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Full Length Research Paper

Weather and seasonal effects on growth, seed yield and soluble carbohydrate concentrations in selected maize cultivars in the humid areas of Nigeria.

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A study was conducted in 2001 and 2002 to identify genotypic attributes relevant to performance and adaptation of ten maize cultivars grown on the field in the rainy and in the late seasons (terminal drought situation) in a humid zone of Nigeria. Data were collected on shoot biomass and seed yield and on leaf tissue concentrations of chlorophyll a and b and water soluble (non-structural) carbohydrate in the maize cultivars evaluated. Significant cultivar and seasonal effects on growth duration, dry matter production, assimilate reserves and seed yield in the cultivars of maize were obtained. In general, late maturing varieties of maize produced higher seed yield than the early maturing varieties, and when both were sown in the rainy season, they produced larger seed yield than the late season crop. Lower values of chlorophyll concentrations in leaf tissues were obtained for late season maize, but non-significant differences were found for late and early maturing cultivars. Although, the concentrations of non-structural carbohydrates were higher in dry season maize compared to rainy season crop, however, the increased intensities of drought and temperatures during the reproductive phase in the late season could have reduced kernel number (sink size) in the maize cultivars.

Key words: Maize, soluble carbohydrate, chlorophyll, yield, cropping seasons, tropics.

INTRODUCTION

In the humid tropics, maize is grown as an early and late season crop. The early crop is planted at the onset of the rainy season before the rains are fully established, however, the late season crop is planted during the short second cycle of rains, a sowing which terminates in terminal drought. There are sharp variations in soil water and thermal regimes in the early part of the rainy season (early vegetative phase of maize growth) and in the later part of the late cropping season (terminal drought situation). These episodes of extreme events could impose different degrees of drought stress conditions on the crop and affected growth duration, plant size, dry matter production, assimilate reserves and partitioning to grain in crops. In plants, hydrothermal sensitivity of physiological processes (i.e. critical pre and post-anthesis period, anthesis-silking interval) is reported (Pressman et al., 2002; Sato et al., 2002; Wardlaw, 2002). Physiological plasticity and hence coping strategies in crops under extreme weather events during crop growth will contribute to enhanced plant tolerance of these events (Banziger et al., 1997). In crops, traits such as biomass accumulation, leaf area dynamics (duration of canopy), capacity for assimilate reserve and mobilisation to reproductive structures (grain) are important to the survival, crop functioning and hence its productivity under variable soil water and thermal regimes of the sowing seasons (Hall et al., 1992; Timsina et al., 1993; San Jose et al., 2003).

Stem water soluble carbohydrate (WSC) is a useful trait and could provide indication of potential drought resistance in crop species and cultivars under diverse growing environments (Bidinger et al., 1977; Arconi et al., 1980; Schnyer, 1993; Volaire et al., 1998; Foulkes et al., 2002). Water deficit during the grain filling period enhanced senescence could lead to increased remobilization of WSC stored in vegetative tissues to grain (Bidinger et al., 1977; Schnyer, 1993; Foulkes et al., 2001; Yang et al., 2001). Stem sugars contribute to grain yield under irrigated conditions while water soluble carbohydrate (WSC) concentrations is reported as a reliable indicator of grain yield under drought (Foulkes et al., 2002). A significant proportion of WSC reserves was translocated to seed in wheat under drought (Bidinger et al., 1977; Schnyer, 1993; Foulkes et al., 2001). In another study, water deficit during the

the grain filling period enhanced senescence and led to increased remobilization of WSC stored in vegetative tissues to grain in rice (Yang et al., 2001). Leaf senescence can accelerate at high leaf soluble carbohydrate concentration (Ceppi et al*.,* 1987), and Rajcan et al. (1999) established critical/threshold soluble-carbohydrate concentration from a relation of chlorophyll concentrations (SPAD reading) and leaf soluble carbohydrate concentration for the initiation of senescence. Routine agronomic importance of stem water soluble carbohydrates (WSC) as trait providing early indication of potential drought resistance in crop species and cultivars merits study in diverse growing environments (Arconi et al., 1980; Schnyer, 1993; Volaire and Lelievre, 1997; Volaire et al., 1998). However, information is scarce on the association of WSC with genotypic adaptation and grain yield of most annual crops from the humid tropics where growing seasons are characterized by varying episodes of extreme weather events.

Therefore, analysis of genotype performance under field conditions is basic to understanding environmental effects on crop growth at various cropping seasons and the ultimate performance of a cultivar. This understandding is of utmost importance in the strategies to improve genotypic adaptation and hence the productivity of crops in drought prone areas where varying degrees of soil moisture deficits are encountered at some stages of crop growth/cycle.

