DARMS B1
(NARRDS/DARMS Form No.1)

National Agriculture and Resources Research and Development System/Development of Agriculture Research Monitoring System

PART I. BASIC INFORMATION

1. Project Title: Lodging in Sugarcane Fields: Assessing its Significance on Productivity and Predicting Lodging-Induced Losses

2. Researchers: Rachel J. Sarol
Senior Science Research Specialist

Maria Vina A. Serrano
Chief Science Research Specialist

Benjamin G. Manlapaz
Supervising Science Research Specialist

3. Implementing Agency: Sugar Regulatory Administration

4. Research Sites: SRA-LAREC Pampanga

5. Duration

5.1 Date Started: Febraury 2021
5.2 Date Ended : September 2023
Submission of Terminal Report: September 2023

6. Development/Ecosystem Zone: Upland, Plain

7. Technology Level: Technology Generation

Prepared by:

RACHEL J. SAROL
Senior Science Research Specialist

Endorsed by:

RAPHAEL HENRI B. MUNDO, RCh
Chief Science Research Specialist – AARD

Noted by:

ENGR. LAVERNE C. OLALIA
Manager III, RDE L&M

Certified Completed:

ATTY. IGNACIO S. SANTILLANA
Deputy Administrator II, RDE

Lodging in Sugarcane Fields: Assessing its Significance on Productivity and Predicting Lodging-Induced Losses

R.J Sarol*; M.V Serrano; B.G Manlapaz
Agro-Allied Research Division, Luzon Agricultural Research and Extension Center
Floridablanca, Pampanga

ABSTRACT

Crop lodging is known as a limiting factor in crop productivity, and sugarcane production is not exempt from this. To quantify the influence of cane lodging on yield and yield components, eight sugarcane cultivars were evaluated: Phil 09-1969, Phil 06-2289, Phil 99-1793, Phil 8013, Phil 75-44, Phil 6607, VMC 84-525, VMC 7139. The experimental trial was laid out in an 8x2 factorial in RCBD under sandy soil conditions at the Sugar Regulatory Administration-Luzon Agricultural Research and Extension Center, Paguiruan, Floridablanca, Pampanga, in plant cane. Sugarcane varieties performed differently in terms of yield and yield components. Phil 06-2289, Phil 6607, Phil 99-1793, Phil 75-44, and VMC 84-524 obtained the highest cane yield in plant cane while, the same variety exhibited the highest tonnage excluding VMC 84-524 and Phil 6607 in succeeding ratoon cane. In Plant cane, it was found that Phil 06-2289, Phil 8013, Phil 09-1969, Phil 99-1793, Phil 6607, and VMC 71-39 have high sugar rendement in lodge canes, while comparable performance is found among varieties in non-lodge treatment. In ratoon cane all varieties except for Phil 66-07 exhibited comparable result. The highest sugar yield was obtained by Phil 06-2289 and Phil 99-1793 in Plant cane while the same varieties including Phil 09-1969, Phil 8013 and Phil 75-44 in ratoon cane. Cane lodging affects stalk attributes, cane tonnage, juice quality, and sugar yield. The cane tonnage and sugar rendement decreased by 12% and 9 in plant cane while, 38% and 7% in ratoon cane, respectively, when the canes were lodged. The reduction in cane tonnage of lodge canes was mainly attributed to the stalk characteristics, which are shorter, thinner, and lighter. Also, a significant amount of rat damage and pest infestation was observed which contribute to the reduction of cane tonnage. decreasing sugar rendement was observed in lodge canes due to poor juice quality, which is attributed to low-level of brix, polarity, and purity. The quality reduction in the cane juice was due to the dilution effects of the stalk damage, dead stalk, damage from rats and pests, and the formation of side shoots, late tillers and suckers. Lodging decreased cane tonnage and sugar rendement, resulting in a reduction of sugar yield (Lkg/ha) by 19% and 47% in plant and ratoon cane, respectively. This experiment showed that under sandy soil conditions, lodging is an explicit barrier to the yield potential of sugarcane varieties.

INTRODUCTION

The climate, type of soil, and variety of sugarcane grown by farmers substantially influence sugarcane production. Among these, climatic factors have the most significant impact. During sugarcane's growth and development, specific climatic conditions are required for the crop to attain its full potential in terms of germination, tillering, elongation, and ripening. However, crop performance may be seriously affected when excessive moisture and strong winds occur at the elongation stage, resulting in cane lodging.

Lodging is the failure, instability, and loss of crop erectness that happens when a crop falls over from its natural upright position because its stem or roots have failed (Singh, 2002; Bonnette et al.,2005; Li et al., 2019). There are two types of lodging in sugarcane: stem lodging, in which the stalks bend, while root lodging, in which root anchoring fails and roots are ripped out from the ground. Stem lodging happens when the weight above ground is greater than the strength of the root system, and root lodging happens when the weight above ground is greater than the mechanical support strength of the base of the stem (Mizuno et al., 2018; Mulsanti et al., 2018) and both can occur simultaneously in the same area. It is possible for both types of lodging to occur concurrently in the same field. In most cases, lodging occurs in sugarcane plantation when the soil is moist, which provides poor support for the crop's roots; the leaf canopy is wet, which alters the crop's center of gravity; and there is a strong wind. All these elements work together to shift the crop’s center of gravity, causing it to lean over (Singh et al., 2002). In addition, the variety used, climatic conditions, and management practices made significant contribution to lodging (Ishimaru et al., 2008; Merugumala et al., 2019).

Many studies have found that lodged cane reduces sugarcane productivity (Singh, 2002; Berding and Hurney (2005); McIntyre et al., 2015; Singkham et al., 2016; Yang et al., 2016; Shanmuganathan et al., 2017). This means that lodging poses a possible threat to the economic harvest of sugarcane, and it is known to decrease productivity by reducing cane yield and quality. Numerous studies on the incidence of lodging in various crops, such as rice (Marcelo et al., 2017), corn (Villayer et al., 2021), and mungbean (Jarilla et al., 2008) have been conducted, but few on sugarcane.

Known to sit in the typhoon belt in the Pacific, the Philippines is often visited by an average of 20 typhoons each year, causing extensive damage to most crops, including sugarcane. Additionally, given the changes in climatic conditions, ecological locations, and cultivars planted in the sugarcane-producing areas of the country, a comprehensive evaluation of cane lodging is required to assist the industry in the use of appropriate technologies, crop estimation damage and the formulation of relevant policies in response to the needs of the industry. Hence, the study was conducted to quantify losses and determine the influence of cane lodging on cane tonnage and stalk attributes, juice quality and sugar yield of both plant and ratoon cane.

METHODOLOGY

Experimental site

The study was laid out in the experimental area of the SRA-Luzon Agricultural Research and Extension Center (SRA-LAREC), Paguiruan, Floridablanca, Pampanga, located at 14°59’20.04” N and 120°31’39.04” E with an elevation of 27 meters above sea level and under sandy loam soil. The study was conducted in the plant and ratoon cane from February 2019-February 2022.

Treatments and Experimental Design

The experiment was laid out in an 8x2 factorial, randomized complete block design with four replications per treatment. Each treatment plot measured six rows by nine meters and was spaced 1.3 meters apart. Plots were separated from each other on all sides by 2.6-meter borders. This was done to make sure that later on, lodging in one plot would have as little impact as possible on the plots next to it.

Factor A is composed of different varieties, namely: Phil 8013, Phil 75-44, Phil 66-07, Phil 99-1793, Phil 06-2289, Phil 09-1969, VMC 84-524, and VMC 71-39. These varieties are widely used and planted on a large scale in different mill districts, which is the basis for selecting varieties. Phil 99-1793, Phil 06-2289, and Phil 09-1969 are the newly released and promising varieties.

There were two treatments for factor B. The non-lodging treatment, the cane was permitted to grow through bamboo frames or bamboo scaffoldings that physically prevented lodging on each plot (**Figure 1**). The structure was mainly compost of posts and beams. A total of 12 bamboo poles (vertical posts), each measuring 4 meters in length and approximately 2.5 inches in diameter, were buried in the soil at a depth of 75 cm. At a height of 1.8 meters, a vertical beams of bamboo was wired to the vertical posts to form a grid through which the canes grow. Two diagonal bamboo braces were also installed at each row to support the structure, maintain the stability of bamboo frames, and act as stalk supports for the sugarcane stalks, so they did not lodge. On the other treatment (lodging), the cane was not supported, so it could lodge at any time. The effect of lodging on cane productivity can be quantified using this experimental procedure (Singh et al., 2002).

