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Determining Optimum Harvest Age of Sugarcane Varieties on the Newly Establishing Sugar Project in the Tropical Areas of Tendaho, Ethiopia

Hadush Hagos[1]*, Luel Mengistu[1] and Yohannes Mequanint[2]

[1]*Ethiopian Sugar Corporation, Research and Training Division, Sugarcane Production Research Directorate, Agronomy and Protection Research Team, Wonji Research Center, P.O.Box 15, Wonji, Ethiopia*
[2]*Ethiopian Sugar Corporation, Research and Training Division, Sugarcane Production Research Directorate, Wonji Research Center, P.O.Box 15, Wonji, Ethiopia*

Abstract

Field experiment was conducted to determine the optimum maturity of the major sugarcane varieties (*Saccharium officinarium* L.) with high sucrose content and sugar yield. Six levels of harvest ages (10, 12, 14, 16, 18 and 20 months) and four major varieties N-14, NCO-334, CO-680 and B52-298 which cover 90% of the area were used in a completely randomized block design with 6x4x3 factorial treatment arrangements. All data's were collected at the end of each level of harvest ages. Analysis of variance (ANOVA) showed that harvest age significantly influenced quality parameters (brix, pol, purity and ERS) and yield parameters (plant height, cane yield and sugar yield) ($P<0.001$). The important parameters of maximizing sugar yield and net revenue in relation to harvest date and crop age is expressed by t/ha/month as an index of time value of sugarcane crop. Considering the time value, increase in harvest age showed a negative impact on brix, pol, estimated recoverable sucrose, cane yield and sugar yield in the tropical area of Ethiopia. As a result high sugar yield was recorded at the early harvesting ages 12 and 14 months. However, optimum sugar yield was recorded on 12 months harvest age with economically acceptable marginal rates of return 178.13%. Therefore, adjusting harvest age to 12 months for the major sugarcane varieties was economically recommended to obtain optimum sugar yield with efficient time use at the tropical areas of Tendaho.

Keywords: Sugar project; ERS (Estimated recoverable sucrose); Sugarcane; Marginal rate of return

Introduction

Age of harvest is one of the most important factors affecting sugarcane productivity. Varietal differences in growth and maturity rates must be considered when harvesting decisions are made [1]. In addition to the difference of varietal maturity rates, environmental conditions, management practices, and pest pressure also influence the optimal harvest age of sugarcane along the coast. The climate elements, temperature, solar radiation, relative humidity and total rainfall variables that account for a major variation in harvest age among sugarcane growing countries [2]. Sugarcane varieties developed in South African Sugarcane Research Institute (SASRI) exhibit pronounced differences in their suitability to different harvest ages with faster maturing varieties being more suited to the 12-month cycle, and slower maturing varieties being suited to the 18-month cycle along the coast [3].

Cane maturity is usually determined by monitoring sugar yield parameters such as: Pol % cane, Brix % cane, commercial cane .sugar (CCS) and ton cane per hectare (TCH). However, most researchers focus their evaluation on Pol % cane and its value ranged from 10.49 - 17.86 [4]. In milling operations, the preferred varieties are those with Pol % cane and Brix % cane values nearly equal at maturity, and a Pol value 16 or greater and purity of 80 % or greater are commercially acceptable [5].

Sugarcane varieties differ in their ability to mature at different stages. In Iran for instance, the optimum age to harvest for certain cane varieties depends on whether the cane is early maturing (10-12 months), medium maturing (12 months) or late maturing (14-16 months) [6]. Some sugarcane varieties have relatively high sucrose content in early season and are defined as early maturing while it is the converse in others which are known as late maturing [6]. The crop season is also variable in different countries being 20 - 24 months in Hawaii, 13-19 months in Jamaica, 12-18 months in India, 16 months in Mauritius, 15 months in Queensland (Australia) and 10-14 months in Brazil [7].

Some sugarcane varieties must be harvested before achieving maximum sucrose levels to sustain early-season milling operations. "Early maturing" varieties are preferentially harvested during this time, recognizing that they may not have reached their peak sucrose content, but may have higher sucrose content than other later-maturing varieties [8]. Consequently, lack of maturity status makes it difficult to make informed harvest scheduling decisions and the time of ripening depends on characteristics which are closely related to the length of growing period [8]. The peak sucrose content of sugarcane at harvest time is affected by different growing and plant physiological conditions during the maturation period. Furthermore, the variation among soil on cane fields causes considerable differences in soil moisture holding capacity, degree of drying, and, consequently, the rate at which cane fields ripen [9].

