EFFECT OF CLIMATE VARIABILITY ON SUGARCANE BREEDING IN NIGERIA

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ABSTRACT

Flowering in sugarcane (*Saccharum species*) is poor and variable at many tropical locations due to sub-optimal photoperiod. The situation is often compounded by moisture stress with the consequence of poor pollination success from hybridization programmes. This study assessed the impact of variability in weather factors on sugarcane breeding activities of two sugarcane breeding stations in Nigeria. Data showed that the highest pollination success was recorded for crosses (bi-parentals and polycrosses) in 2005 flowering season at Badeggi while none of the fuzz from the two types of crosses was viable in 2007 and 2008 respectively. The difference in pollination success between polycrosses and bi-parentals in 2005 season was 50 percent (%) while that between 2005 and 2006 flowering season for the bi-parentals was 75(%). Seedling mortality was the highest at Ilorin in 2008 and those that survived could not be advanced to the yield testing stage I due to poor morphological characteristics exhibited by the few surviving progenies. The difference between the year with highest pollination success (2007) and other years on this station were 78.96 and 43.35% respectively while that between 2009 and 2008 was 62.29%. We conclude that high temperatures during the ripening period acting singly or in combination with sub-optimal photoperiodism during flowering, was responsible for low viability of fuzz (sugarcane seeds) recorded in both stations in the last three years. Therefore, acquisition of infrastructure to improve flowering by imposing stronger photoperiodic stimuli for initiation, by avoiding high initiation temperatures, or both, along with identification of suitable locations that facilitate making crosses among the best parents available, will lead to attainment of self-sufficiency in sugar production in Nigeria.

Keywords: *Climate Change, Variability and Sugarcane Breeding*

INTRODUCTION

Increase productivity in sugarcane (*Saccharum officinarum* L.) in recent years can be attributable to improvement in genetic capacity of newly developed genotypes for sugar yields (cane yield and sucrose content) and better understanding of the interplay of genotype x environment, often referred to as G x E interaction. However, these improvements have been accompanied by the acceleration of environmental degradation and climate change which has direct effects on sugarcane breeding with the consequence of hampering the release of new improved varieties of sugarcane for enhanced sugarcane productivity and food security. The risks associated with climate variabilities lie in the interaction of several systems with many variables that must be collectively considered. Man's activity has already changed atmospheric characteristics such as temperature, rainfall, carbon dioxide (CO_2) levels and ground level ozone. According to Singh (1994), the overall effect of instability in weather factors on agriculture will depend on the balance of these effects. Thus, an assessment of the effects of global climate changes on agriculture might help to properly anticipate and adapt sugarcane breeding to maximize sugar production. A review of studies conducted over the past few years for many different sites across the world revealed few, if any, robust conclusions of either the magnitude or direction of impact for individual countries or regions (Fischer *et al*., 2002).

Sugarcane breeding is highly sensitive to climate variability and weather extremes such as droughts, floods and severe storms. Among environmental factors that impact on sugarcane breeding are diurnal temperatures (Clements and Awada 1967; Adejuwon, 1988), rainfall amount and distribution (Olaoye, 1996), sub-optimal photoperiod (Berding and Hurney, 2005), rising atmospheric concentrations of CO_2 (Rosenzweig *et al*., 1995) and pollution levels. For example, intermittent occurrences of night temperatures below 18°C during the period of floral induction reduces flowering intensity and/or delay seedling emergence (Coleman, 1963; Gosnell, 1973; Pereira *et al*., 1983) while frequent occurrences of daytime temperatures exceeding 31°C acting singly or in combination with moisture stress, have also been implicated in similar reduction in flowering intensity or delay emergence (Ellis *et al*., 1967; Nuss and Brett, 1977). Harsh weather condition also result in pollen abortion or premature pollen shed which limit cross manipulation by breeders during the crossing period. Furthermore, study conducted in Nigeria has shown that amount and distribution of rainfall during flowering do affect pollen viability and seed set in sugarcane (Olaoye, 1996). The implication of these vagaries in climatic factors through a combination of soil moisture stress and high daily temperatures in some years, is that both induction and flowering intensity are affected(Nayamuth *et. al.*, 2003), with the consequence that cross combinations are often restricted to the best possible among the parents flowering on a day rather than to either combinations among the best parents or desired parental clones for crossing (Berding, 2005).