It was postulated that traits such as biomass accumulation, leaf area development and capacity for assimilate reserve which are important to growth and yield formation are affected by genotypic potentials of maize cultivars under variable soil water and thermal regimes of the rainy and late sowing seasons. Experiments were therefore conducted to evaluate differences in genotypic attributes (such as shoot biomass and seed yield and on leaf tissue concentrations of chlorophyll a and b and water soluble carbohydrate) which are relevant to performance and adaptation in ten maize cultivars grown on the field in the rainy and in the late (terminal drought situation) planting seasons in a humid zone of Nigeria. This information may contribute to the expansion of cultivation and profitability of maize production in the humid south of Nigeria and elsewhere in Africa.

MATERIALS AND METHODS

Two scenarios of balance between demand for and supply of water is presented in the humid rainforest zone of Nigeria (site of study). Therefore, the growth, development and yield potentials of ten maize cultivars grown in the rainy and the dry post-rainy (late) season cropping opportunities were studied in 2001 and 2002. Cultivars were chosen on the basis of contrasting growth duration (anthesis/silking dates) and the possibility of differences in stem WSC concentrations and hence grain yield formation in ten maize cultivars under the circumstances of the prevailing episodes of weather events of the rainy and late cropping seasons. This study was carried out at the Teaching and Research Farm of the Federal University of Technology, Akure, (lat $7^0$5 N, long $5^0$10 E), a tropical rainforest zone of southern Nigeria. The sandy loam soil at the site of study is an Alfisol classified as clayey skeletal oxic-paleustalf (USDA). The nutrient status of surface soil for 0 - 15cm at the experimental site before planting pH 6.8; N (0.19 mg/kg); P (7.69 mg/kg); K, Ca and Mg (1.75, 0.84, 4.39 cmol/kg soil respecti-vely); organic matter (2.42 g/kg), bulk density (1.28 Mg/m3) and water holding capacity (0.061 g/g).

The experimental site, five year fallow vegetation, was manually cleared. Seeds of the selected maize cultivars were sown on 20th April and 13th September, 2001 and 14th April and 15th September 2002 (respective early and late season crop) at a spacing of 90 between the rows and 30cm within the rows into the field. The field was separated into five blocks of eight plots per block while each plot has a dimension of 4 x 4m contained 54 plants. The maize cultivars were randomly assigned to plots at four replications per cultivar (treatment). There was a 1m guard row between block and plots. The plots received single application of 150 kg/ha NPK (a compound mineral fertilizer consisting of N, P and K in 15:15:15 ratio) at three weeks after planting (WAP) and all plots were manually weeded at 3 and 7 WAP. Maximum soil temperature at 5 cm depth were measured weekly at 1500h. In bothe rainy and late season crops, soil moisture storage was determined at 4, 8 and 12 weeks after planting (WAP) at 0-60 cm depths using drill core samplers. At each soil depths, samples were collected at five spots/plot while the samples were oven-dried for 24 hours and at 105 °C. Reference evapotranspiration (PET) was estimated according to the Penman- Monteith equation (Allen et al., 1998). The weather condition recorded within 300m of the experiment site over the period of the experiment, from 2001 to 2002 is given in Table 1.

Agronomic characters of root and shoot biomass, plant height, 50% anthesis dates, concentrations of chlorophyll and water soluble carbohydrates in plant tissues, yield and yield components were measured. Number of senesced leaves per plant was taken starting from 50% anthesis date to physiological maturity, this coincided with period of active leaf senescence (Borras et al., 2003). The number of senesced leaves was recorded weekly, and a leaf was considered senesced when half or more of its area had yellowed (Borras et al., 2003). Total leaf senescence per plant was recorded as the sum of all senesced leaves/plant within each genotype. For destructive sampling, from $2m^2$ at the center of each plot, a total of twenty plants from each cultivar were randomly sampled, ten plants/cultivar were used for the determination of leaf area, and chlorophyll and water soluble carbohydrate concentrations. At 50% anthesis date, leaves were clipped off the stems and leaf area was measured with leaf area meter Li 2000 (Mayashi Denko, Japan). The concentrations of chlorophyll a and b in leaf tissues and the accumulation of water-soluble carbohydrate (WSC) in stem internodes and leaf tissues were measured from ten plants randomly selected from each cultivar. The flag leaves and the 3rd leaves above and below the ear were sampled between 50% anthesis and silking dates in each maize cultivar and cropping season for the determination of chlorophyll a and b concentrations. Chlorophyll a and b concentrations was analysed following the method described by Dwyer et al. (1995) and Iremiren et al. (1997). WSC in the 3rd leaves below and above the ear (including leaf sheaths), the flag leaf and stem internode in each genotype and cropping season in the post-anthesis period at 3-4 weeks after silking in the early maturing cultivars and at 4-5 weeks after silking in the late maturing cultivars. Destructive harvests were performed on five plants per cultivar approximately 3 h after sunrise in order to minimize effects of diurnal variations of leaf sugars (Dwyer et al., 1995). Samples were oven dried at 80°C for 48 h and ground to pass through 1mm screen. WSC were extracted for 60 min in 80% ethanol (at 80°C) and twice in water (100°C) at a dry tissue to volume ratio of 100 mg to 8 ml. WSC concentrations were then measured using the anthrone method (Yemm and Willis, 1954 cited by Dwyer et al., 1995. In addition, another ten plants were randomly selected from each ciltivar from which ears/cobs (apical and sub-apical ears) were harvested at physiological maturity, kernel number per plant was