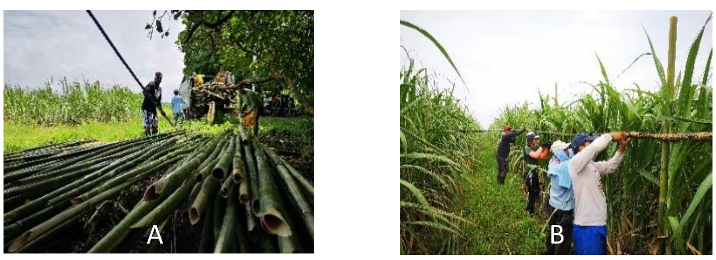


Figure 1. Installation of frames/scaffoldings to prevent cane lodging (A. preparation of bamboo framing/scaffolding materials; B. Installation)

A visual rating that ranged from 1 to 5 was used to record the degree of cane lodging inside each plot. A rating of 1 indicated totally erect cane, while a rating of 5 indicated a completely lodged cane.

The degree of severity in lodging was divided into five levels or degrees based essentially on China's national agricultural industry-standard NY/T1301-2007. The extent (area) of lodging as a percentage of the area planted. The levels were as follows:

Level 1: no lodging
Level 2: Slightly lodge; lodging area is less than 20% of the plot; and the stems are inclined stems at an angle less than 30°
Level 3: Moderately lodge. Small, scattered patches of lodging; lodging area 20%-40% of the plot; an inclined angle of 30°-45°
Level 4: Heavily lodge; large lodging areas with scattered patches, lodging area 40%–80% of the plot; inclined angle of 45°–60°
Level 5: Severe lodging. Lodging in large, contiguous areas; lodging area more than 80% of the plot; inclined angle greater than 60°

Statistical Analysis

Analysis of variance (ANOVA) was used to analyze variation among treatments. Tukey's Honestly Significant Difference (HSD) was used to compare means at a 5% probability level. The statistical Tool for Agricultural Research (STAR) developed by IRRI was used for the statistical analyses performed in this study.

RESULT AND DISCUSSION

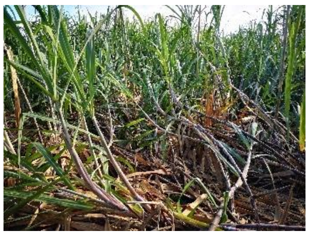
Strong Winds Accompanied by Heavy Rainfall Cause Lodging

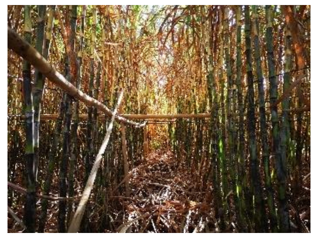
The experimental area is located at an elevation of 27 meters above sea level. It was classified as sandy based on the proportion of soil particles, with a soil pH of 6.76. The mean organic matter of soil was 0.61%, with an available amount of 26ppm of Phosphorus, 241ppm of K, 1959ppm of Calcium, and 80ppm of magnesium.

Average temperatures were 24.37^{o}C during the germination stage (January-February), 26.47^{o}C at tillering stage (February-May), 25.90^{o}C at the stalk elongation stage (May-August), 24.35^{o}C at the ripening stage (September-January) in plant cane. Total rainfall of 1,767 was recorded. In both cropping seasons, the distribution varied, and maximum rainfall of 516.6 and 206.5mm was recorded in July. The average global irradiation of 248,656 and 269,720 kWh/m^2 was recorded, while the maximum irradiation of 300,202 was recorded in March.

Strong winds accompanied by heavy rain at 7 MAP caused serious in severe lodging in all plots without bamboo poles except for Phil 09-1969. Through regular visual lodging assessments, the progression and severity of lodging were monitored.

Despite these adverse weather events, the bamboo scaffoldings effectively prevented lodging in the not-lodged treatment (control) (**Figure 2**). This made it possible to precisely quantify the effect that lodging on different yield and yield components.





2A. Without bamboo frames (lodging treatment) 2B. With bamboo frames (Non-lodging treatment)

Figure 2. Plot with and without bamboo frames/scaffoldings

Lodging Reduced Cane Tonnage of both Plant and Ratoon cane

Searching for varieties exhibiting high cane tonnage (TC/ha) and high sucrose content (Lkg/TC) is an essential endeavor in sugarcane production. Thus, all the breeding programs, and ever-evolving production technologies, including the development of new technologies, are aimed at enhancing crop yield to achieve food security.

The impact of cane lodging had a notable effect on the tonnage (TC/Ha) for both plant cane and the subsequent ratoon cane. The cane tonnage of sugarcane varieties as influenced by lodging is shown in Table 1 for plant cane and Table 2 for ratoon cane. Data showed highly significant differences in terms of the variety tested. Phil 06-2289 produced the highest cane tonnage in both plant and ratoon cane, which was comparable to Phil 6607, Phil 99-1793, VMC 84-524, and Phil 75-44, with mean values of 160.58 TC/ha, 141.47 TC/ha, 139.39 TC/ha, 132.55 TC/ha, and 131.35 TC/ha, respectively in plant cane. While in ratoon cane all varieties were comparable except for Phil 6607, VMC 84-524 and VMC 71-39. These differences were mainly due to the favorable stalk characteristics of both varieties. These data may reveal genetic differences between varieties, which may help explain some of the variations in cane and sugar yields, given that each variety may have its own unique adaptation qualities for a given environment and emphasizes the importance of choosing varieties based on their specific qualities and suitability for the given conditions.

Significant differences were also observed in lodged and non-lodged canes of both plant and ratoon cane. The non-lodging canes had the highest cane tonnage compared to the lodged canes, with a mean value of 142.36 TC/ha compared to 126.36 TC/ha in plant cane and 103.87 TC/Ha compared to 75.03 TC/Ha in ratoon cane, a 12% and 38% decrease, respectively. Among varieties, Phil 99-1793 in plant cane and VMC 84-524 in ratoon cane were observed to have the highest percentage decrease of about 23% and 65%, respectively. On the other hand, Phil 09-1969 in plant cane and Phil 6607 in ratoon cane were observed to have the lowest yield decrease of about 3% and 17%, respectively. During plant cane, based on morphological attributes, Phil 09-1969 has distinct morphological traits compared to other varieties, which explains why this variety has the lowest yield decline. No or minimal lodging incidence was observed for this variety, whether with or without bamboo scaffolding. Phil 09-1969 has an ideal plant structure, the "tower type structure," based on stalk diameter ratios at the stalk's base, middle, and bottom. Breeders like to select the "tower type" of plant as the ideal plant type during the breeding process (Liu, 2017). Despite unfavorable weather conditions like heavy winds, this plant structure was stable and able of minimizing losses (Johnson et al., 1998). In order to ensure stability, the "tower" structure is necessary, especially for the broad, long leafed varieties. So, by providing the ratio of sugarcane's base, middle, and top diameters would help breeders get a better idea of how resistant it is to lodge.

This implies that the occurrence of lodging significantly contributed to variation in the total cane weight per hectare, emphasizing the importance of considering lodging as key factor influencing productivity in both plant and ratoon crops. The observed impact of lodging suggests that variations in cane tonnage are not solely determined by inherent ability of a variety but are significantly affected by lodging events. Farmers and agricultural practitioners should, therefore, be attentive to lodging occurrences as they contribute to yield variability.

Cane Lodging Influence Stalk Attributes

Cane lodging had a considerable impact on cane tonnage, with the 12% and 38% cane yield reduction in plant and ratoon cane, respectively was due to the influence of cane lodging on various stalk parameters. Stalk parameters that are highly affected by cane lodging were stalk length, stalk diameter, and eventually stalk weight (**Table 3, 4, 5 & 6**).

