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Research Article

Screening of Sugarcane Varieties for Tolerance to Water Deficiency Using Containers

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The negative effects of water deficiency in sugarcane production caused by climate change on the productivity of sugarcane can be mitigated by drought tolerant varieties. A 14 × 2 factorial arrangement in completely randomised design replicated three times was used to screen 14 varieties for drought tolerance at the Zimbabwe Sugar Experiment Station (ZSAES). The first factor was the sugarcane varieties *viz* ZN1, ZN2, ZN3, ZN4, ZN5, ZN6, ZN7, ZN8, ZN9, ZN10, CP72–1312, NCo376, N14, and CP72–2086. The second factor comprised of two levels of irrigation, namely, well-watered (100% by volume) and water-deficit stressed (30% by volume). The parameters measured in this study which included tiller count, leaf SPAD index, total plant dry mass, photosynthetic rate, and leaf temperature were found not suitable for screening sugarcane for tolerance to water-deficit stress. Water-deficit stressed varieties ZN1, ZN8, ZN10, and N14 had the tallest stalks. Varieties CP72–2086, ZN2, ZN5, CP72–1312, ZN4, ZN6, and ZN9 were stunted, indicating that they were probably drought-sensitive. Leaf vapour pressure deficits of varieties ZN8, ZN10 and N14 were higher in water-stressed plants than in the well-watered ones. The vapour pressure deficit of well-watered NCo376 plants was higher than that of water-stressed plants. Furthermore, the stomatal conductance of water-stressed NCo376 plants was greater than that of the other varieties tested, showing more tolerance to drought. Based on stem height, stomatal conductance, vapour pressure deficit, transpiration rate and dry matter parameters measured in the present study, sugarcane varieties that are recommended to cane farmers in Zimbabwe when faced with drought are NCo376, ZN1, ZN8, ZN10 and ZN14.

1. Introduction

The Zimbabwe's sugarcane industry is being threatened by the adverse effects of water deficits and rainfall variability caused by climate change. Marin et al. [1] warned that climate change is projected to have adverse effects on rainfall patterns, resulting in droughts and floods across the planet. It is predicted that in Southern Africa, climate change will cause more frequent droughts [2]. In Zimbabwe, frequent droughts are likely to curtail the production of many crops including sugarcane. Several dams including Mutirikwi-Tokwe; Manjirenji-Siya; and Manyuchi, supply irrigation water to the sugarcane estates [3]. However, poor and erratic rainfall due to climate change may result in poor replenishment of these dams, leading to a shortage in irrigation water [4].

One of the mitigation and adaptation strategies against water deficit due to droughts caused by climate change in sugarcane production in Zimbabwe involves planting drought tolerant varieties [5]. The degree of tolerance to water-deficit varies among sugarcane genotypes [6, 7]. However, in Zimbabwe, selection criteria for sugarcane genotypes released do not include water-deficit tolerance. The selection of varieties in Zimbabwe is mainly based on high cane and sugar yields, tolerance to smut and ratoon stunting disease, and ability to resist sugarcane stalk borer

(*Eldana saccharina*), among others [8]. Screening of sugarcane varieties for drought tolerance needs to be added to the selection criteria of sugarcane genotypes.

Screening sugarcane genotypes for water-deficit tolerance in the field may be costly due to substantial requirements such as seed cane, water, fertilisers, herbicides and other inputs. Also, controlling irrigation and other sources of water in the field is difficult. Instead of screening the sugarcane varieties in the field, selection can be done in containers. Screening sugarcane varieties in containers enables the researcher to control variables such as irrigation, nutrition, and growing medium. Using containers in screening sugarcane varieties is also likely to reduce costs since the area required is small, which means fewer inputs for growing the plants.

According to Ferreira et al. [9] the most important stages of sugarcane sensitive to water-deficit are tillering and stem elongation phases. Therefore, the screening of sugarcane varieties for tolerance to water-deficit can be done in containers in the first few months of growth. The aim of the study was to screen sugarcane varieties commercially grown in Zimbabwe for their tolerance to water-deficit.

2. Materials and Methods

The study was conducted at the Zimbabwe Sugar Association Experiment Station (ZSAES) located in the South Eastern Lowveld of Zimbabwe (21°01′S: 28°38′N; 430 m above sea level). The area receives an average rainfall of 625 mm per annum, much of which falls in summer (October to March). The mean air temperature ranges from 16°C in June and July to 26°C in October to January.

2.1. Experimental Design and Experimental Procedure. A completely randomised design (CRD) was used consisting of a factorial treatment combination of 14 varieties and two levels of water application in which the treatment combinations were each replicated three times. The 14 sugarcane varieties tested in the experiment were ZN1, ZN2, ZN3, ZN4, ZN5, ZN6, ZN7, ZN8, ZN9, ZN10, CP72–1312, NCo376, N14, and CP72–2086. The two levels of irrigation tested were well-watered with 160 ml of water (100% of field capacity) and water-stressed with 48 ml of water (30% of field capacity). The field capacity was determined using the water budget method [8].