Table 1. Weather data at the site of the experiment (2001 and 2002)

	Experiment One											
	Jan	**Feb**	**Mar**	**April**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Rainfall(mm)	0	1.4	33.2	53.5	97.9	205	268.7	253.6	211.9	129	27.8	14.1
Min.Temp(^{o}C)	19.6	21.4	22.8	21.5	21.8	21.0	21.1	21.3	1.5	21.8	20.9	19.8
Max. Temp.(^{o}C	32.1	33.4	33.6	32.4	31.7	30.6	29.2	29.9	29.4	30.1	31.8	31.2
VPD (kPa)	2.8	3.1	3.3	3.4	3.1	3.0	2.8	2.5	2.7	2.9	3.0	2.4
Sunshine (hrs)[a]	189.3	217.4	225.7	194.6	189.3	161.9	108.7	89.5	96.3	147.2	209.1	158.6
Rn (MJm^{-2}day^{-1})[b]	13.5	15.8	16.6	16.3	18.5	16.7	13.8	10.1	13.6	15.1	14.5	14.8
Eo (mm.month^{-1})[c]	209	185	238	132	108	98	91	86	97	102	30	148
	Experiment Two											
Rainfall (mm)	0	5	19	39	189	257	288	327	271	193	68	23
Min. Temp (^{o}C)	17.9	20.6	22.3	22.9	21.3	20.8	21.2	20.8	21.5	21.8	20.9	19.5
Max. Temp.(^{o}C)	31.8	32.6	33.3	32.9	31.6	30.3	29.6	28.7	29.6	30.3	31.7	30.6
VPD (kPa)	3.0	3.2	3.3	3.4	3.2	3.0	2.8	2.3	2.6	2.9	3.1	2.8
Sunshine (hrs)[a]	191	219	238	206	183	177	128	93	138	219	235	193
Rn (MJm^{-2}day^{-1})[b]	12.3	16.1	17.8	17.1	16.2	14.9	12.9	9.8	13.1	14.8	15.5	14.1
Eo (mm.month^{-1})[c]	212	193	243	167	113	101	86	82	93	110	125	155

Air temperature and rainfall (monthly means of daily values or monthly totals)
a. Total sunshine
b. Incoming solar radiation (Rn)
c. Open water evaporation (Eo)

counted and mean kernel weight was computed from the average of ten sample weights of kernel/cob.

Due to the similar yearly response of maize in the same seasons of sowing, results from the same seasons of sowing were pooled and means of two trials presented after season by year analysis block experiment. Data collected were subjected to analysis of variance (ANOVA) test to determine the significance of main effects of cultivar, maturity type and seasons of sowing and their interactions (Steel et al., 1997).

RESULTS

Soil hydrothermal regimes

Table 1 presents meteorological variables at the site of experiment during maize growth in the respective rainy and late cropping seasons of 2001 and 2002. There were high probabilities of occurrence of dry spells between rainfall episodes particularly in the early part of the rainy season. The second half (later part) of the late cropping season was characterised by increased atomspheric demand (vpd), solar intensity and air temperatures in addition to negligible rainfall. This coincided with anthesis/silking and grain filling stage of maize.

There is a non-consistent pattern of soil temperature regimes under rainy season maize (Figure 1a). In the late cropping season (Figure 1b) higher ranges of soil temperatures were obtained in the late maturing types of maize during their vegetative growth. In this group, following the attainment of maximum leaf area development (about 7 WAP), declining status of soil temperatures was obtained, a period during which heavy (active) sensecence had occurred in the early maturity type.