Table 1. Cane yield (TC/ha) of sugarcane varieties as influence of lodging under sandy soil condition at plant cane

Variety	Non-lodge	Lodge	Means	Percent Decrease
Phil 09-1969	119.52	115.90	117.71[c]	3%
Phil 06-2289	173.89	147.27	160.58[a]	15%
Phil 99-1793	157.48	121.30	139.39[ab]	23%
Phil 8013	127.65	117.78	122.72[bc]	8%
Phil 75-44	136.54	126.16	131.35[ab]	8%
Phil 66-07	153.85	129.09	141.47[ab]	16%
VMC 84-524	138.43	126.66	132.55[ab]	8%
VMC 71-39	131.48	126.74	129.11[bc]	4%
Means	145.62[a]	127.86[b]		12%
C.V.	14.48			

Table 2. Cane yield (TC/ha) of sugarcane varieties as influence of lodging under sandy soil condition at ratoon cane

Variety	Non-lodge	Lodge	Means	Percent Decrease
Phil 09-1969	111.73	90.48	101.10[a]	23%
Phil 06-2289	123.81	100.40	112.10[a]	23%
Phil 99-1793	121.13	77.58	99.36[a]	56%
Phil 8013	108.10	77.03	92.57[ab]	40%
Phil 75-44	120.03	82.82	101.43[a]	45%
Phil 66-07	65.57	55.92	60.75[c]	17%
VMC 84-524	92.08	55.95	74.01[bc]	65%
VMC 71-39	88.48	60.06	74.27[bc]	47%
Means	103.87[a]	75.03[b]		38%
C.V.	14.93			

Table 3. Stalk attributes of different sugarcane varieties as influence of lodging under sandy soil condition at plant cane

Variety	Tillers			Millable			Stalk length			Stalk weight		
	Non-lodge	Lodge	Means	Non-lodge	Lodge	Means	Non-lodge	Lodge	Means	Non-lodge	Lodge	Means
Phil 09-1969	329	326	328^{b}	215	204	210^{c}	267.00	223.80	245.40^{b}	2.59	2.08	2.34^{ab}
Phil 06-2289	407	383	395^{a}	315	372	343^{ab}	292.55	257.68	275.12^{ab}	2.37	1.76	2.07^{bc}
Phil 99-1793	402	418	410^{b}	313	310	311^{ab}	317.63	273.03	295.33^{ab}	2.87	2.25	2.56^{a}
Phil 8013	372	389	381^{ab}	370	313	341^{ab}	371.28	279.18	325.23^{a}	2.33	1.73	2.03^{bc}
Phil 75-44	430	451	440^{a}	257	302	280^{b}	281.03	264.50	272.77^{ab}	2.31	2.04	2.18^{abc}
Phil 66-07	462	447	454^{a}	396	366	381^{a}	262.18	240.00	251.09^{b}	2.05	1.59	1.82^{c}
VMC 84-524	402	418	410^{a}	344	320	332^{ab}	274.30	267.08	270.69^{ab}	2.42	1.96	2.19^{abc}
VMC 71-39	373	379	376^{ab}	380	323	351^{ab}	314.68	264.35	289.52^{ab}	2.25	1.71	1.98^{bc}
Means	397	401	ns	324	314	ns	301.95^{a}	263.69^{b}		2.37^{a}	1.86^{b}	
C.V.	12.53			13.87			13.17			12.31		

Table 4. Stalk attributes of different sugarcane varieties as influence of lodging under sandy soil condition at ratoon cane

Variety	Tillers			Millable			Stalk length			Stalk weight		
	Non-lodge	Lodge	Means	Non-lodge	Lodge	Means	Non-lodge	Lodge	Means	Non-lodge	Lodge	Means
Phil 09-1969	329	326	328^{b}	243	209	226^{d}	253.45	228.65	241.05^{a}	2.16	2.01	2.08^{a}
Phil 06-2289	407	383	395^{ab}	338	302	320^{a}	251.48	212.80	232.14^{a}	1.72	1.55	1.64^{b}
Phil 99-1793	402	418	410^{a}	284	256	270^{bcd}	268.48	220.53	244.50^{a}	2.01	1.43	1.72^{b}
Phil 8013	364	389	377^{ab}	309	282	295^{abc}	259.68	243.48	251.58^{a}	1.64	1.27	1.45^{bc}
Phil 75-44	429	451	440^{a}	325	301	313^{ab}	251.28	220.35	235.81^{a}	1.73	1.29	1.51^{bc}
Phil 66-07	461	447	454^{a}	263	255	259^{cd}	190.28	196.68	193.48^{b}	1.22	1.03	1.13^{d}
VMC 84-524	420	403	411^{a}	246	235	240^{d}	245.48	201.45	223.46^{ab}	1.75	1.12	1.43^{bc}
VMC 71-39	373	379	376^{ab}	310	273	292^{abc}	236.45	207.73	222.09^{ab}	1.33	1.00	1.16^{cd}
Means	398	399	ns	290	264	ns	244.57^{a}	216.46^{b}		1.69^{a}	1.34^{b}	
C.V.	12.80			11.30			10.33			14.50		

Table 5. Stalk diameter (mm) of different sugarcane varieties as influence of lodging under sandy soil condition at plant cane

Variety	Base			Middle			Top		
	Non-lodge	Lodge	Means	Non-lodge	Lodge	Means	Non-lodge	Lodge	Means
Phil 09-1969	35.65	34.78	35.22^{a}	34.84	33.72	34.28^{a}	31.98^{a}	32.11^{a}	32.05
Phil 06-2289	30.38	29.51	29.95^{bcd}	31.16	28.87	30.02^{bc}	27.74^{b}	28.08^{b}	27.91
Phil 99-1793	31.11	30.76	30.94^{bc}	31.90	30.97	31.44^{b}	31.55^{a}	28.26^{b}	29.91
Phil 8013	30.79	28.87	29.83^{cd}	30.51	26.27	28.39^{c}	29.69^{ab}	23.94^{ab}	26.82
Phil 75-44	31.29	30.96	31.13^{bc}	31.40	30.16	30.78^{b}	28.73^{ab}	26.66^{bc}	27.70
Phil 66-07	28.54	27.54	28.04^{d}	32.08	28.55	30.32^{bc}	27.44^{b}	26.15^{bc}	26.80
VMC 84-524	33.13	31.61	32.37^{b}	32.39	29.61	31.00^{b}	29.62 ^{ab}	26.89^{bc}	28.26
VMC 71-39	30.16	29.18	29.67^{bcd}	29.27	27.28	28.28^{c}	27.37^{b}	25.33^{bc}	26.35
Means	30.77	29.78		31.24^{a}	28.82^{b}		28.88^{a}	26.47^{b}	
C.V.	5.08			4.54			5.71		

Table 6. Stalk diameter (mm) of different sugarcane varieties as influence of lodging under sandy soil condition at ratoon cane

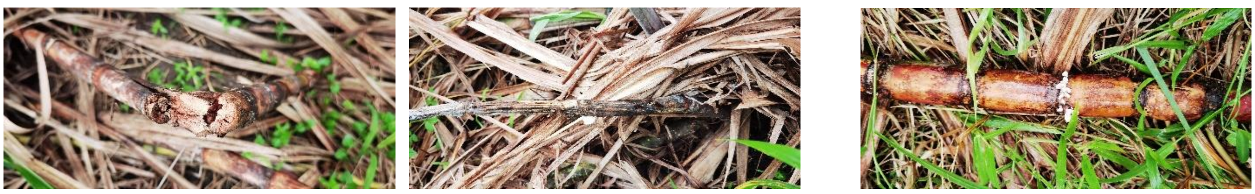
Variety	Base			Middle			Top		
	Non-lodge	Lodge	Means	Non-lodge	Lodge	Means	Non-lodge	Lodge	Means
Phil 09-1969	34.4	33.10	33.75^{a}	34.48	33.80	34.14^{a}	31.60	31.33	31.46^{a}
Phil 06-2289	28.6	26.82	27.72^{bc}	28.54	27.74	28.14^{bc}	26.63	26.16	26.39^{bc}
Phil 99-1793	31.4	27.91	29.65^{b}	30.98	28.23	29.61^{b}	29.63	26.27	27.95^{b}
Phil 8013	28.5	23.88	26.20^{c}	28.39	24.17	26.28^{cd}	26.13	23.23	24.68^{bc}
Phil 75-44	30.5	25.43	27.95^{bc}	30.56	24.29	27.42^{cd}	28.42	24.06	26.24^{bc}
Phil 66-07	27.7	23.63	25.64^{cd}	28.56	24.89	26.72^{bcd}	26.94	24.49	25.71^{bc}
VMC 84-524	30.4	25.36	27.88^{bc}	31.55	25.71	28.63^{bcd}	28.03	25.54	26.78^{bc}
VMC 71-39	25.7	21.75	23.73^{d}	26.91	22.61	24.76^{d}	25.81	21.51	23.66^{c}
Means	29.6^{a}	25.98^{b}		30.00^{a}	26.43^{b}		27.90^{a}	25.32^{b}	
C.V.	5.41			6.27			8.24		

Physical Damage to Roots and Above-Ground Parts

After the sugarcane plants are lodged, some of the roots are snapped and damage. As a result, the root system is unable to obtain adequate carbohydrates from the soil, which weakens life activity and reduces the amount of water and nutrient uptake (Zhang et al., 2015). Also, the growth of the lodge cane is affected since the canopy of the plant was loosened and some roots were damage, and the cane plant are grown in bending orientations.