Sugarcane setts were cut at the base from 12-months old varieties using sterilised cane knives. Knives were sterilised by immersing for 5 minutes in diluted propan-2-ol or isopropanol (JEYES fluid) (0.5 L JEYES fluid per 10 L of water). Three internodes from the base and top of the stalk were discarded. Before planting, one-eyed setts were cut from the remaining stalk and dipped for 5 minutes in triadimenol (Shavit) (1 ml Shavit/1000 ml of water) to prevent ratoon stunting disease. Three sterilised single-eyed setts of each variety were planted 40 mm deep close to the centre of a container (54 cm diameter and 90 cm depth) in a filter cake + pine bark (1 : 1 v/v) medium on 20 September 2018. The emerged plants were thinned at 14 days after planting (DAP) to leave one plant per container. A blend fertiliser Triple 16 (16% N, 16% P_2O_5 and 16% K_2O) was applied at a rate of 937.5 mg/l to the surface of the media in containers at 14 DAP and, thereafter, fortnightly until 70 DAP. The plants were irrigated with one litre per container per day for the first 14 DAP until germination. Weeds were removed by hand pulling. Regent (Fipronil) insecticide was sprayed at the base of the containers and around the experimental site to control termites and aphids. White grubs were controlled at planting using Carbrayl 85 WP (1-naphthol N-methylcarbamate) at the rate of 200 g Carbrayl in 200 L of water which was applied every fortnight.

2.2. Measurements and Statistical Analysis. Stem height (cm) of the primary tiller was measured using a metre rule, from the base of the plant at the surface of the medium to the apex of the plant at 150 DAP. Tiller number in each container was taken at 150 DAP. SPAD index was measured on topmost leaf with visible dewlap (TVD leaf) on the primary tiller at 150 DAP using chlorophyll metre (model Minolta SPAD-502, Minolta Co., Osaka, Japan) [10]. Leaf temperature, photosynthetic rate, transpiration, stomatal conductance, and vapour pressure deficit were measured on the TVD leaf of primary tillers between 0700 and 1000 hours using a portable photosynthetic system (CIRAS 3 model, PP systems, Amesbury, United States of America) at 150 DAP. Relative water content was determined on the TVD leaf of primary tiller at 149 DAP [11]. All tillers per pot were harvested by cutting at the base and separated into leaves, stems, and trash. The roots were removed from the pots and the growth medium carefully washed off them. All plant parts were placed in a forced-air oven at 105°C for 72 hours. The total dry mater was determined as the sum of dried roots, leaves, stems, and trash. The data were subjected to Fisher's Analysis of Variance (ANOVA) using Genstat Version 14th edition software (VSN international Ltd, Hemel Hempstead, United Kingdom). Treatment means were separated using Least Significant Difference and Standard Error Difference tests at 5% level [12].

3. Results

3.1. Stem Height of Primary Tillers. There was an interaction between sugarcane variety and water application rate on stem height at 150 DAP (Figure 1). Stem height was not significantly affected by water application rate in the varieties ZN1, ZN3, ZN5, CP72–1312, and CP72–2086 (Figure 1). In contrast, stem height decreased in the water stressed treatment in the varieties ZN2, ZN6, ZN7, ZN8, ZN9, ZN10, and N14 (Figure 1).

3.2. Number of Sugarcane Tillers per Variety. There was no interaction ($p = 0.281$) between sugarcane variety and water application rate on number of tillers. The test varieties differed significantly in tillering. Variety ZN2 produced more tillers than the other varieties tested (Figure 2). Sugarcane varieties ZN3, ZN1, ZN4, ZN5, ZN6, ZN7, ZN8, ZN9, and N14 had fewer tillers when compared to the rest.

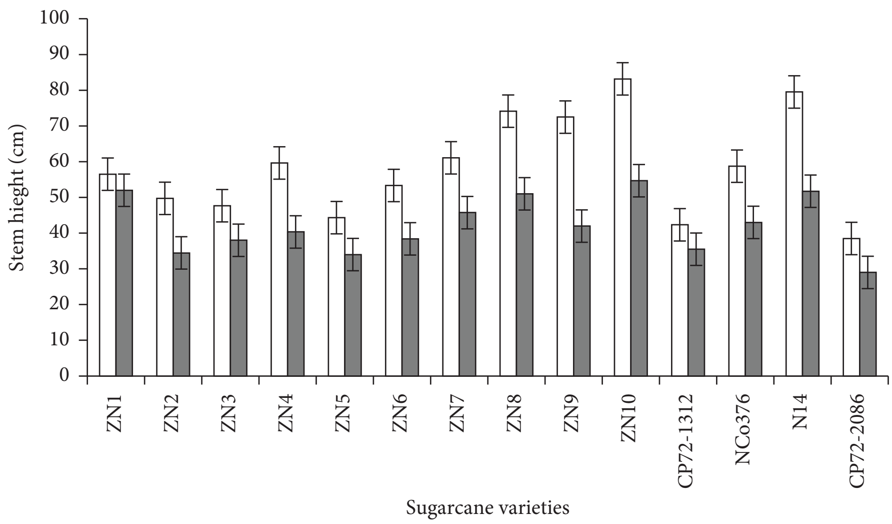

Figure 1: A comparison of stem height of primary tillers sugarcane varieties under □ well-watered or ■ water-stressed treatments at 150 DAP.