Sugarcane variety development activities in Nigeria have focused on the development of productive varieties for cultivation on the sugarcane plantations. Flowering usually commences from early September in most of the locations and may extend till early December, especially in the late flowering clones. However, due to lack of specialized glasshouse for effecting crosses (polycrosses, bi-parentals) under ideal conditions, breeders have depended on carrying out their breeding activities under natural conditions which often are subjected to unfavourable weather conditions. Recent observations have shown mixed results in pollination success arising from poor seed set in fuzz (sugarcane seeds) collected from various crosses, which previously have yielded superior progenies, subsequently high yielding varieties. The apparent failure in outcomes of pollination suggests either pollen abortion or premature pollen shed or at the extreme, poor seed set, which may be directly related to unfavourable environmental conditions during the flowering period. According to Berding and Hurney (2005), sub-optimal photoperiod is largely responsible for poor and variable flowering in programmes located close to the equator, which may be confounded with high day temperatures, consequently, poor seed setting from the fuzz collected from the arrows (flowers) after pollination. In other words, unsuitable photoperiods may impose limitations on pollination success from sugarcane crosses not withstanding favourable temperature resulting from global warming. This report highlights the outcomes of varietal development activities from the two sugarcane breeding stations in Nigeria – National Cereals Research Institute (NCRI), Badeggi and Unilorin Sugar Research Institute (USRI), Ilorin.

METHODOLOGY

Hybridization procedure

Details of the conventional hybridization procedures adopted by the two breeding stations are similar to those of other sugarcane breeding stations but with slight modification at a certain instance (see for example, Olaoye, 2001). Briefly, male and female clones are identified among the flowering clones in the germplasm collections by conducting pollen fertility and viability tests, followed by utilizing the identified female clones (male sterile) and male fertile clones (males) from the germplasm in crosses. Crosses were usually set up during the flowering season using either of the three approaches (bi-parentals, polycross or modified polycross). At the end of flowering season, fuzz were harvested from the crosses, teased and stored in polythene bags kept in the freezer to maintain viability pending raising of the fuzz. Seedlings were then raised in trays filled with germinating medium (sterilized top soil mixed with bagasse and filter mud) and covered with polythene sheets to maintain optimum temperature for germination. Additional seedling management often include the application of ferrous sulphate solution to supplement iron (Fe^{3+}) which seedling may lack at this stage. Seedlings were then transplanted into the nursery beds as from four weeks after sprouting and maintained until the end of the flowering season before selection of progenies based on a set of criteria, including stalks/stool, sucrose content and freedom from diseases.

Meteorological data

For the study reported herein, weather data recorded during the flowering period which were collected either from the breeding station (Badeggi) or in its vicinity (Ilorin) were analyzed to make inferences on the outcomes of the breeding activities in the two stations.

RESULTS AND DISCUSSION

Climatic data (rainfall and temperatures) during the flowering period for Badeggi (2005-2008) and pollination success for the breeding station are presented in Table 1. The major difference in rainfall intensity (amount) between the four years was the volume recorded for October in 2005 which was the highest compared to other years. Differences in diurnal temperatures (each month) between the years were also similar. However, while minimum temperature was within the acceptable limit for normal induction of flowering in sugarcane, the average maximum temperatures exceeded $31^{o}C$ for most part. The highest pollination success was recorded for both crosses (bi-parentals and polycrosses) in 2005 flowering season followed by 2006 season but with no germination recorded for polycrosses. None of the fuzz in the two types of crosses was viable in 2007 and 2008 respectively. The difference in pollination success between polycrosses and bi-parentals in 2005 season was 50 percent (%) while difference between 2005 and 2006 flowering season for the bi-parentals was 75(%).

