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The Effect of Harvesting Age on Maturity Indices of Quality Parameters of Sugarcane Varieties at Metahara Sugar Estate in Cool Season

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ABSTRACT

A study was conducted in cool season from October to December, 2009 to determine optimum harvest age at specific maturity indices of three sugarcane varieties at Metahara Sugar Estate. The treatments consisted of three harvest age (18, 19 and 20 months after planting, MAP) and three varieties (B52298, NCo334 and Co740) grown on clay soil. Data were collected from plots arranged using two factors in a completely randomized design with twelve replications. Maturity indices (sheath moisture, hand refractometer brix ratio, maturity factor and sucrose to reducing sugar ratio) indicated that there was a lower index of maturity at 18 MAP than 19 and 20 MAP. Higher sheath moisture resulted in a low status of maturity indices (maturity factor and sucrose to reducing sugar ratio) was observed for NCo334 variety at the three harvest ages. However, lower sheath moisture content with good maturity index (maturity factor and sucrose to reducing sugar ratio) was obtained for Co 740 variety at 19 and 20 MAP. The recoverable sucrose was negatively correlated ($P<0.01$) with sheath moisture among the three varieties. Accordingly, good maturity indices were observed at 19 and 20 MAP for Co 740 and B52298 varieties. However, optimum maturity indices were not shown at 20 MAP for NCo 334. Therefore, this study revealed that quality indices of maturity could be a potential criterion's to fix optimum harvest age of sugarcane varieties grown on clay soil.

Keywords: Harvesting age, maturity, indices, juice quality, sugarcane, season.

INTRODUCTION

Sugarcane (*Saccharum officinarum* L.) is an important industrial crop of the World (Hunsingi, 1993). Ethiopia is endowed with conducive cane growing condition that can make the country potential for sugar industry. Consequently, the Ethiopian Government has aimed to enhance sugar production to meet the current and future demand of the country and export surplus sugar abroad by the end of 2014. Various efforts are also made to enhance the productivity of the crop in various parts of the country by making sound studies (Netsanet *et al.*, 2014a; Netsanet *et al*., 2014b).

In Ethiopian Sugar Estates, cane maturity is customarily determined by taking the crop age and appearance as criteria for several years. From the scientific point of view, the current practice is rigid because crop maturity in sugarcane is greatly affected by planting time, crop management practices, varieties and weather conditions. In line with this Milanes*et al*., (2010) reported that chronological age of sugarcane is not a reliable guide to determine cane maturity alone. Therefore, other factors such as weather conditions, varieties and soil type may have more direct bearing on the real maturity of canes than the crop age. From a holistic point of view, harvesting schedule of Metahara Sugar Estate has not followed chronological order of sugar quality indices as the existing harvesting practice does not consider physiological, anatomical and latent conditions of canes before harvesting. Consequently, the Sugar Estate harvests canes with ages ranging from 18 to 24 MAP without considering the extent of cane maturity before to fix time of harvest for all cane varieties (MSF, 2006). Thus, proper cane harvesting should be done at right methods to identify maturity status of cane varieties.

Pre-harvest cane quality testing is a best tool to monitor the dynamic change on the standing crop with respect to cane. The goal of this quality testing method is to provide productivity evaluation before harvesting so as to increase the efficiency of strategic and administrative decisions (Salassi *et al*., 2002). Currently, however, information on the effect of pre-harvest sampling and chronological order of harvest fields on cane yield and quality has limited application at Metahara Sugar Estate. Therefore, this study was conducted with the objective of determining optimum harvesting age based on maturity indices of sugarcane varieties grown on clay soil.

MATERIALS AND METHODS

Description of Experimental Site

The Estate is located in the Awash Valley basin at 80˚ 53' N and 390˚ 52' E, about 200 km south east of Addis Ababa in Oromiya Regional State with a mean elevation of 950 m.a.s.l. The area has mean maximum and minimum temperatures of 33.2 and 17.7°C, respectively. The mean maximum and minimum relative humidity is 88 and 37.7%, respectively. The soil types of the sugar estate are grouped into four distinct textural groups as heavy clay, clay, clay loamy and loamy soil groups.