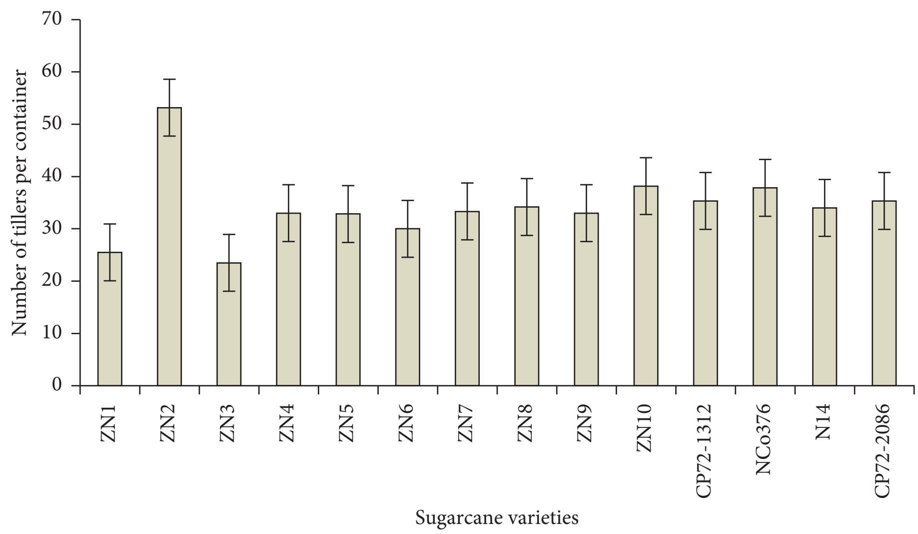

Figure 2: Number of tillers per sugarcane variety at 150 DAP.

Sugarcane plants grown under water-stressed conditions produced more tillers than the well-watered plants (Figure 3).

3.3. SPAD Index of Primary Tiller Leaves with TVDs. There was an interaction ($p = 0.411$) between the varieties and the water application rate on leaf SPAD index was not significant. Variety ZN3 had the highest leaf SPAD index but was not significantly different from that for ZN2, ZN5, and NCo376 (Figure 4). Variety ZN4 had the lowest leaf SPAD index but was not significantly different from that of ZN1 and ZN10 (Figure 4).

3.4. Vapour Pressure Deficit (kPa) of the Primary Tiller TVD Leaf. There was interaction between sugarcane variety and water application rate on vapour pressure deficit of the primary tiller TVD leaf. The leaf vapour pressure deficit was not significantly affected by water application rate in 10 of the 14 test varieties (ZN1, ZN2, ZN3, ZN4, ZN5, ZN6, ZN7, ZN9, CP72–1312, and CP72–2086) (Figure 5). In contrast, the leaf vapour pressure deficit increased markedly in three (ZN8, ZN10 and N14) of the remaining four varieties in the water stressed plants (Figure 5) and decreased in the fourth variety (NCo376) (Figure 5).

3.5. Relative Water Content, Photosynthetic Rate, and Temperature of the Primary Tiller TVD Leaf. There was no interaction between variety and water application rate on relative water content, photosynthetic rate, and leaf temperature. Of all the varieties tested, only ZN2 and ZN10 had relative water content of <80% (Table 1), although it was insignificant when compared to other. Well-watered plants had 4.9% more relative water content than water-stressed

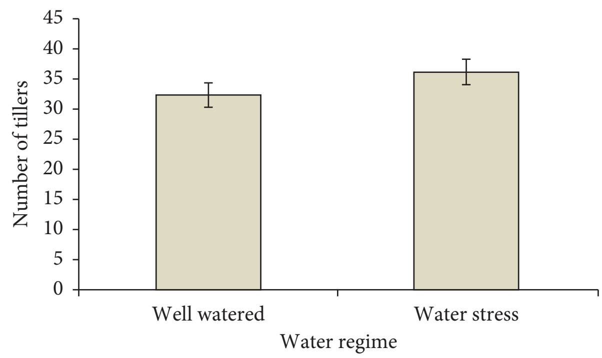

Figure 3: A comparison of tillers production in well-watered and water-stressed plants.

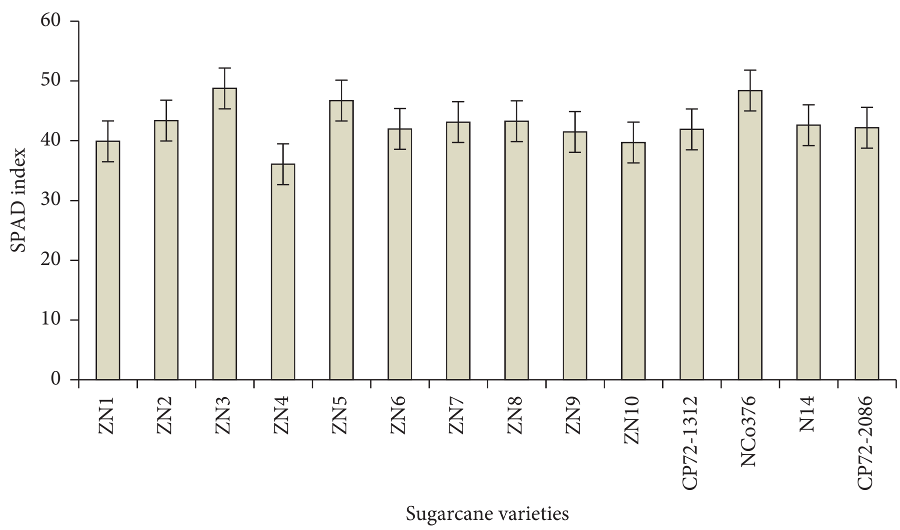

Figure 4: A comparison of SPAD indices of primary tiller-leaves among commercial sugarcane varieties.

plants. Similarly, the photosynthetic rate of well-watered plants was higher than that of water-stressed plants by 46.8% (Table 1).