Climatic factors during the flowering season in 2008 and 2009 at Ilorin are presented in Table 2. Rainfall figures for the two years followed the normal pattern for the station except that rains were heavy in October of 2009 compared to the same month in 2008. Both minimum and maximum temperatures were similar to temperatures recorded for Badeggi station but with maximum values at Ilorin lower than for Badeggi (Table 1). Diurnal temperatures during the flowering season were generally high in 2009 but accompanied by longer sunshine hours especially in November and December of 2009 respectively. Relative humidity on the other hand diminished with decreasing rainfall intensity.

Seedling parameters relating to pollination success between 2007 and 2009 at Ilorin are presented in Table 3. The station recorded the lowest pollination success in 2008 flowering season while the best year was in 2007. Seedling mortality was the highest in 2008 and those that survived could not be advanced to the yield testing stage I due to poor morphological characteristics exhibited by the few surviving progenies. Seedling survival improved in 2009, probably due to additional precautionary measures adopted during fuzz raising by treating the fuzz with fungicide solution. The difference between the year with highest pollination success (2007) and other years were 78.96 and 43.35% respectively while that between 2009 and 2008 was 62.29%.

Changes in flowering behaviour among the progenies derived from 27 polycrosses between seedling stage and stage I of the preliminary yield testing are presented in Table 4. Many of the non-flowering progenies except those derived from nine maternal parents (SP 70-1005, S17, B 74163, N51137, B 47419, B 4681, B 84185, and CP75108) flowered with many of them exhibiting profuse flowering (Figure 1). Surprisingly, all the progenies from two maternal parents (B 014 and SP 701284) which were advanced to the yield testing stage based on non-flowering attributes among other parameters, flowered and some of them profusely too. However, none of the flowering progenies changed in flowering status between the two selection stages.

Variability in climate is likely to impact on sugarcane breeding activities in areas located to the equator (for example, Nigeria), where sub-optimal photoperiod is largely responsible for poor and variable flowering (Berding and Hurney, 2005). Coleman (1969) noted that each stage of the flowering process is temperature dependent as it involves biochemical processes while daytime and nighttime optimal temperatures for flower initiation and characterization of natural environments for sugarcane flowering ability have been reported to be around 28°C and 23°C respectively (Clements and Awada 1967). Although the minimum temperatures during flowering in the two breeding stations were within the acceptable limit for normal induction of flowering in sugarcane (Coleman, 1963; Gosnell, 1973; Pereira *et al*., 1983), the average maximum temperatures exceeded 31^{o}C for most part, a condition that has been reported to be responsible for poor seed set in many crosses (Ellis *et al*., 1967; Nuss and Brett, 1977).

The fact that pollination success at Badeggi was best in 2005 with the lowest maximum temperature in November therefore suggests that high temperatures during the ripening period may have also contributed to the observed failure of seed set in the crosses between 2006 and 2008. Furthermore, the preponderance of flowering among several progenies previously selected as non-flowering at Ilorin may also result from weather variability, through a combination of diurnal and high daily temperatures, which has been shown to affect both induction and flowering intensity (Coleman 1969). Since the progenies advanced to the yield testing stage were selected at the end of flowering period, the sudden change in flowering status may not be unconnected with extremes of temperature and/or diurnal temperatures associated with the current world global warming in the last few years which according to previous studies on climate and flowering in sugarcane, may induce flowering in non-flowering types and also affect the extent of flowering (Ellis *et al*., 1967; Gosnell, 1973). This may also be responsible for the problems currently being encountered by the two breeding stations in their fuzz raising and seedling selection programmes. Coleman (1969) as well as Gosnell (1973) and Moore (1987), have identified photoperiodism, location (altitude) temperature, moisture stress and nutrition level as factors that affect the timing and intensity of flowering.

