature in general ranges from 23.0 to 27.6 ^{0}C which is higher than the mean day temperature range required for maximum accumulation of sucrose (Gururaj, 2001; Legendre, 1975). Furthermore, the presence of rain would also contribute its share for the low recovery especially after the main rainy season in a similar way as Wonji-Shoa and Metahara Sugar Factories (Figure 1). It is common to observe low recovery at the early and late period of crushing at Finchaa Sugar Factory (Data not presented). The rainfall experienced in these areas (Table 2) in the main rainy period (summer) will also impose a challenge in the early crushing period.

4. Conclusion

This study has displayed the problem of natural sugarcane ripening in the sugar factories of the country with available data and the possibility of the challenge in the emerging ones. Research and developments made abroad showed the possibility of solving the problem of ripening in the early and late periods of cane crushing by using chemical ripeners. Some studies conducted in Ethiopia also indicated the presence of response, though inconclusive and further work is required. The appreciation of the ripening problem needs to be the point of departure for successful integration of sugarcane ripeners. Thus, it is emphasized that the presence of low recovery in the early and late periods of crushing is a conspicuous challenge of the sugar factories.

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