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Original Research

Effect of Percent and Stage of Leaf Defoliation on the Quality of Sugarcane, at Arjo - Dedessa Sugar Factory, in Western Ethiopia

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Abstract

Sugarcane (*Saccharum spp.*) is unusual among field crops in that it is not the seed that have economic values, but rather the stalk. Sucrose is extracted from the large stalks that are produced by sugarcane plants. The effect of percent and stage of defoliation sucrose content as well as recovery percentage of sugar cane is still unknown. The experiment was conducted at Arjo-Didessa Sugar Factory which is located in East Wollega Zone of Oromia Regional State with the objective of determining the effect of leaf defoliation at different stages of sugarcane (*Saccharum officinarum*) on the quality. Effect of leaf defoliation at three different stages on quality of sugarcane juice was studied under field conditions. The methodology used include seven percent of leaf defoliation comprises of 10%, 20%, 30%, 40%, 50%, 60% and 0% (control) and three growth stages of defoliation at 9, 10 and 11 month of sugarcane was arranged in Randomized Complete Block Design. From the results obtained, the analysis of variance indicated the sugar recovery in stems of defoliated sugarcane (11.70 %) from 30 % leaf removal at 11 month age was significantly different from undefoliated (9.03 %) when defoliation applied at 0 % of leaf removal with 9 month age. These results indicated that sugar cane plants could be partially defoliated with changing sucrose production and the retention of defoliated leave in the field providing advantage to the sugar factory, that should be used as fodder, increase nutrient conservation, reduce weed growth, and conserve soil moisture on substantial losses of C and N due to sugarcane leaf burning at harvesting stage. However, further research is required to strengthen the investigation and repeating similar research on different location are necessary to recommend to all Ethiopian sugar factories.

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INTRODUCTION

Sugarcane is one of the most important crops in the world (Dagar *et al*., 2002). Sugarcane belongs to the genus (*Saccharum* L.,) of the grass family (Poaceae) and originated in Papua New Guinea, as original habitat and from where it spread to south East Asia and India in the course of few thousand years (Bull, 2000).

The Office of Agricultural Economy, (2008) reported that the sugarcane burned in the field had many disadvantages such as weight reduction, microorganism destroyed easily, rapid decrease of sweetness, high production cost of plant, that organic material and structure in soil were destroyed and decreased sugar production. Sugarcane harvesting is a critical step that must be managed to maintain good quality and quantity of sugarcane production. Farmers harvesting sugarcane have a leaves-removing or leave defoliating step and cut the stem closing to the soil, then cut the top of sugarcane stem. Leaves and leaf sheaths of sugarcane caused delay of harvesting. Moreover, the sugarcane crop that has not been fully leaves-removed (leave defoliations) could carry some soil, sand and mud, thus damaging the downstream sugarcane process machine and reduced sugar yield (Yangyeun and Wongpicheth, 2008).

The contamination will be increased more when using the car to grip sugarcane to the truck. Sugarcane leaf-defoliating tools could help to speed up sugarcane harvest and reduce contamination. However, researchers in the past had focused on tools or equipments used to help harvest sugarcane crop; for example, sugarcane harvester, knife used for sugarcane crop on performance to sugarcane harvester. However, leaf-removal machinery can solve the problems of sugarcane burning and reduce contaminants. Retention of unburned residues can increase nutrient conservation, reduce weed growth, and conserve soil moisture on the other hand substantial losses of C and N due to sugarcane residue burning have been reported (Viator *et al*., 2006).

In general physiological and morphological responses of individual plants to defoliation was evaluated in chronological sequence beginning with plant function during "steady state" growth prior to defoliation, followed by the short-term effects of defoliation, and concluding with long-term processes contributing to the reestablishment of "steady-state" growth (Steingraeber *et al*., 1993). Particularly according to Gutierrez *et al* (2004), mechanical defoliation of sugar cane plants (*Saccharum* spp.) will provide leaves that can be used as fodder but the effect of partial mechanical defoliation on sucrose content, enzyme activities and agronomic parameters of sugar cane is still unknown and also the concentration of sucrose in the stems of partial defoliated plants was significantly different from that found in intact plants. Similarly, Dendooven *et al.* (2004) indicated that some agronomic parameters and enzyme activities were different in defoliated plants compared with intact plants except for the moisture content which was higher in defoliated plants than in intact ones. These makes sugar cane plants could be partially defoliated changing sucrose production and agronomic parameters while providing leaves that could be used as fodder.