3.6. Stomatal Conductance (mmol $H_2O^{m-2\cdot s-1}$) of Primary Tiller Leaves with TVD. There was interaction between variety and water application rate on stomatal conductance at 150 DAP. Stomatal conductance was not significantly affected by water application rate in the varieties ZN1, ZN2, ZN3, ZN4, ZN5, ZN6, ZN7, ZN9, CP72–1312, and CP72–2086 (Figure 6). In contrast, stomatal conductance increased significantly in the water stressed treatment in the variety NCo376 only (Figure 6). Stomatal conductance decreased in the water-stressed treatment in the varieties ZN8, ZN10, and N14 (Figure 6).

3.7. Transpiration Rate of the Primary Tiller TVD Leaf. The interaction between variety and water application rate on transpiration rate was significant at 150 DAP. Whereas the transpiration rate was not significantly affected by water application rate in the varieties ZN1, ZN2, ZN3, ZN4, ZN6, ZN7, ZN9, CP72–1312, NCo376, and CP72–2086 (Figure 7). In contrast, transpiration rate decreased in the water-stressed treatment in the varieties ZN5, ZN8, ZN10 and N14 (Figure 7).

Relationships between transpiration rate and vapour pressure deficit (Figure 8(a)) as well as between stomatal conductance and vapour pressure deficit (Figure 8(b)) were inversely linear. However, the relationship between transpiration rate and vapour pressure deficit was a linear positive (Figure 8(c)).

3.8. Number of Internodes and Internode Lengths of Primary Tillers. There were more internodes in well-watered plants than in water-stressed plants. At 150 DAP, variety N14 had more internodes than ZN1, ZN2, ZN3, ZN4, ZN5, ZN6, CP72–1312, NCo376, and CP72–2086 (Table 2). However, the number of internodes on N14 variety was similar to ZN7, ZN8 and ZN10 varieties. Variety CP72–2086 had the least number of internodes but was not different from ZN6 and ZN2 (Table 2).

On average, varieties ZN3, ZN10, ZN6, and ZN10 had the longest internodes (Table 2). In contrast, ZN2, ZN4, ZN5, ZN7, and CP72–2086 had the shortest average internode length (Table 2). From the first to the eighth

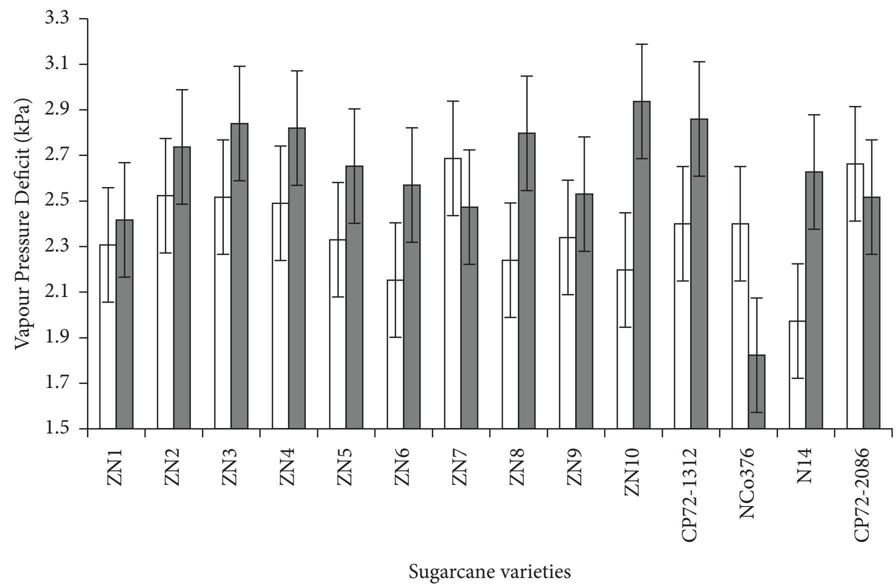

Figure 5: Vapour pressure deficit in the primary tiller TVD leaf among sugarcane varieties under well-watered □ or water stressed ■ treatments.

Table 1: Relative water content, photosynthetic rate, and temperature of leaf with TVD of primary tillers of sugarcane varieties and water application rate treatments.