There were significant differences in soil moisture storage among sampling dates in the respective rainy and late sowing seasons (Figure 2a and b) within 0–60 cm depth. This appeared to have stemmed from the pattern of rainfall events at site of experiment during the different cropping seasons. During the rainy season, there were increases in soil moisture reserves with depth from maize establishment to maturity (12 WAT) (Figure 2a). Shorter periods between rains (frequency) during crop cycle in the rainy season enhanced soil moisture storage (Figure 2a). Similar trends and hence non-significant differences in soil moisture storage at each sampling dates were obtained. However, in the late season, remarkably higher soil moisture storage was obtained at 4 and 8 WAP over 12 WAP (Figure 2b). This trend denoted increasing intensities of soil moisture deficits during reproductive growth phase in the late season thus following the negligible rainfall amounts at close of season. The dynamics of rainfall and PET during the year (Figure 3) shows the occurrence of negligible rains and high values of evaporative demand in the earlier part of the rainy season. However, sharp declines in the amount and frequency of fall of rain and concurrent increasing intensities of evaporative demand was the situation in the late sowing season. These events coincided with the reproductive (silking and grain filling) periods in the maize cultivars.

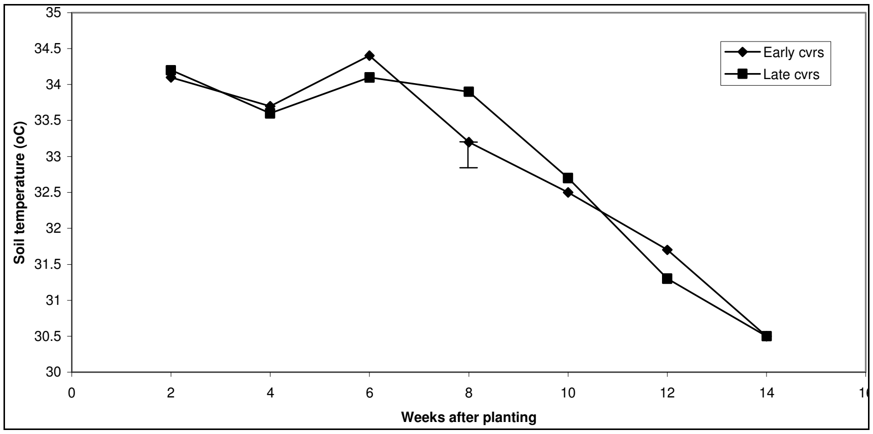

Figure 1a. Time-course of soil temperatures in rainy season maize at 5 cm depth.

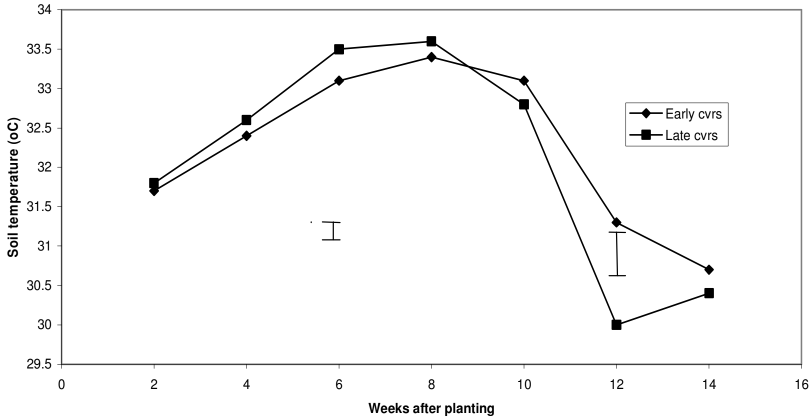

Figure 1b. Time-course of soil temperature (1500h) in late season maize at 5 cm depth.

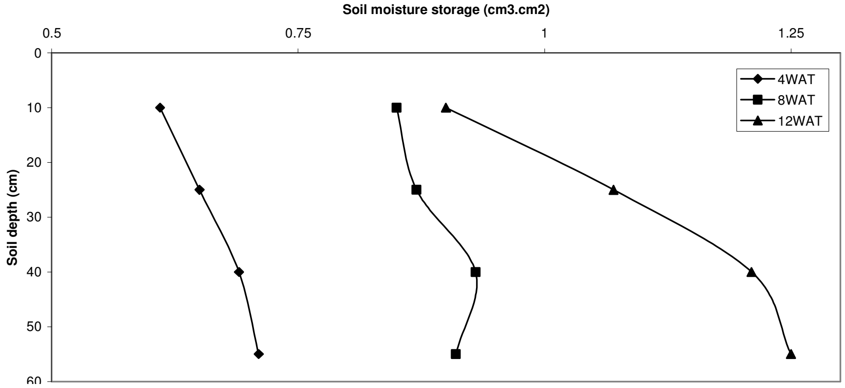

Figure 2a. Changes in soil moisture storage with depth during maize growth in the rainy season.