In Ethiopian Sugar Estates usually cane maturity is customarily determined by taking the crop age and appearance as criteria for several years. From Scientific point of view chronological age of sugarcane is not a reliable guide to determine cane maturity alone [10]. Therefore, other factors such as varieties, weather conditions, and

***Corresponding author:** Hadush Hagos, Ethiopian Sugar Corporation, Research and Training Division, Sugarcane Research Directorate, Agronomy and Pretction Research Team, Wonji Research Center, P.O.Box 15, Wonji, Ethiopia, Tel: +251913823479; E-mail: hadgos@gmail.com

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soil type may have more direct bearing on the real maturity of canes than the crop age [11]. The current sugar production of the Ethiopian Sugar Industry covers only 60% of the annual demand for domestic Consumption while the deficient is imported from abroad. In order to make the country self-sufficient in sugar and export the surplus sugar and produce ethanol and other by-products, the Federal government of Ethiopia is working to establish sugarcane plantation on more than 400,000 ha in addition to the vast expansion project of the previously established farms with erection of high crashing capacity 10 new sugar mills.

The importance of determining yield potentials for sugarcane has been noted by many scientists with goals to aim for barriers to be broken. Law of the minimum suggests that there is always some factor limiting yield. Therefore, yield potential need to be defined in terms of the limiting factor [12]. There are many reasons for lower productivity of sugarcane but the most pertinent is improper implementation of sugarcane management practices [13].

However, harvesting many fields without considering crop age are common constraints in sugarcane production in the tropical areas of Ethiopian. Many sugarcane fields in tropical areas of Ethiopia were covered with over-stand cane having an age range of 20-30 month old. This will cause a decline both in yield and quality of sugarcane production due to heavy lodging, and remobilization of accumulated sucrose to supply newly growing side shoots. Similarly, over aged canes deteriorate their sucrose content by heavy lodging and remobilized to supply the unproductive bull shoots (newly growing shoots) [14]. Optimum harvest age of sugarcane varieties was not studied yet in the tropical area of Ethiopia. Considering this drawback, the study was carried out with the objective to determine the optimum harvest age of the major sugarcane varieties with high sucrose content and sugar yield.

Materials and Method

The experiment was conducted in the newly establishing Sugar Project of Tendaho which covers an area of 50,000 ha. Soils of the area were clay, silty-clay-loam in texture with mean maximum temperatures and average annual rainfall of 37.7°C; 220 mm. Six levels of harvest ages (10, 12, 14, 16, 18 and 20 months) and four major varieties N-14, NCO-334, CO-680 and B52-298 which cover 90% of the area were used in a completely randomized block design with 6x4x3 factorial treatment arrangements. Each plot had six rows with 6 m length and 1.45 m width for each row (6 m x 1.45 m x 6 rows) having an area of 52.2 m^2 for a single plot. The distance between plots was 2.9 m while it was 4.35 m between replications. The harvested plot consisted of four rows with 6 m length and 1.45 m width each (6 m x 1.45 m x 4 rows) with an area of 34.8 m^2.

To investigate the effects of the treatments quality and yield parameters were measured during the study. At harvest, twenty milleable stalks from the middle four rows were randomly sampled for weight measurement and total population of the middle four rows were counted to estimate cane yield [15]. Half of the twenty stalks were used for stalk length measurement and analysis of quality parameters (brix, pol and estimated recoverable sucrose) in the laboratory. Temperature corrected refractometer brix and saccharometer were used to determine the brix and pol percent of the cane [16]. Estimated recoverable sucrose was the combined effect of brix and pol percent's [17]. At the last sugar yield was estimated from cane yield and estimated recoverable sucrose [18]. All cultural practices were executed based on the current practices of Tendaho Sugar Project except harvesting. Economic analysis was done using partial budget analysis procedures [19]. The effect of harvest age on sugar yield of sugarcane varieties was analyzed using the appropriate analytical software (SAS 9). Mean separation was conducted using Duncan's Multiple Test Range (DMTR) at 5% probability level whenever significant differences were detected in the F-test.