Variety	Relative water content (%)	Photosynthetic rate (μmol CO_2 $m^{-2}{\cdot}s^{-1}$)	Leaf temperature (°C)
ZN1	85.02	9.9	37.15
ZN2	78.62	10.7	36.12
ZN3	84.81	15.4	37.35
ZN4	88.48	13.1	37.43
ZN5	85.03	18.0	36.97
ZN6	86.64	11.7	36.47
ZN7	84.90	10.9	36.45
ZN8	84.14	17.2	37.22
ZN9	82.26	10.8	36.15
ZN10	79.81	9.7	37.65
CP72–1312	82.01	20.5	37.38
NCo376	82.41	12.5	36.32
N14	84.52	16.8	36.18
CP72–2086	83.34	10.6	36.28
P value	0.457	0.657	0.684
LSD	NS	NS	NS
Water application rate			
Well-watered	85.68a	16.0a	36.91
Water-stressed	81.7b	10.9b	36.67
P value	0.006	0.018	0.484
LSD	2.746	4.21	NS
Interaction			
P value	0.582	0.591	0.581
LSD	NS	NS	NS
CV (%)	7.5	71.7	4.2

Mean values indicated by different letters within a column differ significantly from each other at the $p = 0.05$ level. LSD—least significant difference; NS—not significantly different; CV—coefficient of variation.

internode, the lengths of internodes of well-watered plants increased more than that of water-stressed plants (Table 2). There was a 75% decrease in the average lengths of internodes of water-stressed plants (Table 2).

3.9. Number of Green Leaves and Green Leaf Area. There was no interaction between variety and water application rate on number of green leaves and green leaf area. Varieties ZN2, ZN8, ZN10, NCo376, and N14 had the highest number of

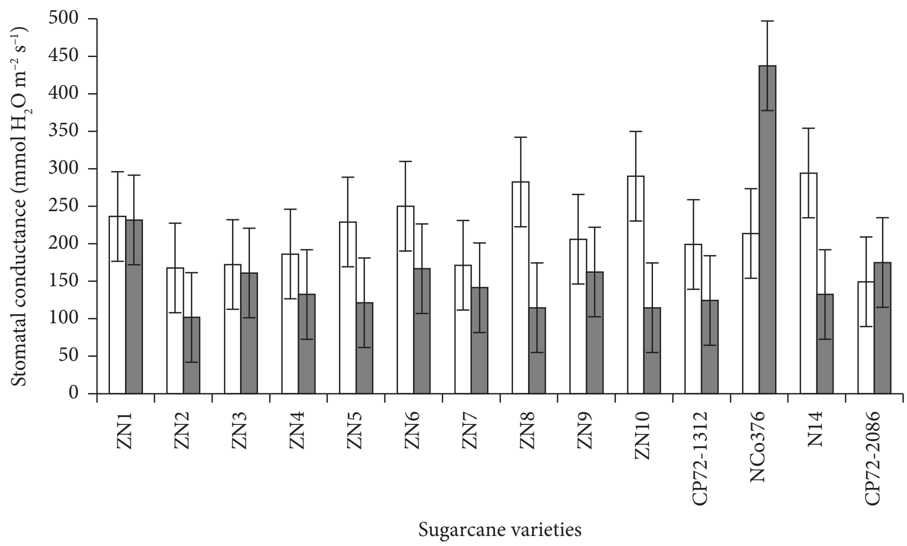

Figure 6: A comparison of stomatal conductance of primary tiller leaves among sugarcane varieties under □ well-watered or ■ water-stressed treatments at 150 DAP.

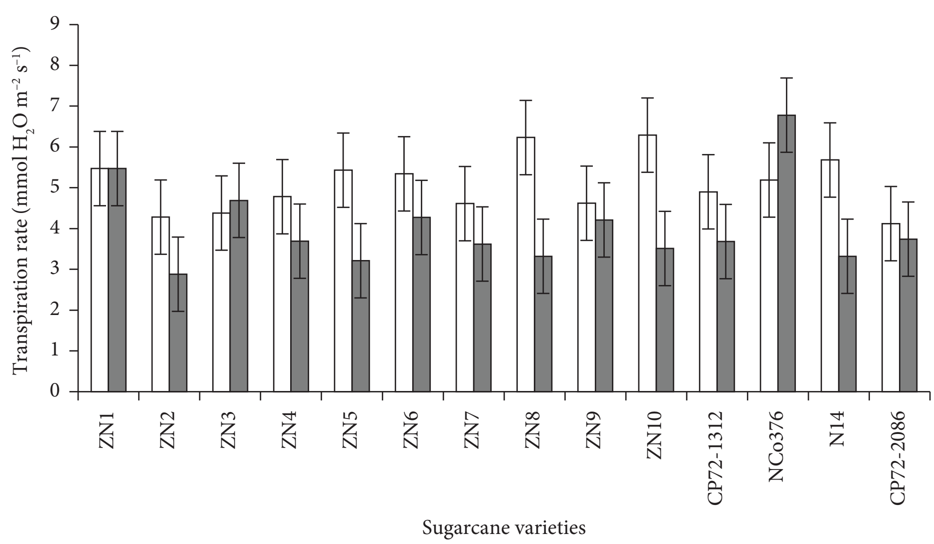

Figure 7: A comparison of transpiration rate of the primary tiller TVD leaf of different sugarcane varieties under □ well-watered or ■ water-stressed at 150 DAP.

green leaves per container. In contrast, varieties ZN1, ZN3, ZN4, ZN5, ZN6, ZN7, ZN9, CP72–1312 and CP72–2086 had the fewest green leaves per container (Table 3). Well-watered had more green leaves and green leaf area per container than water-stressed plants (Table 3). There were no differences in green leaf area among varieties tested.