When sugarcane plants lodge, they have to re-establish themselves a few weeks later. This is likely because of a phototropic stimulus-response (Praveen & Huq, 2021; Humbert, 2013) and because the sugarcane plants will continue seeking more sunlight, and their stem tips will grow upward. This makes the sugarcane node's meristematic tissue proliferate rapidly, making it more fragile and easy to break (**Figure 3a**) (Paraskevopoulos et al., 2016). The tops of sugarcane plants are sometimes cut or snapped during extreme wind conditions, resulting in the death of the stalks (**Figure 3b**). These losses are considerable since most tall and vigorous tops are damaged, causing the plant to stop growing and the sugarcane plant to dry out (**Figure 3c**). Furthermore, rats preferred to nest in sugarcane bushes and consume many stalks.

q Overall, the above incident will cause the stalk to be shorter, thinner, and lighter, which will lead to a low cane yield.



3a. Broken stalk **3b**. Dead stalk **3c.** Dry out stalk

Figure 3. Stalk damage due to lodging

Orthogonal Partitioning Between Phil and VMC Varieties

Orthogonal contrast is a comparison used to identify differences across groups. The result showed no significant differences between the variety types **(Appendix Table 1).** This indicates that the yield performance and varietal response to the lodging of these two breeding organizations are comparable. This implies that lodging will reduce cane yields regardless of variety.

Lodging Influences Juice Quality

To quantify the extent of lodging-related losses, replicated plots of fully erect and completely lodged samples were selected for juice analysis. The findings revealed significant differences in lodging and no-lodging, and the variety used of both plant and ratoon cane.

The amount of sucrose present in the cane juice is a key indicator of canes quality and is useful for determining the juice quality that affects sugar recovery (Thangavelu, 2007). Therefore, monitoring and understanding the sucrose content in the cane juice are essential aspects of assessing the suitability of sugarcane for optimal sugar extraction and production processes. This information provides valuable insights into the sugar recovery potential and overall quality of sugarcane crops, guiding decision-making in the sugar industry. Sugar rendement of plant cane was influence by cane lodging and each variety have responded differently (Table 7). Among varieties, highest sugar rendement in lodged condition was recorded in Phil 06-2289 comparable to Phil 8013, VMC 71-39, Phil 09-1969, Phil 99-1793 and Phil 66-07 having mean values of 2.15Lkg/TC, 2.11 Lkg/TC, 2.11Lkg/TC, 2.06LKg/TC, 1.90LKg/TC and 1.80LKg/TC, respectively. The variation in sucrose concentration is primarily attributable to the genetic makeup of the varieties. In ratoon cane, highest sugar rendement among varieties was recorded in Phil 8013 and comparable to all other varieties except for Phil 75-44 and Phil 66-07 (Table 8).

Based on the results, the average sugar rendement of lodge cane in plant and ratoon cane is approximately 9% and 7% lower than that of non-lodge cane, respectively. The absence of sugar rendement reduction of Phil 09-1969 among the tested cultivars can be attributed to its non-lodging or extremely minimal lodging characteristics. Phil 09-1969's observed resistance to lodging during both the plant cane and ratoon cane which likely contributed to the preservation of its sugar rendement. The minimal bending or leaning of stalks would have ensured efficient sunlight exposure, nutrient uptake, and overall healthier crop conditions, thereby mitigating the typical reduction in sugar content associated with lodging in other varieties. The field observations affirm the expectation that lodging-resistant or minimally lodging varieties, such as Phil 09-1969, would exhibit more consistent and sustained sugar rendement.

Characteristics that Influence Juice Quality

Juice quality indices such as brix, polarity (pol), and apparent purity are commonly used criteria in maturity determination and quality judgment. Brix concentration indicates the quality of the juice in terms of soluble solids, whereas apparent purity indicates the percentage of sucrose in the juice's total solids (Verlag, 2019). Pol is the apparent sucrose content expressed as a mass percent, as determined by the optical rotation of polarized light passing through a sugar solution (Alluri, 2019). Significant differences in brix and pol among varieties were observed in both plant and ratoon cane. This could be attributed to differences in the inherent capacity to collect sucrose at maturity, including the production, transport, and sugar storage in the stalks' parenchyma cells (Sarol *et al*., 2019). However, it's noteworthy that brix, polarity, and apparent purity are markedly influenced by cane lodging, as indicated in Table 9 & 10. The presence of lodging contributes to reductions in the quality of sugarcane juice across all parameters. Cane lodging can disrupt the efficient production and transport of sucrose, leading to lower concentrations of soluble solids and apparent sucrose content in the juice.

The observed differences in brix and pol among sugarcane varieties are likely linked to their inherent capabilities in sucrose accumulation. However, the significant influence of cane lodging on juice quality parameters underscores the importance of considering and managing lodging effects to maintain

Table 7. Sugar Rendement (LKg/TC) of different sugarcane varieties as influence of lodging under sandy soil condition at plant cane

Variety	Non-lodge	Lodge	Means	Percent Decrease
Phil 09-1969	1.93^{a}	2.06^{ab}	2.00	
Phil 06-2289	2.21^{a}	2.15^{a}	2.18	3%
Phil 99-1793	2.11^{a}	1.90^{ab}	2.01	10%
Phil 8013	2.25^{a}	2.11^{ab}	2.18	6%
Phil 75-44	1.96^{a}	1.76^{b}	1.86	10%
Phil 66-07	1.94^{a}	1.80^{ab}	1.87	7%
VMC 84-524	2.24^{a}	1.76^{b}	2.00	21%
VMC 71-39	2.22^{a}	2.11^{ab}	2.17	5%
Means	2.13^{a}	1.94^{b}		9%
C.V.	7.80			

Table 8. Sugar Rendement (LKg/TC) of different sugarcane varieties as influence of lodging under sandy soil condition at ratoon cane

Variety	Non-lodge	Lodge	Means	Percent Decrease
Phil 09-1969	2.03	2.10	2.07^{ab}	
Phil 06-2289	2.27	2.15	2.21^{a}	6%
Phil 99-1793	2.14	1.96	2.05^{ab}	9%
Phil 8013	2.30	2.15	2.22^{a}	7%
Phil 75-44	2.08	1.92	2.00^{b}	8%
Phil 66-07	1.86	1.66	1.76^{c}	12%
VMC 84-524	2.18	2.04	2.11^{ab}	2%
VMC 71-39	2.20	2.04	2.12^{ab}	7%
Means	2.13^{a}	2.01^{b}		7%
C.V.	5.73			

Table 9. Juice quality parameters of different sugarcane varieties as influence of lodging under sandy soil condition at plant cane

Variety	Brix			Polarity			Purity		
	Non-lodge	Lodge	Means	Non-lodge	Lodge	Means	Non-lodge	Lodge	Means
Phil 09-1969	20.72	21.14	20.93^{ab}	79.55	83.54	81.55^{ab}	94.63	92.10	93.37
Phil 06-2289	22.82	22.24	22.53^{a}	90.37	87.76	89.07^{a}	94.14	94.16	94.15
Phil 99-1793	21.85	20.16	21.01^{ab}	86.13	77.91	82.02^{ab}	94.19	92.66	93.43
Phil 8013	23.23	21.49	22.36^{a}	92.30	85.53	88.92^{a}	95.19	94.43	94.81
Phil 75-44	20.12	18.54	19.33^{b}	79.15	71.52	75.34^{b}	94.71	93.16	93.94
Phil 66-07	19.92	18.77	19.35^{b}	78.23	72.90	75.57^{b}	94.56	93.94	94.25
VMC 84-524	23.09	19.16	21.13^{ab}	91.76	72.71	82.24^{ab}	94.42	91.25	92.84
VMC 71-39	22.54	21.56	22.05^{a}	90.03	85.65	87.84^{a}	95.19	94.98	95.09
Means	21.94^{a}	20.27^{b}		86.85^{a}	79.14^{b}		94.63^{a}	93.51^{b}	
C.V.	6.38			7.58			1.93		