Result and Discussion

Stalk height was significantly (P<0.0001) affected by harvest time (Table 1). The stalk height significantly increased with increasing harvest age until 16 months of the four varieties. This result demonstrated that there was a substantial amount of growth in terms of stalk height at the latest harvesting ages for the sugarcane varieties [20]. According to [21], ripening in sugarcane is characterized by rapid accumulation of sugar with a concomitant reduction in vegetative growth and cane elongation. The current study demonstrated that, a significant increase of stalk height from 10 to 16 months increase cane tonnage substantially during harvest time. However, the continued growth on top of cane in terms of stalk height may pose a problem on sugar recovery during processing [22]. This is due to the fact that the juice from the tops of young cane contains starch, ash, soluble polysaccharides and reducing sugars [23]. The stalk height showed significant (P<0.0001) difference

Harvest age (months)	PH (m)	CY (t/ha/month)	SY (t/ha/month)	Brix%	Pol%	ERS%
10	2.43^{d}	82.27^{a}	0.73^{b}	16.06^{b}	13.37^{b}	8.91^{c}
12	2.64^{c}	91.36^{a}	1.03^{a}	18.11^{a}	16.05^{a}	11.24^{b}
14	2.97^{b}	81.92^{a}	0.98^{a}	17.60^{a}	16.37^{a}	11.87^{a}
16	3.16^{a}	67.72^{b}	0.76^{b}	18.12^{a}	16.12^{a}	11.32^{ab}
18	3.19^{a}	53.33^{c}	0.48^{c}	16.10^{b}	13.51^{b}	9.07^{c}
20	3.20^{a}	40.88^{d}	0.26^{d}	14.05^{c}	10.63^{c}	6.49^{d}
Varieties						
N-14	2.83^{b}	68.91^{a}	0.71^{ab}	17.29^{a}	14.77^{b}	10.00^{b}
NCO-334	2.91^{b}	66.22^{a}	0.64^{b}	15.19^{c}	13.35^{d}	9.30^{c}
CO-680	3.19^{a}	72.43^{a}	0.73^{ab}	16.57^{b}	14.00^{c}	9.45^{c}
B52298	2.79^{b}	70.76^{a}	0.76^{a}	17.64^{a}	15.28^{a}	10.51^{a}
Age*Var	**ns**	**ns**	**ns**	***	***	***
CV (%)	**7.89**	**17.25**	**20.85**	**5.12**	**5.31**	**6.95**

Means followed by the same letter within a column are not significantly different. PH, stalk height (P<0.0001); CY: cane yield (P<0.001); SY: sugar yield (P<0.001); Brix%: Percentage of refractometer brix (p<0.001); Pol%: percentage of sacharometer pol (p<0.001); ERS: estimated recoverable sucrose (p<0.001); MAP: months after planting; ns: non-significant

Table 1: Yield and quality parameters of sugarcane varieties cane as influenced by harvest age in the tropical areas of Tendaho.

HA (month)	Sugar yield (t/ha/month)	Gross field benefit ($ USD /ha/month)	Total variable cost ($USD / ha/month)	Net benefit ($USD /ha/ month)	Change in net benefit ($USD /ha/month)	MRR (%)
10	0.73	484.43	0	484.43		
12	1.03	683.51	71.58	611.93	127.50	178.13
14	0.98	650.33	143.16	507.17		
16	0.76	504.34	214.74	289.60		
18	0.48	318.53	286.32	32.21		
20	0.26	172.54	357.89	(185.36)		

HA: harvest age; MRR: Marginal rate of return.

Table 2: Partial budget analysis of the sugarcane cane as influenced by harvest age.

with the four sugarcane varieties. CO-680 variety recorded the highest length as compared with N-14, NCo-334 and B52298 varieties (Table 1). This could be attributed to the difference in growth habit among sugarcane varieties during ripening period. In agreement with this result, another research results recorded there is varietals difference in stalk height among the sugarcane varieties [24].