3.10. Total Plant and Root Dry Matter and Shoot: Root Ratio. Varieties ZN2, ZN5, and N14 had similar and greater root dry matter than the other varieties tested (Table 4). Similarly, varieties ZN9, ZN10, NCo376, CP72 2086, ZN8, ZN7, ZN6, ZN4, ZN3, and ZN1 had greater and equal shoot:root ratios (Table 4). Varieties ZN7, ZN4, ZN5, ZN6, ZN8, ZN9, ZN10, CP72–1312, N14, and CP72–2086 had heavier and similar total plant dry matter (Table 4). Well-watered plants had heavier roots, greater total plant dry matter and shoot:root than water-stressed plants (Table 4).

4. Discussion

Varieties ZN1, ZN3, ZN5, CP72–1312, NCo376 and CP72–2086 were comparatively taller under water-deficit stress than ZN2, ZN6, ZN7, ZN8, ZN9, ZN10 and N14 as a result of longer internodes lengths. This suggested that stem growth of varieties ZN1, ZN3, ZN5, CP72–1312, NCo376 and CP72–2086 was more tolerant of water stress than was the case with varieties ZN2, ZN6, ZN7, ZN8, ZN9, ZN10 and N14. Perhaps, may be explained by genetic differences that existed between sugarcane varieties in extraction of water, which influences stem elongation [9]. Water-deficit reduces stem elongation of

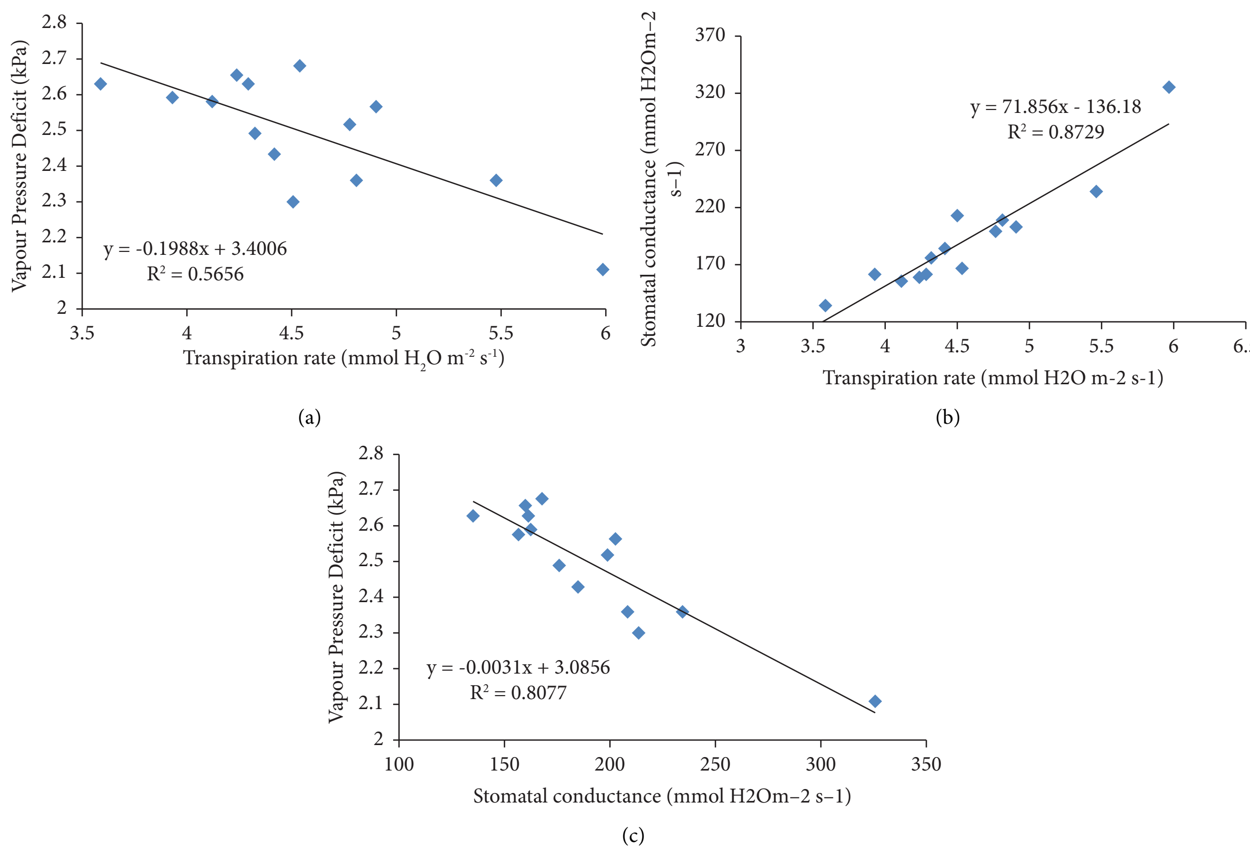

Figure 8: Relationship between transpiration rate and vapour pressure deficit (a); transpiration rate and stomatal conductance (b); stomatal conductance and vapour pressure deficit (c).

Table 2: Number and length of internodes (cm) of primary tillers among sugarcane varieties and water application rate.