Effects of cultivar, maturity type and sowing season on crop phenology, biomass and seed yield

Genotypic effect is profound on the attainment or duration of growth phases especially flowering date (Table 2a and b). Differences in flowering date exert some variations on seed yield presumably in due to prevailing weather conditions during grain filling. Therefore, the attainment of 50% flowering date (tasselling/anthesis) among the cultivars elicited various responses in maize in terms of values

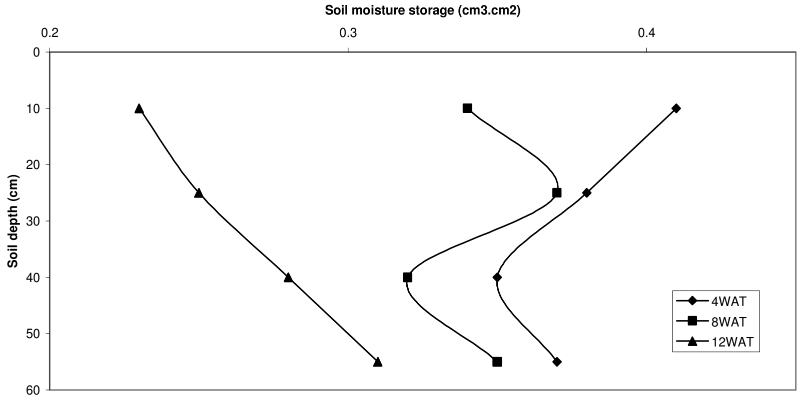

Figure 2b. Changes in soil moisture storage with depth during maize growth in the late season

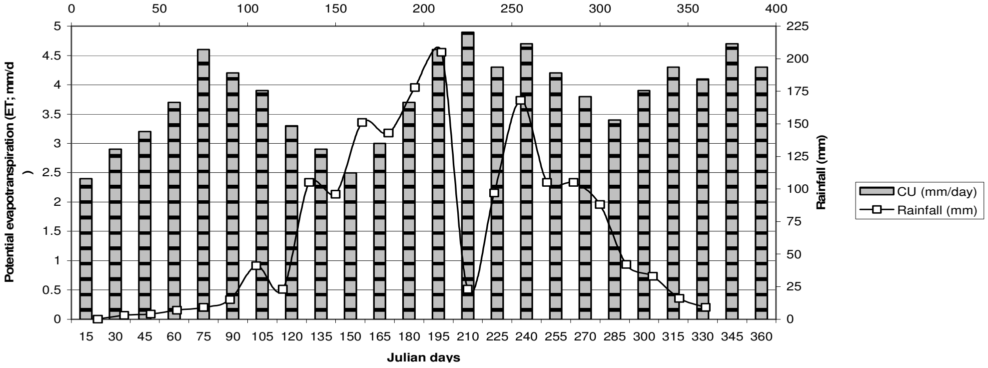

Figure 3. Dynamics of consumptive water use (Cu) and rainfall amount at site of experiment

Table 2a. Effects of cultivar and maturity group on the growth and yield characters of maize (rainy season crop)

	Root wt (g)	Shoot wt (g)	No. of Senes. leaf	Green leaf area (m^2)	Plant (ht)(cm	50% Flowering date (days)	Dehusked cob wt (g)	No. of kernels/plant	Mean kernel wt (mg)	Seed yield/plant (g)
Maize cultivars										
ACR 91Suwan1- SR (L	57.3	116.4	5.2	8.13	159.6	51	160.3	838	247	228.3
ACR 93 T2L COMP1- (L)	53.1	123.3	5.3	8.37	157.8	54	154.7	796	236	221.9
AK 94-DMR-E R-Y (L)	49.5	131.3	4.7	7.84	155.1	50	165.1	753	251	214.5
AK 9928 DMR SR (L	51.3	125.6	5.2	7.67	162.4	53	148.5	724	257	209.5
T2L COMP4C3 (L)	47.6	118.4	4.8	8.19	173.1	50	173.6	885	261	233.1
ACR 97 T2ECOMP3 X4 (E)	39.3	93.7	5.6	7.24	132.5	34	130.7	548	221	191.4
ACR 95 TE COMP4 C3 (E	36.7	88.4	5.5	7.06	128.4	32	137.4	485	208	177.3
ACR 89-DMR-E R- white	31.9	82.7	6.1	6.83	123.9	33	114.6	393	203	167.5
AK 9331-DMR SR (E)	28.4	78.1	6.3	6.59	130.3	31	126.2	527	216	183.7
T2E COMP3C2 (E)	31.7	73.8	6.4	6.16	125.7	31	119.5	457	197	171.8
SE. (129df)	2.59	3.56	0.17	0.32	6.33	1.72	6.59	17.55	6.49	7.73
Maturity groups										
Late maturing	51.8	123.0	5.1	8.04	161.6	51.6	160.4	799	250	221.5
Early maturing	29.6	83.3	6.0	6.78	128.2	32.2	125.7	482	209	178.3
SE. (129df)	2.7	3.3	0.5	0.27	5.8	1.4	7.3	11.9	8.2	5.8