Experimental Procedure and Design

A study was conducted from October 2009 to December 2009 at Metahara Sugar Estate to determine optimum harvesting age at specific maturity indices of sugarcane varieties. For the study, six experimental sites were selected from clay texture which covers 63% of cane of Metahara Sugar Estate (Anon, 2009). Three cane varieties (B52298, NCo334, and CO740) planted by Metahara Sugar Estate on 30 April 2008 on clay soil were used for the study in order to determine optimum harvest age at specific maturity indices of sugarcane varieties. The harvest ages of those varieties were 18, 19 and 20 MAP that rested in October, November and December, respectively.

The three varieties were grown separately at three sites (fields) on clay soil. The necessary parameters were collected from the three varieties grown on clay soil with about the same planting and harvesting date. Twelve replications of the sampling spot for each variety were allocated in an 'X' shape sampling survey over 87 m^2 area. Each harvest months were allocated as a stratum separate spot which was laid out by selecting twelve rows with 5 m length keeping 1.45 m row spacing with a sampling spot area of 87 m^2 from the existing plantation of the estate for each variety. From each stratum spot a separate sample was selected using a multistage and simple random sampling per each month. Data were collected from plots arranged using two factors in a completely randomized design with twelve replications.

The cane and juice samples were taken from predetermined spots well within the boarder of the sampling area ($87m^2$) for juice and cane yield parameters. The ratio of hand refractometer brix reading of top one third of stalk to bottom one third of the stalk was determined by hand refractometer brix reading device from five randomly selected millable stalks. The sucrose to reducing sugar ratio was determined from crushed juice taken from the top portion of the cane (8-10 internodes). Maturity factor is the fraction of the difference of estimated sucrose of the bottom-one third of whole cane stalk to the top-one third of the stalk over the bottom one third of the stalk from five randomly selected millable stalks (Bakker, 1999).

Juice analysis (Brix, Pol and Purity) was determined randomly from 20 crushed millable stalks on each sampling spot at harvest following the procedures of Yusof *et al*., (2000). The juice brix which refers to the total solids present in the juice expressed in percentage was measured by using refractometer brix reading device from crushed juice. The percent pol is an apparent sucrose content of a sugar product determined by a means of a polar meter. The recoverable sucrose refers to the total recoverable sugar percent in the cane. This was calculated as described by (Yusof *et al*., 2000) as: Percent Recoverable Sucrose (%) = ([Pol % -(Brix-Pol %) 0.61] 0.75). Purity is the percentage of pol percent to brix reading in crushed juice. Cane yield was determined on each harvest time by weighing the total harvested millable stalk from a multi stage sampling spots of 29 m^2 areas with a weighing balance of 200 kg capacity. Sugar yield was estimated as the product of cane yield per hectare and average estimated recoverable sucrose content (%) of 20 millable canes taken from the sampling spots (Yusof *et al*., 2000) as: Sugar yield = [Cane Yield (t/ha) x Estimated Recoverable sucrose (%)] /100. Leaf sheath moisture content was determined by taken twenty leaf sheath samples from five millable stalks per plot starting from +3, +4, +5, and +6 leaf sheaths counting from top of the cane to the bottom (Clements, 1980).

Data Analysis

The collected parameters of the three harvest age for three varieties grown on clay soil over three sites, a pooled analysis was conducted with two factors (harvest age and variety) by a completely randomized design using Gen Stat, 12.2.

RESULTS AND DISCUSSIONS

Analysis of the data indicated that the sheath moisture content at 18 months after planting (MAP) was higher than that of 19 and 20 MAP (Table 1). The sheath moisture content for variety Co740 close to a lower limit of standard moisture index (68%) of ripening cane at all harvest times (Table 2). However, B52298 and NCo334 varieties reached beyond the upper limit standard moisture index (74%) at harvest time of 20MAP (Table 2). The sheath moisture content of Co740 was significantly lower than that of B52298 and NCo334 (Table 1). According to Bakker (1999), a moisture level of 68-74% in sheath of 3^{rd} to 6^{th} leaves from the top has been used as an index of ripeness of sugarcane. The sugarcane variety of NCo334 had high sheath moisture content with lush green appearance followed by B52298 and Co740 on the three harvest times (Table 1). In line with this, Saliendra *et al*. (1991) found that sugarcane varieties differ in their ability to obtain soil moisture at a given tension and their ability to protect against excessive loss through transpiration. The recoverable sucrose of the three varieties was negatively correlated ($P< 0.05$) with sheath moisture content (Figure 1 and Table 1).