Variety	Number of internodes	Length of internodes (cm)					
		1st	4th	5th	6th	8th	Average
ZN1	10.3cd	3.7d	4.6bcd	4.6cde	3.7abc	3.4bc	4.1bcd
ZN2	8.7ab	1.7a	2.7a	2.8a	2.8a	1.0a	2.6a
ZN3	9.7bc	3.2cd	4.5bc	4.8de	5.3d	5.6ef	4.8de
ZN4	10.2cd	2.1abc	3.3a	3.4ab	2.9a	4.4cde	3.1ab
ZN5	10.2cd	2.1abc	2.9a	2.7a	2.6a	2.7b	2.6a
ZN6	8.0a	2.9bcd	4.9cd	5.7e	4.9cd	6.3f	4.6de
ZN7	11.2de	2.2abc	3.6ab	3.5abc	3.5ab	3.8bcd	3.3abc
ZN8	11.8e	2.3abc	4.4bc	4.3bcd	4.1bcd	3.8bcd	3.8bcd
ZN9	11.3de	2.1abc	4.6bcd	4.1bcd	4.2bcd	3.6bcd	3.8bcd
ZN10	11.3de	2.7abcd	5.6d	4.9de	4.5bcd	4.2cd	4.5de
CP72–1312	9.5bc	1.9bab	3.6ab	4.1bcd	4.7bcd	4.9de	3.8bcd
NCo376	10.0bcd	3.0bcd	4.5bc	4.2bcd	4.4bcd	4.8de	4.3cd
N14	12.5e	3.1cd	4.7cd	4.6cd	4.1bcd	3.5bcd	4.0bcd
CP72–2086	7.7a	1.9ab	3.1a	2.8a	2.7a	3.2bc	3.2ab
P value	<0.001	0.031	<0.001	<0.001	<0.001	<0.001	<0.001
LSD	1.498	1.17	1.03	1.16	1.21	1.39	1.08
Water application rate							
Well-watered	12.5a	3.1a	5.3a	5.3a	5.2a	5.6a	4.9a
Water stress	7.9b	1.9b	2.9b	2.8b	2.5b	2.3b	2.8b
P value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
LSD	0.566	0.44	0.39	0.44	0.46	0.53	0.41
CV (%)	12.7	40.8	21.8	24.9	27	30.4	24.2

Mean values indicated by different letters within a column differ significantly from each other at the $p = 0.05$ level. LSD—least significant difference; NS—not significantly different; CV—coefficient of variation.

Table 3: Number of green leaves and green leaf area per container of 14 commercial sugarcane varieties between well-watered or water-stressed measured at 150 DAP.

Variety	Number of green leaves	Green leaf area (m^2)
ZN1	155.3a	4.19
ZN2	221.5d	4.49
ZN3	147.2a	3.40
ZN4	174.2abc	4.62
ZN5	161.0ab	3.83
ZN6	146.7a	5.41
ZN7	142.8a	4.49
ZN8	198.3bcd	3.29
ZN9	146.7a	4.74
ZN10	218.8d	4.08
CP72–1312	175.2abc	4.98
NCo376	203.2cd	3.40
N14	216.3d	4.45
CP72–2086	172.2abc	5.23
P value	<0.001	0.158
LSD	37.87	NS
Water application rate		
Well-watered	201.1a	5.79a
Water stress	153.0b	2.87b
P value	<0.001	<0.001
LSD	14.32	0.59
Interaction		
P value	0.403	0.162
LSD	NS	NS
CV (%)	18.5	31.3

Mean values indicated by different letters within a column differ significantly from each other at the $p = 0.05$ level. LSD—least significant difference; NS—not significantly different; CV—coefficient of variation.

Table 4: Effect of variety on whole plant dry mater, root dry matter, and the shoot:root ration at 150 DAP.

Variety	Root dry matter	Total plant dry matter	Shoot:root
ZN1	493ab	1859a	3.63abc
ZN2	801.7c	2342d	1.93a
ZN3	358.8a	1919ab	4.38bc
ZN4	477.9a	2077abcd	3.29abc
ZN5	829.2c	2256cd	1.80a
ZN6	529.8ab	2158bcd	3.93bc
ZN7	470.2ab	2352d	3.93bc
ZN8	466.5ab	2081abcd	3.38abc
ZN9	397.6ab	2331d	5.05c
ZN10	472.4ab	2136abcd	3.63abc
CP72–1312	376.5a	2139abcd	4.88c
NCo376	385.9a	2038abc	4.40bc
N14	624.3bc	2275cd	2.85ab
CP72–2086	473.6ab	2279cd	3.73abc
P value	<0.001	0.014	0.046
LSD	227.1	286.4	1.999
Water application rate			
Well-watered	636a	3072a	4.82a
Water stress	387b	1248b	2.51b
P value	<0.001	<0.001	<0.001
LSD	85.9	108.3	0.755
CV (%)	38.4	11.5	47.2

Mean values indicated by different letters within a column differ significantly from each other at the $p = 0.05$ level. LSD—least significant difference; NS—–not significantly different; CV—coefficient of variation.

plants by decreasing cell elongation because of poor cell turgor pressure [13]. Water-deficit stress may also cause a decline in cell division, resulting in poor stem growth [13–15].