Table 2b. Effects of cultivar and maturity group on the growth and yield characters of maize (late season crop)

	Root wt (g)	Shoot wt (g)	No. of Senes. leaf	Green leaf area (m^2)	Plant (ht)	50% silking date	Dehusked cob	No. of kernels/ plant	Mean kernel wt (mg)	Seed yield/ plant (g)
Maize cultivars										
ACR 91 Suwan1- SR (L)	63.5	107.4	7.5	7.28	142.5	48	139.3	813	207	208.7
ACR 93 T2L COMP1- (L	60.3	118.7	6.9	7.57	151.3	50	131.6	786	202	201.3
AK 94-DMR-E R-Y (L	56.4	124.6	6.1	6.58	147.5	48	143.7	748	217	194.1
AK 9928 DMR SR (L	49.7	114.1	7.2	6.46	142.9	50	125.4	727	213	188.9
T2L COMP4C3 (L)	53.4	121.2	6.4	7.75	163.6	47	151.1	872	236	213.7
ACR 97 T2E COMP3 X4(E	44.9	103.4	7.3	5.86	127.2	31	116.8	539	198	184.1
ACR 95 TE COMP4 C3 (E)	39.2	94.7	7.8	5.42	124.3	30	120.4	473	209	159.6
ACR 89-DMR-E R-W (E)	35.7	88.2	8.4	6.15	120.7	31	98.9	380	182	161.2
AK 9331-DMR SR (E)	31.4	82.3	8.7	5.73	126.4	30	111.5	531	201	128.5
T2E COMP3C2 (E)	28.5	77.5	9.1	5.29	119.5	29	105.8	463	179	119.4
S.E. (129df)	3.99	4.93	0.31	0.26	5.67	3.08	5.46	18.95	5.39	9.56
Maturity groups										
Late maturing	56.7	117.2	6.8	7.13	149.6	49	138.2	789	215	201.3
Early maturing	35.9	89.2	8.3	6.3	123.6	30	110.6	477	194	150.5
S.E. (129df)	4.1	5.7	0.4	0.3	8.6	2.5	4.2	11.4	7.1	6.8

of root and shoot biomass yield. The effect of maturity type was also important on growth duration as characterised by flowering date (Table 2a and b). The patterns of leaf area development were similar among maize genotypes, however, a wide range of maximum leaf area was obtained in maize grown in the rainy (early) and late sowing seasons (Table 2a and b). The rainy season presented more favourable environmental conditions which enhanced leaf and shoot biomass development than in late season maize. There were marked shifts in pre and post flowering growing environmental conditions in the rainy and late cropping seasons, these factors seemed to have regulated senscence in maize cultivars evaluated.

Greater dry matter accumulation was produced in late maturing types, and pronounced differences occurred within the maturity types in values of leaf area/plant. However, a wide range of maximum leaf area was obtained in maize grown in the rainy (early) and late sowing seasons. The late maturing cultivars were associated with greater leaf longevity characterised by low number of senesced leaves/plant. Among the cultivars, these trends were consistent in both rainy and late sowing seasons. The rainy season presented more favourable environmental conditions (Table 1) which could have enhanced leaf and shoot biomass development than in late season maize. The episodes of high soil moisture deficit during post flowering growth phase late season appeared to have enhanced leaf senescence in the maize cultivars. A leaf was considered senesced when half or more of its area had yello-wed laminars, and this is followed by the death of the organ (necrosis). Active senescence characterised by rapid rates of leaf death, involved leaves with bigger leaf areas and was rated among the cultivars between silking and 400°C day after silking. In the maize cultivars, differences in the onset of active leaf senescence was largely determined by the attainment of 50% anthesis (growth duration) within a maturity type particularly under the terminal drought situation of the late cropping season. However, the initiation of active senescence seem to be dependent on the growing environment perceived by the crop, thermal time requirement for senescence initiation was around 400-450°Cday^{-1} from sowing for late season crop of maize. Within cultivars of same maturity groups, the onset of active senescence began at same time, however, active senescence was delayed by over a week in the late maturity groups particularly under the terminal drought situation of the late cropping season (Data not shown).