The Ethiopian Government is building modern sugar factories and expanding the existing ones with the aim of maximizing the production volume to alleviate the scarcity of sugar in the country (EIA, 2008). This work was conducted in view of the limited information on the effect of leaf defoliation at different stages of sugarcane on biomass yield and quality but the hypotheses tested in these studies, the effect of leaf defoliation at different stages of sugarcane on biomass yield and quality were superior in defoliated than undefoliated sugarcane. This research was initiated with the objective of to evaluate the effect of defoliation at different stages on yield, quality, and response of sugarcane crop to defoliation and its advantage to increase sugar recovery at Arjo-Didessa Sugar Factory.

MATERIALS AND METHODS

Description of the Study Area

The experiment was conducted at Arjo-Didessa Sugar Factory located in East Wollega Zone of Oromia Regional State. Arjo Dedessa Sugar Factory is located at 9^0 N latitude and 39^0 E longitudes, with an altitude of 1300-1600 masl. The area receives high rain fall from June to September with average of 1477 mm annually. The mean average temprature of the study area is 22^0C, the soil types of the experimental site are dominated by Vertisols and few red Latosols (ESISC, 2008).

Experimental Materials and Design

NCO-334 sugarcane variety was used as an experimental material. Treatments comprising six levels of defoliation percent, 10 %, 20 %, 40 %, 50 %, 60 % and control of 0 % of percent of defoliation at three different stages of sugarcane, that is, at 9 month growth stage (S_1), 10 month growth stage (S_2) and at 11 month growth stage (S_3) and each of which replicated three times. The percent of defoliation was made after counting total number of leaf from three randomly sampled and the leaf was defoliated according to their treatment. The two factors were combined factorially and arranged in randomized complete block design (RCBD). The actual experimental area was designed with PL = number of treatment x plot length + spacing between plot x number of block – 1i.e (7 X 5m + 2m x 3 -1= 40m) and PW = number of block x plot width + spacing between block + number of spacing (3 x 7.25m + 2m x2 =25.75m). The total area used was 40m x 25.75m (1030m^2). Plot width = 1.45 x 5 and plot length= 5m, the distance between block used were 2m, between plot were 1m and the sugarcane was spaced at 1.45m between rows.

Data Collection and Sampling

The data were collected on four quality parameters (%Brix, %Pol, % purity and cane recovery (sucrose %) attributes. The middle two rows out of the four rows in each plot were used for data collection, the number of plants per row was 1260 and the distance between rows were 1.45m. Brix % was measured in the cane juice analytical laboratory of Arjo Dedesa Sugar Factory with the help of bench refracto meter. The refracto meter was adjusted to zero with distilled water. A drop of juice was placed on the refracto meter then the brix was read (Blackburn, 1984).

The polarization of juice was measured by a Polari meter according to the method described by Horne's dry lead (South African Sugar Technologist's Association (1985). Approximately 150 ml of the sample was taken in a bottle provided with stopper. Sufficient lead sub acetate powder (1.5g) was added for clarification, shacked vigorously to disperse the lead sub-acetate completely and then allowed to stand and filtered through a fluted filter paper held in the funnel. Some of the filtrate was used for rinsing the Pol tube and filled completely. Then the polarization (Saccharimeter reading) was read. The Pol % obtained from Schmitz’s table by using the Brix of the sample and Saccharimeter reading. Pol % is actually cane sugar present in the juice, expressed in percentage (Khedkar *etal*. 2000).

There for Purity % was determined with the help of the following relationship following Islam *et al*., (2011).

$$\textbf{Purity \%} = \frac{(\text{Pol \%}) \times 100}{\text{Brix \%}}$$

Sugar recovery was calculated with the help of the following formula following Islam *et al*., (2011).

Recoverable Sucrose (%) =

$$[\text{\% Pol} - (\text{\%brix} - \text{\%Pol})\ 0.52]\ 0.75$$

Where: 0.52 =Non-sugar factor and 0.75 =Cane factor

Data Analysis

The data collected were subjected to analysis of variance (ANOVA) using SAS software (SAS, 2004). Treatment means that exhibited significant differences were separated using the least significant difference at 5% level of significance (SAS, 2004).

RESULTS AND DISCUSSION

The analysis of variance for the different quality parameters recorded are presented in Table 1. The analysis of variance table for percent of defoliation showed a highly significance difference for all quality parameters while stage of defoliation showed significantly (P< 0.05) effect on all the parameters except for sucrose percentage. Similarly, their interaction effect showed that a significance difference for all characters except for purity percent (Table 1).