The lack of interaction of variety and water application rate on number of tillers corroborates the observation by Ryes et al. [16] that tiller production during formative stages of sugarcane was not different among genotypes. Tillering is a complex physiological process which is affected by a wide array of factors that include environmental, endogenous, biotic and their interactions [17]. Tiller number in grasses is controlled by quantitative trait loci that have additive and not dominant effects [18]. For example, quantitative trait loci that affects tillering identified at early stages of plant growth of rice was undetectable at maturation stage [19]. Although there was no interaction between variety and water application rate, the main effects were significant. Variety ZN2 had more tillers than other varieties. Ryes et al. [16] also reported differences in tiller count among ten sugarcane genotypes. This suggested the presence of genetic variation among sugarcane genotypes on tiller production. The present study also showed more tillering of plants under water-deficit stress than well-watered plants during the early stages. Water deficit-stress can promote tillering as a way of compensating for the reduced assimilation production during drought [20].

The absence of any interaction between water application rate and variety on leaf SPAD index, suggests that this parameter is not useful for screening varieties for tolerance to water-deficit stress, especially in the formative stage of sugarcane growth. This was contrary to the findings by Silva et al. [6, 10] who recommended, that the leaf SPAD index could be used to screen sugarcane varieties for their tolerance to water deficit-stress. The present results showed varietal differences in leaf SPAD indices, and indication of genetic influence on this parameter, and could perhaps be linked to differences in nitrogen extraction. There is a strong correlation between nitrogen uptake and leaf SPAD index of sugarcane plants [21–23].

Varieties ZN8, ZN10, and N14 had higher leaf vapour pressure deficits than the other varieties under water-deficit stress. Higher vapour pressure deficit in plants causes the leaves to close their stomata under drought, and thus facilitating conserving water [12]. This assertion was confirmed by negative relationship between vapour pressure deficit and stomatal conductance (Figure 8(a)) or transpiration rate (Figure 8(c)). The stomatal conductance and transpiration rates of ZN8, ZN10, and N14 were significantly lower in water stressed plants (Figures 6 and 7). Thus varieties ZN8, ZN10, and N14 conserved more water than the other genotypes tested under drought [15]. Varieties ZN8, ZN10, and N14 were among varieties with higher total plant dry matter. Sugarcane varieties with higher dry matter and low stomatal conductance were reported to conserve water under drought conditions and to be tolerant to water deficit stress by avoidance of dehydration [9, 24]. Variety NCo376 had lower leaf vapour pressure deficit than other varieties under water-deficit stress (Figure 5). In addition, the stomatal conductance of variety NCo376 was higher in water stressed plants (Figure 6). NCo376 variety was among varieties with higher total plant dry mass (Table 4). These results suggested that NCo376 has a greater dehydration tolerance mechanism which allowed it to accumulate dry matter under water-deficit stress than other varieties tested [25]. Sugarcane varieties with dehydration tolerance mechanism under water-deficit stress are important for growing during drought seasons [9].

ZN8, ZN10, N14, and NCo376 were among varieties with the highest shoot: root ratio (Table 4). This confirms the tolerance of ZN8, ZN10, N14, and NCo376 to water-deficit stress when compared to the other genotypes. Under water deficit stress, plants enhance their root system as a tactic to extract more water, therefore, reduce shoot: root ratio [26]. Under drought conditions, plants re-allocate assimilates from shoot growth to root growth and this increases root length [27]. Lemoine et al. [28] reported that mild water deficit stress restricts shoot growth with little effect on root growth. In addition, ZN8, ZN10, N14, and NCo376 were among varieties with more green leaves than other varieties (Table 3). This supported the assertion that water deficit stress did not affect the shoot growth of ZN8, ZN10, N14, and NCo376.

There were neither interactions between water application rate and variety nor significant differences among varieties on relative water content, photosynthetic rate, and leaf temperature (Table 1). Thus, relative water content, photosynthetic rate, and leaf temperature were parameters not suitable for use in screening sugarcane varieties to water deficit. This was in contrast to results by Silva et al. [29] and Marchiori et al. [30], who reported that sugarcane varieties could be screened for their tolerance to water deficit using relative water content, photosynthetic rate and leaf temperature. Although there were no significant differences between varieties, the relative water contents of ZN2 and ZN10 were <80% (Table 1), indicating high sensitivity to water-deficit stress [31]. Water-deficit stressed plants had a reduced photosynthetic rate relative to well-watered plants (Table 1). Oskabe et al. [32] reported that during drought, plant cells accumulate abscisic acid in the guard cells triggering stomatal closure which ultimately reduce photosynthesis. Other results of water deficit reducing photosynthesis have been reported in plants [33] and in sugarcane [9].

There were neither interactions between variety and water application rate nor differences among varieties on green leaf area (Table 3). In contrast, Castro-Nava et al. [34] noted significant differences between sugarcane genotypes in terms of green leaf area in their response to water-deficit stress, and this was conspicuous as the plant aged. The green leaf area of sugarcane in this study was determined at 150 DAP, which might have been too early to note the differences between varieties in their response to water-deficit stress.

5. Conclusions

Based on stem height, stomatal conductance, vapour pressure deficit, transpiration rate, and dry matter parameters measured in the present study, sugarcane varieties that are recommended to cane farmers in Zimbabwe when faced with drought are NCo376, ZN1, ZN8, ZN10, and N14. Further research in the screening of genotypes should include the use of molecular fingerprinting techniques to increase precision in identifying drought tolerant varieties. There is also need to include all released and unreleased genotypes in the screening of varieties to identify tolerant varieties for use in future breeding programs.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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