The effect of genotype and growth duration (maturity type) was evident on the number and weight of kernels per plant and harvest index (HI – the ratio of seed yield to total above ground biomass) (Table 2a and b). In late season characterized by increased intensities of drought and temperatures during the reproductive phase (anthesis-grain filling periods), reduced sink size (kernel number) was obtained. Within groups of maize cultivars of same growth duration, however, little differences in values of seed yield under same seasons of sowing was obtained (Table 2a and b). Nevertheless, differences in kernel number in the two maturity groups of maize cultivars during the cropping season was remarkable. In addition, seasonal effect was pronounced on almost all the growth and yield parameters evaluated in this study (Table 3).

Table 3. Effects of sowing dates (rainy and late) on the growth and yield characters of maize

	Root wt (g)	Shoot wt (g)	No. of senescence leaf	Green leaf area (m^2)	Plant (ht)	50% silking date	Dehusked cob	No.of kernels /plant	Mean kernel wt (mg)	Seed yield /plant (g)
Sowing dates										
Rainy season	42.7	103.2	5.5	7.41	144.9	41.9	143.1	640.6	229.7	199.9
Late season	48.3	103.2	7.5	6.41	136.6	36.3	124.5	633.2	204.4	176.0
S.E. (129df)	2.4	1.3	0.3	0.2	4.8	1.7	8.1	7.9	9.3	7.5

Table 4a. Effects of cultivar and maturity group on the concentrations of chlorophyll a and b and water soluble carbohydrate (WSC) (rainy season crop).

	Chlorophyll conc.(mg/g)		**WSC conc. (mg glucose/g DM)**		
	a	**b**	**Stem internode**	**3rd leaf below the ear**	**Flag leaf**
Maize cultivars					
ACR 91 Suwan1- SR (L)	0.45	1.27	113.3	46.3	23.1
ACR 93 T2L COMP1(L	0.51	1.30	117.1	41.7	19.7
sAK 94-DMR-E R-Y (L	0.47	1.28	115.8	39.8	20.3
AK 9928 DMR SR(L)	0.45	1.31	110.4	43.0	17.2
T2L COMP4C3 (L)	0.50	1.27	107.4	36.7	15.1
ACR 97 T2ECOMP3X4(E	0.41	1.24	91.5	30.3	10.4
ACR 95 TE COMP4C3(E)	0.38	1.21	86.2	32.5	9.8
ACR 89-DMR-E R-W(E	0.35	1.19	75..9	30.6	9.3
AK 9331-DMR SR (E)	0.39	1.23	83.6	28.1	11.2
T2E COMP3C2 (E	0.36	1.21	78.3	25.6	8.7
S.E. (129df)	0.014	0.021	2.62	2.13	1.54
Maturity groups					
Late maturing	0.44	1.25	114.5	46.8	27.3
Early maturing	0.37	1.23	85.6	23.5	9.5
S.E. (129df)	0.01	0.02	5.3	6.1	7.1

Effects of cultivar, maturity type and sowing season on concentrations of chlorophyll and soluble carbohydrates

The concentrations of chlorophyll a and b and stem and leaf assimilate reserves (water soluble carbohydrate) during reproductive growth phase varied among maize cultivars maturity types and sowing date (Table 4a and b). Across cultivars, the magnitudes of chlorophyll a and b concentrations in leaf tissues declined in late season maize compared to the rainy season crops. Contrary to the observed trends of chlorophyll concentrations in leaf tissues, the range of values of soluble carbohydrate concentration in the stem internode and leaf tissues was significantly higher in the late than in the early maturity types (Table 4a and b). WSC concentration is higher in the late than the early season maize (Table 5). Nevertheless, the concentrations were higher in stem internodes compared to the leaves in both seasons

Interaction effects

Pronounced dependence of expression of some cultivar's attributes on the season of sowing was observed for maize particularly the development of leaf area and leaf sensecence, concentrations of chlorophyll and soluble carbohy-drates and seed yield (Table 3 and 5).