Table 1: Mean square values for the quality parameters recorded for sugarcane as affected by the interaction of percent defoliation and stage of defoliation grown at Arjo Dedessa in 2014/15 cropping season

Characters	Sources of Variation				
	PD	ST	PD X ST	MSE	REP
Internodes number	70.88**	3.19ns	4.91*	3.41	5.28
Internodes length	11.83**	2.49ns	3.45*	2.72	3.15
Stem diameter	292.86**	3.05ns	12.89**	10.39	90.04
Internodes weight	113476.73**	2997.57ns	12844**	7548.7	1.34
Sugarcane height	0.032**	0.0043ns	0.061**	0.012	0.02
Leaf area index	61.14**	7.43**	3.75**	0.20	0.54
Biomass yield	14.97**	3.70**	1.08*	0.43	4.30
Number of leaf	3.75**	1.15*	1.17*	0.65	2.49
Brix %	16.82**	1.03*	2.03*	0.58	0.97
Polarity %	22.99*	4.58ns	16.39*	14.42	17.63
Purity %	575.65**	533.36**	366.68ns	378.58	553.1
Sucrose %.	3.78**	0.011ns	0.25*	0.22	0.40

*, ** and ns indicate significance at the 0.05 and 0.01 probability levels and non-significance level, respectively.
PD = Percent of defoliation, ST = Stage of growth, PD x ST = Interaction of percent of defoliation and stage of growth, MSE = Mean square error and REP = Replication

Effect of Defoliation on Brix %

The highest (22.70%) Brix % was recorded when 20% of the leaf removed at 11th month growth stage (Table 2). However, the lowest brix % was recorded at undefoliated with nine month growth stage as18.42 % (Table 2). While defoliating from 60 % of leaf removal at nine month growth stage, 30 % of leaf removal at ten month growth stage and 50 % of leaf removal at11 month growth stage was not significantly different from 40 % of leaf removal at 11 month growth stage (Table 2). This shows that defoliation from 30–60 % recorded indicates the positive in increasing the total soluble solid in the juice.

On average mean value of total soluble solid in juice (brix %) recorded for the three growths stage gave 20.80% (Table 2). From this experimental study the highest brix % was recorded as different stage and percent of defoliation significantly increases. In general in this study the total solids content present in the juice expressed in percentage were unaffected by defoliation but increases quality of sugar (Table 2).

Studies on the quality parameters of cane stalk, juice and leaves in comparison to defoliation have been conducted in a number of cane growing regions. Results from Louisiana (Birkett, 1965), South Africa (Muir *et al*., 2009; Reid and Lionnet, 1989; Scott *et al*., 1978) and Australia (Ivin and Doyle, 1989) shows that the presence of reasonable amounts of brix and fiber in the defoliated cane juice than undefoliated.

The results suggest that the stage of defoliation induces significant changes in sugarcane juice brix % composition and its sensory attributes. The effect of late leaf removal was much more effective than early leaf removal in affecting final brix composition and quality. Brix % from the late defoliation treatment was rated the most preferred as of global value. It has also found that in grape the removal of some of the leaf material from the canopy whilst berry ripening occurs can increase Brix in the fruit (Holzapfel and Rogiers, 2002). It is suggested that it was due to the increased photosynthetic rate of the remaining un-defoliated leave. Conversely (Ezahounani and Williams, 2003) leave defoliation of basal has shown to have no effect on Brix.

Table 2: Mean Values for Brix %, polarity % and sucrose % as affected by percent defoliation and stage of defoliation interaction of sugarcane grown at Arjo Dedessa in 2014/15 cropping season.

Parameter	Brix %			Polarity %		
DF %	Stage of defoliation			Stage of defoliation		
	9	10	11	9	10	11
0	18.42	21.9	19.02	21.15	19.0	21.83
10	19.34	19.0	19.28	20.50	20.5	21.44
20	19.27	18.9	22.70	21.47	20.9	20.30
30	21.60	22.2	21.59	21.36	30.6	20.43
40	21.93	20.7	22.13	19.77	19.1	19.35
50	21.24	21.9	22.34	19.72	19.8	19.64
60	22.01	21.9	19.60	19.92	19.6	20.44
Mean		**20.80**			**20.80**	
CV %		**3.67**			**18.23**	
LSD 0.05		**0.47**			**0.29**	

*, ** and ns indicate significance at the 0.05 and 0.01 probability levels.

Effect of Defoliation on Polarization (Pol %)

The mean value recorded for polarity percent is shown in table 2, was 20.80 % at overall growth stage. The highest polarity percent was recorded from 30 % of leaf removal at ten month growth stage (Table 2). However, the lowest polarity percent was recorded from 0 % of leaf removal at10 month of growth stage (Table 2). This shows that defoliation at 30 % was more beneficial than at 0 % to increase the actual sugar in the juice. Although defoliation affected by 0 %, 20 % and 30 % of leaf removal at 9 month growth stage was not significantly different from 10 % of leaf removal at 11 month of growth stage (Table 2). This indicates defoliation percent was more beneficial than growth stage in this study.