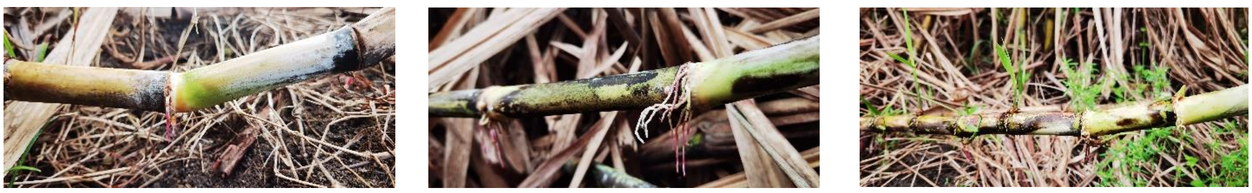
Table 10. Juice quality parameters of different sugarcane varieties as influence of lodging under sandy soil condition at ratoon cane

Variety	Brix			Polarity			Purity		
	Non-lodge	Lodge	Means	Non-lodge	Lodge	Means	Non-lodge	Lodge	Means
Phil 09-1969	20.83	21.60	21.21^{b}	80.79	84.54	82.66^{bc}	94.75	94.53	94.64
Phil 06-2289	24.63	22.26	23.45^{a}	93.18	88.24	90.71^{a}	94.53	94.06	94.29
Phil 99-1793	21.77	20.26	21.02^{b}	86.72	81.13	83.92^{abc}	95.10	94.04	94.57
Phil 8013	23.07	21.76	22.41^{ab}	93.14	86.84	89.99^{a}	95.87	95.45	95.66
Phil 75-44	21.93	20.27	21.10^{b}	85.76	78.53	82.15^{c}	93.44	93.17	93.30
Phil 66-07	19.21	17.96	18.59^{c}	74.91	69.27	72.09^{d}	94.16	91.72	92.94
VMC 84-524	22.80	22.62	22.71^{ab}	89.82	89.13	89.48^{ab}	93.57	93.82	93.70
VMC 71-39	22.38	21.38	21.88^{ab}	89.42	84.03	86.72^{abc}	95.21	93.47	94.34
Means	22.08^{a}	21.01^{b}		86.72^{a}	82.71^{b}		94.58	93.78	ns
C.V.	5.34			5.12			1.94		

optimal juice quality in sugarcane crops. This result highlights the intricate relationship between sugarcane physiology, environmental factors, and juice quality, providing valuable insights for cultivation practices aimed at sustaining high juice quality.

Cane lodging Influence the Growth of Aerial Roots and Side Buds

After the cane was lodged, aerial roots and side shoots were formed (**Figure 4**). When there is sufficient moisture in the soil, the root section of the nodes germinates and elongates to form aerial roots, and later, some lateral buds germinate (Jacobsen et al., 2015). These plant processes will impair the juice quality of lodge canes, resulting in decreased sucrose storage in the stalks. It is expected that the stalks of lodge canes will store less sucrose because the reserved sucrose from the stem is broken down into other forms of hexoses to provide substrate and is used as energy to reinitiate stalk growth, the formation of side shoots and late tillers, and to regain an upright posture and canopy development. In contrast, non-lodge canes have a lower level of reducing sugars such as glucose and fructose (Singh et al., 2002), which generally comprise major impurities in sugarcane juice. As expected, lodged canes have low juice quality, indicating a high concentration of hexoses.



4a. formation of aerials roots　　4b. aerial roots elongation　　4c. sideshoot formation

Figure 4. Formation of aerial roots and sideshoots

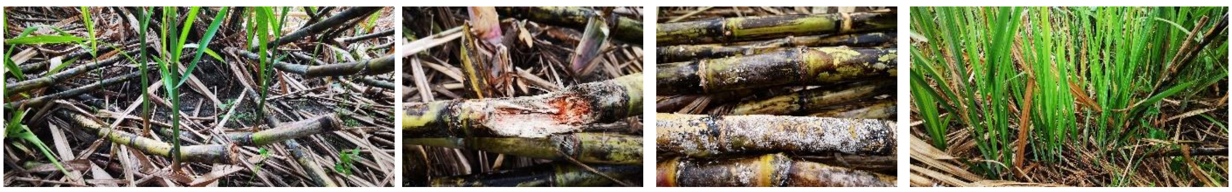
Additionally, the physiological processes of the root system are severely affected, and the uptake and distribution of minerals are compromised (Li et al., 2019). During plant growth and development, the usual physiological conditions of phosphate and potassium uptake from the soil were interrupted, contributing to slow growth, low yield, and poor juice quality (Yanai et al., 2010). The amount of phosphorus taken up by the roots of sugarcane plants after lodging was only one-fourth that of non-lodge plants, according to Chand et al. (2010). Also, the amount of potassium chloride obtained by sugarcane roots after lodging was less than half that of non-lodged plants.

In other instances, strong winds caused the cane to lodge, which broke some vigorous tops and damaged some stalks. In this case, the plant had to reduce apical dominance, allowing the formation of side shoots (**Figure 5a**). Moreover, physically damaged stalks are more likely to allow pathogens to penetrate, leading to bacterial infestation and deterioration in juice quality. Likewise, lodging renders stalks more vulnerable to rat damage and insect pest (aphids), resulting in further losses in cane and sugar yield (**Figure 5b & 5c**).

Lodged Canes Induced Late Tillers

After the cane lodge, the soil surface was directly exposed to sunlight, raising the soil temperature, and increasing the number of ineffective tillers (**Figure 5d**) in the later stage. Late tillers will consume much of the nutrients from the ground and from the stalks, in which there is a rapid conversion of sugars that will lead to a decline in sucrose content and dying up of the stalks (Mcintyre et al., 2015). During harvesting, some farmers included dried sugarcane stalks. If these things happen, the dry sugarcane stalk not only absorbs sugar content but also increases the acidity of the sugarcane juice during milling and causes certain losses (Singh, 2002). Also, high incidence of suckering which is a major cause of the reduction of sugar rendement (recoverable sugar) in lodged canes.

The bending or leaning of lodged sugarcane stalks disrupts the efficient uptake of nutrients from the soil. This impairment in nutrient absorption can further compromise the plant's metabolic processes, hindering the synthesis of sugars and contributing to a decline in sugar yield.



5a **5b** **5c** **5d**

Figure 5. Some observations of sugarcane plant during lodging (**5a.** Formation of side shoots of damage tops; **5b.** Rat damage; **5c.** Presence of Aphids; **5d**.formation of late tillers/suckering)

Lodging Reduces Photosynthetic Activity

Lodging reduces solar interception due to mutual shading caused by clumping of stalks or leaves and overlapping of green leaves (disruption of canopies). Due to the adverse effects of the capture of solar radiation in the field (insufficient light exposure), the leaves of the plants could not get enough light energy to meet the immediate needs of photosynthetic activity. This also stopped the stomata from opening, made it harder for CO2 to get into the leaves, and greatly reduced the photosynthetic intensity (Liu et al., 2016). Then, the sugarcane plants have to cut back on photosynthesis and carbohydrate synthesis. This slows sugar accumulation in segmental storage tissue and makes sugarcane juice with a low brix level when it is harvested.

Zhao et al. (2014) found that the average leaf area of leaves on lodged sugarcane plants were 25.3% and 22.7% narrower than on non-lodge plants. If the photosynthetic area of the plant were reduced, the quantity of photosynthates that the plant demanded would logically decline.

Lodging causes the sugarcane canopy to become entangled and obstructed, limiting the exposure of leaves to sunlight. This reduction in sunlight absorption negatively affects the photosynthetic process, diminishing the plant's ability to produce and accumulate sugars, ultimately leading to decreased sugar yield.