Cane yield and sugar yield were significantly ($p<0.001$) influenced by harvest age. The profitability of sugar yield within various harvest ages considers a time value. So, analysis for harvest age was computed in terms of t/ha/month (Table 1). The important parameters of maximizing sugar yield and net revenue in relation to harvest date and crop age is expressed by t/ha/month as an index of time value of sugarcane crop [25]. Considering the time value, the result of this study revealed that, highest cane yield and sugar yield were recorded on 12 months harvest age, followed by 14 months harvest age. Significant increase in cane yield was recorded with an increase in harvest age from 10 to 14 months [26]. The major drop in sugar yield with an age restriction of below 12 months might be due to many hectares of crop being forced to be harvested when expected yields are extremely low as well as older crops being disallowed [26]. There is no significant difference in cane yield among the four sugarcane varieties. However, high cane yield was recorded from CO-680, N-14 and B52-298 sugarcane varieties (Table 1). On another hand, significant ($P<0.05$) difference in sugar yield was recorded among the sugarcane varieties. The current study revealed the high sucrose content on B52298, CO-680 and N-14 was attributed to a significant increase of sugar yield on these sugarcane varieties (Table 1). Because sugar yield is a function of both cane yield and sucrose accumulation [27].

Increased levels of harvest age significantly ($p<0.001$) influenced all quality parameters. The interaction of harvest age and sugarcane varieties showed highly significant ($p<0.001$) influence on quality parameters (Table 1). The highest pol and estimated recoverable sucrose were obtained at the 14 months harvest age (Table 1). This might be due to the dilution effect of sugarcane enzymes changing the reducing sugars and non-sucrose materials (fiber) to sucrose or it could be due to positive impact of harvest age on the yield components (plant height and cane yield) which allow accumulation of additional soluble solid or sucrose by on the harvest age. Percent of soluble solids, percent pol and estimated recoverable sucrose significantly increased as age of sugarcane increased until 14 months [25]. Beyond 14 months harvest age all quality parameters showed a declining trend which indicates the reduction of sucrose content due to heavy lodging and remobilization to supply the unproductive bull shoots (newly growing shoots (14). Harvesting either under-aged or over-aged cane with improper time of harvest leads to loss in cane yield, sugar recovery, poor juice quality and problems in milling [28]. Significant difference ($p<0.001$) of quality parameters was observed among the four sugarcane varieties. The highest Pol and ERS was recorded on N-14 and B52-298 sugarcane varieties (Table 1). This indicates that, those sugarcane varieties have the probability of high sucrose accumulation if the properly harvested in the proper age.

Economic Analysis

The profitability of sugar yield within various harvest ages considers a time value. So, the partial budget analysis for harvest age was computed in terms of t/ha/month (Table 2). The important parameters of maximizing sugar yield and net revenue in relation to harvest date and crop age is expressed by t/ha/month as an index of time value of sugarcane crop [24].

The partial budget analysis for showed that extending harvest age above 12 months were dominated (Table 2). Marginal rate of return for 12 months harvest age was 178.13%. Increasing harvest age above 12 months lead to increase in additional costs without compensating benefit. The marginal rate of return obtained at 12 months harvest age was above the 100% of the CIMMYT's minimum rate of return required for adoption of agronomic practices. The 178.13% MRR recorded at 12 months harvest age indicated that for every one dollar invested in sugarcane crop it could give a net return of 1.78 USD Dollars. Therefore, 12 months harvest age is more profitable and advisable to sugarcane cane because it gives opportunity to additional profit from investing additional cost.

Conclusions

Harvesting of sugarcane at a proper time i.e., peak maturity, by adopting right technique is necessary to realize maximum sucrose accumulation and sugar production in the tropical area of Tendaho with a least possible field losses under the given growing environment. Improper harvest age is recurrent problems of pre-harvest cultural practices, which severely affect quality and yield of sugarcane cane. All varieties are promising for the environment. However, N-14 and B52298 was recommended to have high percentage of area coverage because of high sucrose accumulation in early ages. The economic analysis indicated that 12 months harvest age gave the highest net benefit of 611.93 $/ha/month with acceptable MRR of 178.13%, respectively. In addition to this, over stand canes affect the growth of consecutive ratoons and creates a suitable environment for pest multiplication. Therefore, adjusting harvest age to 12 months for the major sugarcane varieties was economically recommended to obtain optimum sugar yield with efficient time use at the tropical areas of Tendaho.

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