From the result obtained even if differences exist among defoliation treatment after defoliation polarity percent was increased which have the advantage of having good quality of the actual cane sugar present in the juice. This is due to the increase in the photosynthetic potential of the remaining leaves and leads to enhanced Pol % resulted in biomass accumulation and sucrose yield. Khan and Ahsan, (2000) working on *B. juncea* showed that eliminating the cost of maintaining senescing leaves by leaf removal may lead to increased plant yield. The Pol for the second stage of sugarcane sample meets maximum Pol 99.90 Z set for sugar yield (USC, 2008) and was significantly (P>0.05) higher than for the first and third stage of sugarcane development. Polarization for both defoliated and un-defoliated samples was measured by automatic Polari-meter calibrated in (ISS).

Effect of Defoliation on Purity %

On average the mean value of purity percent recorded was 91.1 % at all growth stage (Table 3). The highest purity percent (96.36 %) was recorded from 9 month growth stage but the lowest (86.31 %) purity percent was recorded at 11 month growth stage (Table 3); this shows that a higher purity indicates the presence of higher sucrose content out of the total solids. The purity of sugar cane process stream products (*e.g.,* cane juice, molasses, raw sugar *etc.*) is a measure of product quality and was determined by calculating the ratio of % Sucrose and % total Solids as a percentage which were measured by double polarization and dry substance measurements.

Table 3: Mean value analysis for purity % as affected stage defoliation effect of sugarcane grown at Arjo - Dedessa in 2014/ 2015 cropping season

Stage of defoliation	**% purity**	**% Defoliation**	**% purity**
9 Month	96.36[a]	0	89.10[b]
10 Month	90.63[a]	10	91.72[b]
11 Month	86.31[b]	20	91.72[b]
Mean	**91.1**	30	94.96[a]
CV	**21.35**	40	86.30[b]
LSD	**12.13**	50	92.40[ab]
		60	91.60[b]
		Mean	**91.1**
		CV	**21.35**
		LSD	**18.53**

Mean within columns followed by the same letters are not significantly different.

Effect of Defoliation on Sucrose Percent

The analysis of variance for sucrose % showed that a highly significant effect for percent of defoliation and the interaction effect, however, stage of defoliation had no significant effect on the sugar recovery (Table1). On average the different factor combinations gave 10.52 % of sucrose % (Figure 1). The highest sucrose percent (11.70 %) was recorded when 11 month growth stages were affected by 30 % of leaf removal and this followed by 20 % of leaf removal at 10 month growth stage. However, relatively the lower sugar recovery (9.03 %) was recorded from undefoliated control 0 % of leaf removal at 9 month growth stage (Figure 1). Hence the interaction effect of defoliation and stage more beneficiary than both of the main factor.

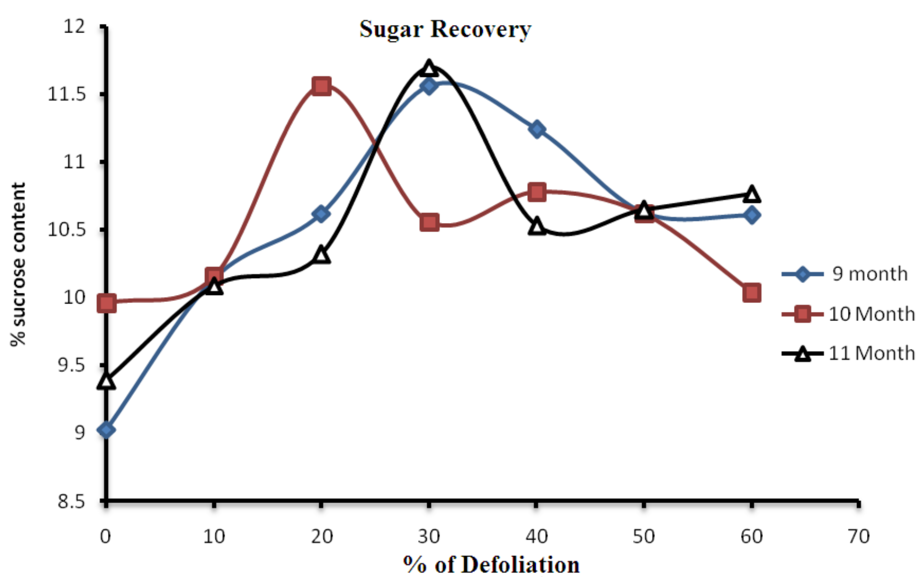

Figure 1: Sucrose concentration % in juice of sugarcane as affected by different stage of defoliation and percent leaf defoliation interaction grown at Arjo Dedessa in 2014/15 cropping season