The current result suggests that the level of sucrose among varieties could be slightly affected by moisture content in cane tissue. Moreover, percent purity of Co740 was higher than NCo334 variety during the study period (Table 1). Therefore, NCo334 may need extended period to drop sheath moisture index to a level attained by Co740 variety so that percent purity can be improved during ripening period. The hand refract meter reading of top to bottom brix ratio was significantly higher at 19 and 20 months than at 18 months harvest time (Table 1). However, the standard hand refractometer brix ratio (0.95-0.98) reading was reached at 20 MAP (Table 1). The difference in top to bottom brix ratio among each harvest month reflects the existence of differences in maturity status of cane during ripening period of sugarcane. According to this study, the maturity status was good at harvest times of 19 and 20 MAP than 18 MAP. However, the hand refractometer brix ratios NCo334 variety was slightly lower than the standard index this brix ratio (Table 1).

Table 1: Effect of harvest age on sheath moisture, juice quality, cane and sugar yield of the three cane varieties grown at Metahara Sugar Estate in 2009/2010 cropping year

Parameters	SM (%)	RS (%)	PU (%)	HBR	CY (t/ha)	SY(t/ha)
Harvest age						
18 MAP	74.93a	12.36	90.02	0.86b	210.77b	26.08
19 MAP	73.86b	12.44	90.02	0.93a	220.15a	27.34
20 MAP	72.83c	12.34	90.51	0.95a	225.04a	27.7
LSD (5%)	0.79	ns	ns	0.03	9.02	Ns
CV (%)	2.3	6.38	2.68	5.89	6.38	6.44
Variety						
B52298	75.14b	12.32	90.23ab	0.96a	246.88a	30.42a
NCo334	76.51a	12.22	89.46b	0.88b	214.61b	26.20b
Co740	69.97c	12.59	90.86a	0.89b	194.47c	24.51c
LSD (5%)	0.79	ns	1.13	0.03	9.02	1.44
CV (%)	2.3	6.38	2.68	5.89	6.38	7.56

Means followed by the same letter case in a column are not significantly different from each other. SM, sheath moisture; RS, recoverable sucrose; PU, percent purity; HRB, hand refractometer brix ratio; CY, cane yield; SY, sugar yield; MAP, month after planting; ns, not significant

Table 2: Sheath moisture content and hand refractometer Brix ratio of three cane varieties in different harvest ages at Metahara Sugar Estate

Parameter	Sheath moisture content			Hand refractometer Brix ratio		
Variety	B52-298	Nco-334	Co-740	B52-298	Nco-334	Co-740
MAP						
18	76.24	78.09	70.45	0.92	0.83	0.83
19	74.89	76.45	70.24	0.98	0.89	0.90
20	74.28	75.00	69.21	1.00	0.92	0.95

Sheath moisture of 68 to 74% is a standard index on ripeness of sugarcane; Hand refractometer Brix ratio of 0.95-0.98 is a standard index on ripeness of sugarcane; MAP, month after planting.

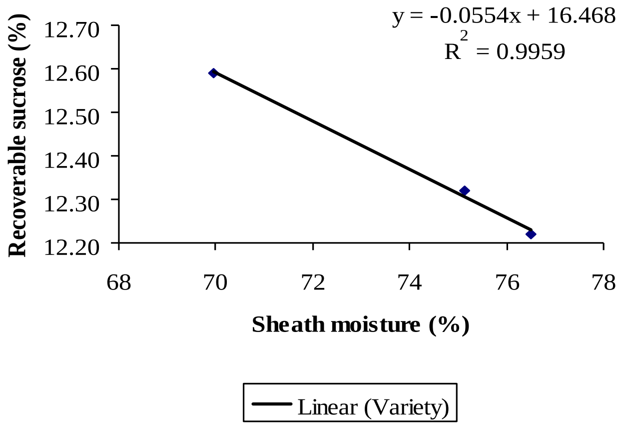

Figure 1: Linear regression between sheath moisture and recoverable sucrose among three sugarcane varieties grown at Metahara Sugar Estate