CONCLUSION

On the basis of the findings, the study has deduced a number of useful recommendations. Apart from investing in infrastructures that improve flowering, consequently enhanced breeding activities, most of all sugar producing countries have also identified locations that are suitable for effecting crosses and fuzz raising under their own conditions. As noted by Berdin (2005), the efficacy of controlled photoperiod facilities is well proven and has been validated in many sugarcane breeding stations. The authors further suggested that many tropical locations could benefit from such infrastructure to improve flowering by imposing stronger photoperiodic stimuli for initiation, by avoiding high initiation temperatures, or both. Acquisition of such infrastructures in Nigeria along with identification of suitable locations that facilitate making crosses among the best parents available, will lead to faster attainment of self-sufficiency in sugar production.

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Table 1: Climatic variables (rainfall and temperature) and n pollination success over a four-year period (Badeggi, Nigeria)

		Temperature (^oC)		Pollination success	
Month	Rainfall (mm)	Minimum	Maximum	Bi-parentals	Polycrosses
			2005		
September	194.0	24	32		
October	122.4	23	32		
November	0.0	20	35	20	40
			2006		
September	138.0	24	33		
October	37.6	23	32		
November	0.0	18	36	5	0
			2007		
September	283.8	22	31		
October	27.3	23	33		
November	0.0	22	36	0	0
			2008		
September	366.4	23	30		
October	89.8	23	32		
November	0.0	20	36	0	0

Table 2: Climatic variables during the flowering season in 2008 and 2009 (Ilorin, Nigeria)

	2008	2009				
					Temperature ^{o}C	
Month	Rainfall (mm)	Rainfall (mm)	Relative Humidity (%)	Sunshine hours	Minimum	Maximum
September	175.60	181.1	87.0	4.55	21.9	30.5
October	106.21	122.8	75.25	5.15	22.0	31.4
November	38.5	4.4	64.75	7.18	20.2	33.4
December	0.0	0.0	59.0	8.33	19.2	35.5

Table 3: Rate of pollination success over a three-year period (Ilorin, Nigeria)

Year	No. of crosses	No. of seedlings raised	Seedling mortality	%Success	No. transferred to field	No. advanced to stage I yield testing
2007	36	546	239	56.28	307	91
2008	45	735	648	11.84	8	0
2009	30	458	312	31.88	118	+

+; Selection will be carried out after flowering season based on set criteria for seedling advancement.

Table 4: Changes in flowering behaviour in 91 progenies derived from 27 Polycrosses between two selection stages (Ilorin, Nigeria)

			Flowering habit				
			Seedling (2007/08)		Stage I (2008/09)		
S/N	Maternal parent	No. of Progenies	Non flowering	Flowering	Non flowering	Flowering	% Change between selection stages
1.	SP70-1005	1	0	1	0	1	0.0
2.	S 17	3	0	3	0	3	0.0
3.	BT 9162	1	1	0	0	1	100.0
4.	Co 995	2	1	1	0	2	50.0
5.	B 74163	2	0	2	0	2	0.0
6.	N51137	1	0	1	0	1	0.0
7.	B47419	2	0	2	0	2	0.0
8.	B4681	5	0	5	0	5	0.0
9.	B84185	2	0	2	0	2	0.0
10.	M31-45	2	0	2	0	2	0.0
11.	B69275	7	6	1	0	7	85.7
12.	CP75108	1	0	1	0	1	0.0
13.	CP72356	3	2	1	0	3	66.7
14.	MCO 270	1	1	0	0	1	100.0
15.	CB 83193	3	3	0	0	3	100.0
16.	N9	2	2	0	1	1	50.0
17.	NCO 79	5	5	0	0	5	100.0
18.	SP 70-1290	2	2	0	0	2	100.0
19.	B 014	13	13	0	0	13	100.0
20.	SP 70-1138	3	3	0	0	3	100.0
21.	Co 945	7	7	0	0	7	100.0
22.	B 74139	5	5	0	0	5	100.0
23.	D 14146	9	9	0	0	9	100.0
24.	R-477	6	6	0	1	5	83.3
25.	SP-7116	2	2	0	0	2	100.0
26.	B76163	2	2	0	0	2	100.0
27.	SP701284	8	8	0	0	8	100.0

Figure 1: Profuse flowering observed among sugarcane progenies many of which were previously selected based on-non flowering habit at the seedling stage (Ilorin, Nigeria).