Therefore, results obtained after affecting the different growth stage by defoliation treatment significantly increases quality of sugar recovery within the juice used to increase the actual cane sugar. Results obtained indicated that the interaction effect was more beneficial than defoliations and stage for improving cane biomass yield and sugar recovery and also defoliated leaves could be used as animal fodder after 9 month of crop age without affecting sugarcane yield.

The sucrose concentration in defoliated sugarcane was significantly different from the un-defoliated sugarcane and there were also significance differences between treatments of defoliations (Figure 1). This agreed with A study by Pammenter and Allison (2002) has shown that defoliation of alternate fully emerged lamina of sugarcane (*Saccharum officinarum* L.) at 155 d decreased the laminas area by 40% and also resulted in proportional partitioning of assimilate in leaves and stem with increased accumulation of sucrose.

Other studies also reported that Partial defoliation has resulted in increases of sucrose contents in Cherry trees (*Prunus Cereasus*) (Layne and Flore, 1995), but (Neefs *et al*., 2002) reported that mechanical partial defoliation of witloof chicory (*Cichorium intybus*) affected plant growth. They found that the total fresh weight of defoliated plants stayed markedly lower compared with intact plants. Integrating production of sugar and using the leaves as fodder will be economically (Naseeven, 1986; Namer, 1991) and ecologically beneficial. Studies on *B. juncea* have shown that removal of shaded leaves (50% of lower leaves at 40 DAS) increases the supply of assimilate more than demand and thus improves growth and photosynthetic potential of the rest of the leaves (Khan *et al.,* 2002b). Anten and Ackerly (2001) reported that partial defoliation (50 and 66% of leaves removed) in palm (*Chamaedorea elegans* Mart.) significantly increased the light available to the remaining leaves and light-saturated photosynthesis per unit leaf area by 10–18%. Recently, (Li *et al*., 2010) reported that defoliation at flowering in chickpea (*Cicer arietinum* L.) when crop canopy is closed allows light penetration into deeper canopy and improves photosynthesis.

Partial defoliation has rejuvenating (make younger) effect on the remaining leaves, restoring the photosynthetic capacity to near the value of newly formed leaves (Wareing *et al.,* 1968, Khan *et al.,* 2008). The plants after defoliation require more assimilates for re growth which is balanced by the increased leaf assimilatory capacity and efficient N use (Lone and Khan 2007).

Ryle *et al.* (1985) reported that recovery of N2 fixation in *T. repens* after removal of half of the shoot tissue was related to the reestablishment and increased photosynthetic capacity after 5, 6, or 9 d of re growth. C4 plants accumulate greater quantities of carbohydrate than C3 plants (Downton 1971). This 'extra' photosynthetic could be used for re growth following defoliation. An advantage of the C4 system is that its net photosynthesis, compared to C3 plants, is greatest in young foliage (Long *et al*., 2006). Thus, the new foliage produced in response to defoliation would replenish the carbohydrate reserves (sucrose) more rapidly in C4 species than in C3 species.

CONCLUSIONS

In light of the results obtained, the different levels and stages of defoliation have a significant effect on all the parameters studied .Partial defoliation in sugarcane (i.e. removal of half leaves) has been shown to not have a long-term negative effect on the biomass yield. Generally the results obtained in this study are based on data of three month experiment and, hence do not warrant the formulation of a clear-cut recommendation.

When defoliation was applied on 30 % of leaf removal at 11 month growth stage in relative to other percent of defoliation and stage higher recovery percentage was recorded. On the other hand trash or leave without defoliating that is delivered with the stalks to the factory could also reduce the quality of sugarcane juice. However, further study is required to support some leaves defoliated in the field should be utilized as a soil fertilizer there is still plenty available for use as biomass; retention of unburned leave can increase nutrient conservation, reduce weed growth, conserve soil moisture and also defoliated leaves could be used as animal fodder after 9month of crop age without affecting sugarcane yield. Defoliation could also be used to renew, refresh and increase growth and photosynthetic rate in sugarcane plants under abiotic stress conditions. However, further research is required to strengthen the investigation and repeating similar research on different location are necessary to recommend to all Ethiopian sugar factories.

Conflict of Interest

None Declared.

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