The difference in top to bottom ratio of hand refractrometer brix reading among the genotypes reflect the existence of genetic variation for the trait in sugarcane. There was a significant interaction between harvest time and variety on sucrose to reducing sugar ratio. Lowest sucrose to reducing sugar ratio for all varieties at 18 MAP revealed that there was an incomplete process of sugar accumulation on top portion of cane. The sucrose to reducing sugar ratio of NCo334 was lower than the other two varieties because this variety had high content of sheath moisture during the study period (Table 3). Thus, highest sucrose to reducing sugar ratio was obtained for Co740 followed by B52298 and NCo334 varieties at 19 and 20 MAP (Table 3). The current result indicated that the lowest values of maturity factor (good status of maturity level) were obtained at 19 and 20 MAP for B52298 and Co740 varieties. Accordingly of this index, maturity status increased from 18 to 19 MAP for B52298 and Co740 varieties (Table 3). However, this index was not a substantial change from 18 to 19 MAP for NCo334 (Table 3). Thus, the variety NCo334 may maintain its development process of vegetative growth from 18 to 19 MAP due to high amount of sheath moisture during the study period than the other varieties. Cane yield at 18 MAP was significantly lower than at 19 and 20 MAP which were not significantly different from each other for these varieties (Table 1).

Table 3: Interacting effects of harvest age and variety on maturity factor and sucrose to reducing sugar ratio at Metahara Sugar Estate in 2009/2010 cropping year

Parameter	**Sucrose to reducing sugar ratio**			**Maturity factor**		
	Variety			**Variety**		
MAP	B52298	NCo334	Co 740	B52298	NCo334	Co740
18	2.2e	2f	2f	20.92b	23.83a	22.92a
19	3.3b	2.4d	4.2a	12.00d	23.92a	12.83cd
20	3.3b	3.1c	4.2a	12.00d	21.83b	13.83c
LSD (5%)		0.11			1.02	
CV (%)		4.58			6.87	

Means followed by the same letter case in a row or column are not significantly different from each other

Sugar yield was not significantly affected by harvest age for the three varieties. The current study revealed the highest cane yield at 19 and 20 MAP was not attributed to a significant increase of sugar yield during these months (Table 1) because sugar yield is a function of both sucrose accumulation and vegetative growth (cane yield). Consequently, a substantial vegetative growth in terms of cane yield at 19 and 20 MAP may cause to retard sucrose accumulation in these months. Thus, vegetative growth in terms of cane yield and sucrose accumulation is a competitive physiological process during maturation period of sugarcane (Inman-Bamber*et al.*, 2008). From this result, it is evident that the ripening determination methodology of the Metahara Sugar Estate is not taking into account the sucrose accumulation during maturation period.

Therefore, the Metahara Sugar Estate should revise its strategy for cane ripening by taking standard sheath moisture and maturity index to fix harvest age with range 18 to 24 MAP instead of using the current practice of visual observation and age as the only criteria to decide fields for harvest. Accordingly, the hand refractometer brix reading from the upper third portion to lower third portion of stalk should be used a maturity indices of 0.98 for B52298 and 0.95-0.98 for Co740 and NCo334 varieties. Similarly, the sheath moisture content (in 3rd to 6th leaf from the top) should be used a maturity indices of 71-73% for B52298 and NCo334 varieties. Moreover, the sheath moisture index at 69-70% should provide a substantial recoverable sucrose for Co 740. Furthermore, the sucrose to reducing sugar ratio with a range of 4 to 4.2 and also maturity factor from 0 to 14% should be used as a maturity index to determine good status of cane maturity at harvest age for the three varieties. The maturity indices of all three varieties showed that the optimum sugar quality was obtained at 19 and 20 MAP as compared to 18 MAP. Moreover, the maturity indices of

NCo334 were relatively lower than the other two varieties at all harvest age. Thus, the maturity period should be extended for NCo334 variety with precise monitoring of sheath moisture regime to improve sugar quality indexes during ripening period. Harvest age of sugar yield (t ha^{-1}) at 18 MAP is biologically justifiable. However, the optimum harvest age for good sugar quality and high cane yield should be available at 19 or 20 MAP for B52298 and Co740. Likewise, good sugar quality and high cane yield is obtained at 20 MAP for NCo334.

CONCLUSION

Good quality maturity indices and high cane yield were observed at 19 and 20 MAP than 18 MAP for Co 740 and B52298 varieties. However, optimum maturity indices were not shown from 18 to 20 MAP for NCo334.Therefore, this study revealed that quality indices of maturity could be a potential criterion's to fix optimum harvest age of sugarcane varieties grown on clay soil.

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