Cane Lodging Cuts Farmers Productivity

Sugar yield is the product of cane tonnage and sugar rendement and is considered the ultimate outcome of the variety's attributes. Improving one or both of these will lead to an increase in sugar yield. Sugar yield was significantly affected by variety and cane lodging of both plant and ratoon cane (Table 11 & 12). The highest sugar yield (Lkg/Ha) was obtained by Phil 06-2289 in both plant and ratoon cane and comparable to Phil 99-1793 only during plant cane and Phil 09-1969, Phil 8013, Phil 99-1793 and Phil 75-44 in ratoon cane. These findings may provide insight into the genetic variability among varieties, which may help explain some of the differences in yields, as each variety may have its own unique adaptation

Table 11. Sugar yield (LKg/ha) of different sugarcane varieties as influence of lodging under sandy soil condition

Variety	Non-lodge	Lodge	Means	Percent Decrease
Phil 09-1969	235.67	238.75	237.21[c]	
Phil 06-2289	384.73	314.52	349.63[a]	18%
Phil 99-1793	332.30	231.19	281.75[ab]	30%
Phil 8013	287.30	248.98	268.14[b]	13%
Phil 75-44	268.87	241.93	255.40[bc]	10%
Phil 66-07	297.12	229.90	263.51[bc]	23%
VMC 84-524	310.81	226.08	268.45[b]	27%
VMC 71-39	291.37	265.00	278.19[b]	9%
Means	310.36[a]	251.09[b]		19%
C.V.	14.39			

Table 12. Sugar yield (LKg/ha) of different sugarcane varieties as influence of lodging under sandy soil condition at ratoon cane

Variety	Non-lodge	Lodge	Means	Percent Decrease
Phil 09-1969	227.45	189.38	208.42[ab]	20%
Phil 06-2289	281.17	215.12	248.15[a]	31%
Phil 99-1793	258.51	150.86	204.68[ab]	71%
Phil 8013	249.08	165.77	207.42[ab]	50%
Phil 75-44	249.98	159.10	204.54[ab]	57%
Phil 66-07	122.22	92.20	107.21[c]	33%
VMC 84-524	201.24	119.78	160.51[b]	68%
VMC 71-39	196.16	123.49	159.82[b]	59%
Means	223.23[a]	151.96[b]		47%
C.V.	16.61			

qualities that allow it to perform optimally in a given condition. Recognizing the unique adaptation qualities of each variety allows for more informed decision-making in variety selection, contributing to sustainable and efficient sugarcane production.

The data reveals that non-lodged canes yielded more sugar compared to their lodged counterparts during the initial plant cane phase. The lodging-induced bending or leaning of sugarcane stalks evidently hampers the efficient utilization of sunlight, nutrient absorption, and overall photosynthetic activity, resulting in a reduction in sugar yield. The impact of lodging becomes more pronounced in the succeeding ratoon cane cycle. Lodged canes experienced a substantial reduction in sugar yield, with a potential loss of up to in 19% in plant cane. This suggests that the adverse effects of lodging persist and even intensify in subsequent growth cycles, possibly due to cumulative stress on the plants and a carry-over of negative impacts from the initial lodging event. The data indicates that lodged canes can experience a significant loss of up to 47% in sugar yield during the ratoon cane. This substantial reduction underscores the severity of the impact of lodging on the ability of sugarcane plants to produce and accumulate sugars. The entangled and bent stalks impede the efficient functioning of the plants, leading to a considerable decline in overall sugar content.

Consequences of Cane lodging

Lodge cane had a lower cane yield than non-lodge cane because there were more dry and decaying stalks, rats, and pest damage. Lodged sugarcane is more susceptible to pest infestations and diseases. The entangled canopy creates favorable conditions for the proliferation of pathogens and pests, requiring additional resources and efforts for disease and pest management. This increased vulnerability can further contribute to a decline in sugar yield. Damaged and dead stalks also had a diluting effect on the sugar rendement, which ultimately influence sugar yield. Singh et al. (2000) supported this result and concluded that the economic losses were mainly due to lodging and were significantly worsened when the diluting effects of extraneous matters during mechanical harvesting (trash, leaves, tops, damaged stalks, unmature stalks, late tillers) were considered.

Sugarcane lodging poses a significant threat to farmers' productivity, impacting both the initial plant cane and the subsequent ratoon cane crops. It affects not only cane yield and juice quality but also profitability. Lodge cane requires additional costs during harvest, which greatly reduces the efficiency of cutting, loading, and transportation (Singkham et al., 2016) and eventually increased harvesting time. It also increases harvesting costs, especially hauling costs, when there is much extraneous matter like soil, leaves, roots, late tillers, and young stalks (Li et al., 2019). Mechanical harvesting of lodge cane increases stool damage and leaves gaps between the hills (Singh et al., 2002). According to Li et al. (2010), mechanical harvesting of lodged crops increases stool damage by up to 24.8% and lowers the potential yield of the successive ratoon. Lodging incidence also slows down the use of mechanization in harvesting, which substantially impedes both its adoption (Li et al., 2010) and thus the modernization of the sugarcane industry (Liu & Fan, 2011).

Cane lodging not only escalates operational costs for farmers but also contributes to lower sugar yield due to the challenges in effectively collecting the cane. The consequences of lodging extend across various aspects of sugarcane cultivation, contributing to a reduction in overall productivity.

Yield Reduction at Different Percent lodging

Based on the result, the occurrence of lodging is a critical factor influencing overall yield. This study delves into the intricate relationship between varying percentages of lodging and the subsequent impact on sugarcane yields. Investigating the consequential yield reductions at different degrees of lodging provides valuable insights into the challenges posed by this phenomenon.

Presented in the following tables is a detailed breakdown of cane yield and sugar yield losses, ranging from 0% to 100% due to varying lodging percentage (Table 12 & 13). These tables offer a comprehensive overview of the quantitative impact of lodging on sugarcane productivity, providing a valuable resource for stakeholders to assess, strategize, and implement targeted measures for optimizing yields under different lodging scenarios.

The calculation of lodging losses relies on the equation developed through the study (Figure 6). The equation takes into consideration various factors influencing yield, providing a systematic and data-driven approach to assess the consequences of lodging in sugarcane cultivation.

$$\frac{\text{(((\% lodging X \# of lodge millable stalks) x Stalk weight of lodge cane)) x Stalk weight of lodge cane) X 10,000 m}^2\text{)}}{\text{Effective plot size m}^2} \text{ X } \frac{\text{1 TC}}{\text{1,000 Kg}} \text{ X LKg/TC of lodge cane}$$

$$+$$

$$\text{(}\frac{\text{(Total millable stalks- \# of lodge millable stalks) X 10,000 m2}}{\text{Effective plot area m}^2}\text{) X } \frac{\text{1 TC}}{\text{1,000 Kg}} \text{ X LKg/TC of non-lodge cane}$$

Figure 6: Percent lodging losses equation

Tonnage computation:

Plot weight of lodge cane = (% lodging X # of lodge millable stalks) x Stalk weight of lodge cane)

Plot weight of non-lodge cane = (Total millable stalks- # of lodge millable stalks)

Effective plot size (m^2) = 4 rows x 1.3m x 9 m=46.8m^2

Plot size = 6 rows (-2 buffer rows), 1.3 furrow distance, 9 Meters length

TC/Ha = $\text{X } \frac{\text{(Effective plot size m}^2\text{)}}{\text{(Effective plot size m}^2\text{)}} = \frac{\text{(10,000 m}^2\text{) (Plot weight Kg)}}{\text{Effective Plot size m}^2\text{)}} \text{ X } \frac{\text{1 TC}}{\text{1,000 Kg}}$

Let: X= TC/Ha

1 Ha=10,000m^2

1,000kg=1TC

TC/Ha of lodge cane = $\frac{\text{(Plot weight of lodge cane kg X 10,000 m}^2\text{)}}{\text{Effective plot area m}^2} \text{ X } \frac{\text{1 TC}}{\text{1,000 Kg}}$

TC/Ha of non lodge cane = $\frac{\text{(Plot weight of non-lodge cane kg X 10,000 m}^2\text{)}}{\text{Effective plot area m}^2} \text{ X } \frac{\text{1 TC}}{\text{1,000 Kg}}$

Total TC/Ha = TC/Ha of lodge cane + TC/Ha of non lodge cane

Sugarcane Rendement Computation:

% Pol = $\frac{\text{Brix X Apparent Purity}}{100}$

PS/TC = $0.1144 \text{ X } \frac{\text{98.5 (Apparent Purity-40)}}{\text{Apparent Purity (98.5-40)}} \text{ X \% Pol}$

Adjusted PS/TC = 0.731 (PS/TC) + 0.0009

PSTC to LKg/TC = Adjusted PS/TC X 1.265

LKG/TC of lodge cane = (Polarity, Purity, Brix of lodge cane)

LKG/TC of non lodge cane = (Polarity, Purity, Brix of non-lodge cane)

Sugar Yield:

LKG/Ha of Lodge cane = LKg/TC of lodge cane X TC/Ha of lodge cane

LKG/Ha of non-lodge cane = LKg/TC of non lodge cane X TC/Ha of non lodge cane

Total LKg/Ha = LKG/Ha of Lodge cane + LKG/Ha of Lodge cane

Yield Reduction at Different Percent Lodging

Table 12. Percent TC/Ha reduction at different percent lodging at ratoon

Variety	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Phil 09-1969	-1%	-1%	-2%	-3%	-3%	-4%	-5%	-5%	-6%	-7%
Phil 06-2289	-1%	-2%	-3%	-4%	-5%	-6%	-7%	-8%	-9%	-11%
Phil 99-1793	-3%	-6%	-10%	-13%	-17%	-21%	-26%	-30%	-35%	-41%
Phil 8013	-2%	-5%	-7%	-10%	-13%	-16%	-19%	-22%	-26%	-29%
Phil 75-44	-3%	-5%	-8%	-11%	-15%	-18%	-22%	-25%	-30%	-34%
Phil 66-07	-1%	-2%	-4%	-5%	-6%	-8%	-9%	-10%	-12%	-13%
VMC 84-524	-4%	-8%	-12%	-17%	-22%	-28%	-34%	-41%	-49%	-58%
VMC 71-39	-2%	-5%	-8%	-11%	-14%	-17%	-20%	-24%	-28%	-32%
Means	**-2%**^{ns}	**-4%** ^{ns}	**-7%***	**-9%****	**-12%****	**-15%****	**-18%****	**-21%****	**-24%****	**-28%****
C.V.	10.16	10.16	10.22	10.34	10.54	10.81	11.15	11.56	12.03	12.57

Table 13. Percent LKG/Ha reduction at different percent lodging at ratoon

Variety	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Phil 09-1969	-1%	-1%	-1%	-1%	-2%	-2%	-3%	-3%	-3%	-4%
Phil 06-2289	-1%	-3%	-5%	-6%	-8%	-10%	-11%	-13%	-15%	-17%
Phil 99-1793	-3%	-3%	-5%	-7%	-9%	-11%	-13%	-15%	-17%	-19%
Phil 8013	-2%	-6%	-9%	-13%	-16%	-20%	-24%	-29%	-34%	-39%
Phil 75-44	-3%	-7%	-10%	-14%	-18%	-23%	-28%	-33%	-39%	-45%
Phil 66-07	-1%	-5%	-7%	-10%	-12%	-15%	-18%	-21%	-25%	-28%
VMC 84-524	-4%	-8%	-12%	-17%	-23%	-28%	-35%	-42%	-50%	-59%
VMC 71-39	-2%	-6%	-10%	-13%	-17%	-22%	-26%	-31%	-37%	-42%
Means	**-2%** ^{ns}	**-5%** ^{ns}	**-7%***	**-10%****	**-13%****	**-16%****	**-20%****	**-23%****	**-27%****	**-32%****
C.V.	12.16	12.17	12.32	12.61	13.03	13.58	14.27	15.07	15.99	17.01

The data on yield reduction holds paramount importance for both predicting yields and assessing damages, offering substantial advantages to the sugarcane industry. It improves the precision of yield estimation predictions, enabling industry stakeholders to make more informed assessments of the potential impact of cane lodging on the industry.

Moreover, this data is instrumental in damage assessment, especially during and after adverse events such as storms or extreme weather conditions. By incorporating lodging percentages into assessments, the data helps gauge the extent of damage to sugarcane crops. This quantitative approach allows for a more precise evaluation of the economic losses incurred by farmers and the industry as a whole. Policymakers and agricultural authorities can use this data for efficient disaster response planning, allocating resources effectively to areas most affected and implementing targeted support measures for affected farmers.

SUMMARY, CONCLUSION, AND RECOMMENDATION

The impact of cane lodging on sugar yield is multifaceted, affecting the quantity, quality, and overall efficiency of sugarcane cultivation. Sugarcane varieties performed differently in terms of yield and yield components. Phil 06-2289, Phil 6607, Phil 99-1793, Phil 75-44 and VMC 84-524 obtained the highest cane yield in plant cane, while the same varieties except for VMC 84-524 and Phil 6607 in succeeding ratoon cane. It was found that Phil 06-2289, Phil 8013, Phil 09-1969, Phil 99-1793, Phil 6607, and VMC 71-39 have high sugar rendement in lodge canes while, comparable performance of all varieties in non-lodge cane during plant cane. In ratoon cane all varieties except for Phil 66-07 exhibited comparable result. Phil 06-2289 and Phil 99-1793 obtained the highest sugar yield in plant cane while the same varieties including Phil 09-1969, Phil 8013 and Phil 75-44 in ratoon cane. The performance of non-lodge (scaffolded) cane was more productive than that of lodged cane. Cane lodging significantly affects stalk attributes, tonnage, juice quality, and sugar yield in both plant and ratoon cane. The yield and sugar rendement were reduced by 12% and 9% in plant cane while, 38% and 7% in ratoon cane, respectively, when the canes were lodged. The reduction in cane yield of lodge canes was mainly attributed to shorter, thinner, and lighter stalks. A significant amount of rat damage and increased susceptibility of the cane to pest infestation. At the same time, the factor that affected the sugar rendement was influenced by the poor juice quality (brix, polarity, and purity). This is due to the dilution effects of the stalk damage, dead stalk, damage from rats and pests, and the formation of side shoots, late tillers, and suckers. Lodging decreased cane tonnage and sugar rendement, resulting in a reduction of sugar yield (Lkg/ha) by 19% and 47% in plant and ratoon cane, respectively. Also, the percent reduction at different lodging incidence is indispensable for improving the accuracy of yield forecasts and streamlining damage assessment processes, ultimately contributing to better-informed decision-making and more resilient sugarcane industry practices. This experiment demonstrated that under sandy soil conditions, lodging is an explicit barrier to the yield potential of sugarcane varieties.

If severe weather conditions prevail, lodging may be more extensive and destructive, resulting in substantially more serious damage than we have estimated. Industry may become more productive and profitable by addressing this issue appropriately. Immediate steps must be taken to limit the impacts of lodging, such as better crop management, to reduce crop losses. Further research into cane lodging is required to acquire a comprehensive understanding of the effects of cane lodging. This is due to the fact that the amount of yield loss that cane lodging causes may vary depending on what crop stage it occurs and how severe it is. Currently, little attention is given to it.

LITERATURE CITED

Alluri, S. (2019, November 7). General Terminology in Sugar Manufacturing Industry | Sugarprocesstech. Sugar Industry Technologies. Retrieved November 29, 2021, from https://www.sugarprocesstech.com/general-terminology-sugar-process/

Bonnett, G. D., Salter, B., Berding, N., & Hurney, A. P. (2005). Environmental stimuli promoting sucker initiation in sugarcane. Field Crops Research, 92(2-3), 219-230.

Chand, M., Lal, R., Khippal, A., Singh, R., & Narang, A. K. (2010). Drought management in sugarcane during pre-monsoon period. Sugar Tech, 12(1), 64-66.

China national agricultural industry standard NY/T1301-2007. Technical procedures for wheat variety regional trials.

Humbert, R. P. (2013). The growing of sugar cane. Elsevier.

Ishimaru, K., Togawa, E., Ookawa, T., Kashiwagi, T., Madoka, Y., & Hirotsu, N. (2008). New target for rice lodging resistance and its effect in a typhoon. Planta, 227(3), 601-609.

Jacobsen, K. R., Fisher, D. G., Maretzki, A., & Moore, P. H. (1992). Developmental changes in the anatomy of the sugarcane stem in relation to phloem unloading and sucrose storage. Botanica Acta, 105(1), 70-80.

Jarilla, F. A., Lanting, G. P., & Alonzo, M. A. M. (2008). Development of improved varieties of mungbean (NSIC Mg14 and NSIC Mg 15) and soybean (EGSY 01-04-71). Philippine Journal of Crop Science (Philippines).

Johnson, D. E., Dingkuhn, M., Jones, M. P., & Mahamane, M. C. (1998). The influence of rice plant type on the effect of weed competition on Oryza sativa and Oryza glaberrima. Weed research (Print), 38(3), 207-216.

Li, X., Lin, S. H., Huang, Q. Y., Liang, Q., Li, Y. J., Yang, L. T., & Li, Y. R. (2019). Advances in research of lodging and evaluation in sugarcane. Applied Ecology and Environmental Research, 17(3), 6095-6105.

Li, Y. R. (2010): Modern Sugarcane Science. – China Agriculture Press, Beijing, pp. 121- 122.

Liu, F. X. (2017): Discussion on the reasonable combination of maize plant type and dense planting. – Agricultural Service 22: 103.

Liu, G. L., & Fan, H. W. (2011). A better active design for optimizing grinding parameters of aviation spiral bevel gears. Journal of Northwestern Polytechnical University, 29(3), 394-399.

LIU, T., LIU, W., REN, M., Du, Y. L., Deng, Y. C., Zou, J. L., ... & Yang, W. Y. (2016a). Effects of shade degrees on photosynthesis and lodging resistance degree of different shade tolerance soybean. Sci Agric Sin, 49(8), 1466-1475.

Liu, W., Deng, Y., Hussain, S., Zou, J., Yuan, J., Luo, L., ... & Yang, W. (2016). Relationship between cellulose accumulation and lodging resistance in the stem of relay intercropped soybean [Glycine max (L.) Merr.]. Field Crops Research, 196, 261-267.

Marcelo, P. N. M., Tapic, R. T., & Manangkil, O. E. (2017). Relationship of culm anatomy and lodging resistance in rice (Oryza sativa L.) genotypes under direct-seeded system. Int J Agr Technol, 13(7.3), 2367-2385.

McIntyre, C. L., Goode, M. L., Cordeiro, G., Bundock, P., Eliott, F., Henry, R. J., ... & Aitken, K. S. (2015). Characterisation of alleles of the sucrose phosphate synthase gene family in sugarcane and their association with sugar-related traits. Molecular Breeding, 35(3), 1-14.

McIntyre, C. L., Goode, M. L., Cordeiro, G., Bundock, P., Eliott, F., Henry, R. J., ... & Aitken, K. S. (2015). Characterisation of alleles of the sucrose phosphate synthase gene family in sugarcane and their association with sugar-related traits. Molecular Breeding, 35(3), 1-14.

Merugumala, G. R., PV, S., Narne, C., BNVSR, R., & PV, R. R. (2019). Molecular breeding of “Swarna,” a mega rice variety for lodging resistance. Molecular Breeding, 39(4), 1-14.

Mizuno, H., Kasuga, S., & Kawahigashi, H. (2018). Root lodging is a physical stress that changes gene expression from sucrose accumulation to degradation in sorghum. BMC plant biology, 18(1), 1-12.

Mulsanti, I. W., Yamamoto, T., Ueda, T., Samadi, A. F., Kamahora, E., Rumanti, I. A., ... & Ookawa, T. (2018). Finding the superior allele of japonica-type for increasing stem lodging resistance in indica rice varieties using chromosome segment substitution lines. Rice, 11(1), 1-14.

Paraskevopoulos, A. L., Singels, A., Tweddle, P. B., & van Heerden, P. D. R. (2016). Quantifying the negative impact of lodging on irrigated sugarcane productivity: a crop modelling assessment. In Proceedings of the Annual Congress-South African Sugar Technologists' Association (No. 89, pp. 154-158). South African Sugar Technologists' Association.

Praveen , K., & Huq. (2021). Signals | Light Signaling in Plants. In Signals | Light Signaling in Plants - ScienceDirect. Encyclopedia of Biological Chemistry III (Third Edition)

Sarol, R., Serrano, M. V., Agsaoay Jr, J., Guiyab, N., Casupanan, A., & Manlapaz, B. (2020). Root Density, Distribution and Yield Relationships of High Yielding Sugarcane Varieties Under Sandy Soil Condition. Review of Plant Studies, 7(1), 1-15.

Shanmuganathan, M., Baskaran, V., & Chandrasekaran, R. (2017). Evaluation of mid-late sugarcane clones for their yield and quality characters in advanced selection stage in plant and ratoon crops. Electronic Journal of Plant Breeding, 8(3), 992-997.

Singh, G., Chapman, S. C., Jackson, P. A., & Lawn, R. J. (2000). Lodging-a major constraint to high yield and CCS in the wet and dry tropics. In Proceedings of the 2000 Conference of the Australian Society of Sugar Cane Technologists held at Bundaberg, Queensland, Australia, 2 May to 5 May 2000. (pp. 315-321). PK Editorial Services.

Singh, G., Chapman, S. C., Jackson, P. A., & Lawn, R. J. (2002). Lodging reduces sucrose accumulation of sugarcane in the wet and dry tropics. Australian Journal of Agricultural Research, 53(11), 1183-1195.

Singkham, N., Songsri, P., Jaisil, P., Jogloy, S., Klomsa-Ard, P., Jonglangklang, N., & Patanothai, A. (2016). Diversity of characteristics associated with lodging resistance in sugarcane germplasm. SABRAO Journal of Breeding & Genetics, 48(1).

Singkham, N., Songsri, P., Jaisil, P., Jogloy, S., Klomsa-Ard, P., Jonglangklang, N., & Patanothai, A. (2016). Diversity of characteristics associated with lodging resistance in sugarcane germplasm. SABRAO Journal of Breeding & Genetics, 48(1).

STAR version 2.0.1, Biometrics, and breeding informatics, PBGB Division. Los Baños, Laguna: International Rice Research Institute, 2014.

Thangavelu, S. "Juice sucrose/total nitrogen ratio in sugarcane genetic stocks and its association with other ratios in juice and cane and sugar yield." INDIAN SUGAR 57, no. 8 (2007): 35.

Verlag Bartens, The Sugar & Sweetener Publisher. (2019, August 5). Peter Rein - Cane Sugar Engineering. Retrieved November 30, 2021, from https://www.bartens.com/book/cane-sugar-engineering/, W. (n.d.). Sugar - Definitions. Wayne Jayes. Retrieved November 30, 2021, from http://www.sugartech.com/definitions/index.php

Villaver, J. P., Alivio, E. M., Hajim, J. A., & Laylay, R. J. H. Traditional maize farming management practices and family involvement of smallholder farmers in Aurora, Zamboanga del Sur, Philippines. Volume 6, 2021, Pages 78-89. https://doi.org/10.1016/B978-0-12-819460-7.00085-2

Yanai, J., Nakata, S., Funakawa, S., NAWATA, E., KATAWATIN, R., & KOSAKI, T. (2010). Effect of NPK application on growth, yield and nutrient uptake by sugarcane on a sandy soil in Northeast Thailand. Tropical Agriculture and Development, 54(4), 113-118.

Yang, W., MO XM, Y. J., YUAN, F., & HUANG, S. (2016). Experimental study on the basic parameters of sugarcane on easy lodging period. Journal of Agricultural Mechanization Reseach, 38(12), 143-148.

Zhang, F. J., Zhang, K. K., Du, C. Z., Li, J., Xing, Y. X., Yang, L. T., & Li, Y. R. (2015). Effect of drought stress on anatomical structure and chloroplast ultrastructure in leaves of sugarcane. Sugar Tech, 17(1), 41-48.

Zhao, Q., Zeng, Y., Yin, Y., Pu, Y., Jackson, L. A., Engle, N. L., ... & Dixon, R. A. (2015). Pinoresinol reductase 1 impacts lignin distribution during secondary cell wall biosynthesis in Arabidopsis. Phytochemistry, 112, 170-178.

Appendix Table 1. Orthogonal partitioning between Phil and VCM varieties

ANOVA TABLE
Response Variable: TC_HA

Source	DF	Sum of Square	Mean Square	F Value	Pr(> F)
Replication	3	311.2395	103.7465	0.28	0.8386
Variety	7	17442.4483	2491.7783	6.76	0.0000
Variety: Phil Vs VMC	1	153.4569	153.4569	0.42	0.5222
Bamboo	1	4091.6811	4091.6811	11.09	0.0017
Variety:Bamboo	7	2056.6807	293.8115	0.80	0.5942
Variety:Bamboo: C0	1	8.1881	8.1881	0.02	0.8822
Error	45	16598.6210	368.8582		
Total	63	40500.6707			