DISCUSSION

The differences in weather events and hence in the magnitudes of soil water content and temperatures which characterized the rainy (early) and late sowing seasons, could explain the results obtained from this study. In particular, in the late season, negligible rainfall and high air and soil temperatures and hence concurrent stresses of increasing intensities of soil moisture deficits and evaporative demand during reproductive growth of maize would enhance decline crop water use (evapotranspiration) and subsequent biomass accumulation and seed yield. The length of the growing season is a function of the number of rainy days in a cropping season and year (Akintola, 1986; Owonubi, 2000). In rainy season crop, extreme hydrothermal regimes coincided with establishment and early vegetative growth, whereas these events occurred during the reproductive growth particularly anthesis/silking and grain filling stage in late season maize.

Table 4b. Effects of cultivar and maturity group on the concentrations of chlorophyll a and b and water soluble carbohydrate (WSC) (late season crop).

	Chlorophyll conc.(mg/g)		WSC conc. (mg glucose/g DM)		
	a	b	Stem internode	3^{rd} leaf below the ear	Flag leaf
Maize cultivars					
ACR 91 Suwan1- SR (L)	0.39	1.11	186.7	67.3	36.5
ACR 93 T2L COMP1(L)	0.41	1.09	191.3	71.6	39.2
AK 94-DMR-E R-Y (L)	0.37	1.13	188.4	69.5	33.6
AK 9928 DMR SR(L)	0.36	1.09	192.1	70.2	29.4
T2L COMP4C3 (L)	0.40	1.14	185.7	67.9	31.8
ACR 97 T2ECOMP3X4(E)	0.30	0.95	158.6	51.1	24.7
ACR 95 TE COMP4C3(E)	0.32	0.97	162.3	53.4	26.2
ACR 89-DMR-E R-W(E)	0.28	0.92	156.4	49.3	22.5
AK 9331-DMR SR (E)	0.26	0.88	160.5	51.8	25.8
T2E COMP3C2 (E)	0.29	0.91	153.8	46.7	20.7
S.E. (129df)	0.021	0.030	3.33	2.34	2.21
Maturity groups					
Late maturing	0.34	1.07	186.7	67.8	32.7
Early maturing	0.27	0.93	158.4	48.5	23.4
S.E. (129df)	0.01	0.03	6.5	8.2	4.6

Table 5. Effects of sowing dates (rainy and late) on the concentrations of chlorophyll a and b and water soluble carbohydrate (WSC) of maize.

	Chlorophyll conc.(mg/g)		WSC conc. (mg glucose/g DM)		
	a	b	Stem internode	3^{rd} leaf below the ear	Flag leaf
Sowing dates					
Rainy season	0.43	1.25	98.0	35.5	13.4
Late season	0.34	1.02	173.6	59.9	29.2
S.E. (129df)	0.02	0.31	11.6	7.4	5.2

These weather events imposed different degrees of drought stress conditions on the crop and affected growth duration, plant size, dry matter production, assimilate reserves and grain yields in the cultivars of maize evaluated. Weather dependent processes such as crop phenology are sensitive to these extreme events of the sowing seasons and hence the responses of maize cultivars evaluated. Agele et al. (2002) reported the effects of variations in soil moisture and thermal regimes during the pre and reproductive stages in the respective rainy and late seasons of sowing on the growth and yield of tomato. In plants, hydrothermal sensitivity of physiological processes (the attainment of anthesis and silking) is reported (Pressman et al., 2002; Sato et al., 2002; Wardlaw, 2002). Bell and Wright (1998a) attributed difference in soil moisture status, temperature and incident radiation to variable rates of phenological development. Nevertheless, the characteristic growth duration (maturity type) of a maize cultivar subjected the cultivar to different levels of exposure to extreme events in post-flowering growth in the late cropping season.

The pattern of leaf development and leaf senescence in maize genotypes differed in the diverse growing environments of the rainy and late sowing seasons. Our result is consistent with the report of Muchow and Carberry (1989), that the cultivation of maize under diverse sowing dates promotes a wide range in maximum leaf area. The onset of leaf senescence in maize is before all leaf area is fully developed (previous to flowering) and progresses at an increased rate during grain filling period (Sadras et al., 2000; Lafarge & Hammer 2002) while active senescence is characterised by rapid rates of leaf death (Colomb et al., 2000; Borras et al., 2003). The effects of senescence whether due to normal aging or accelerated by water stress was exerted through reductions in the area of green leaves in the maize cultivars. In this study, the stressful situations of high energy availability and moisture deficits of the late season decreased leaf longevity and pro-motes senescence rates. The differences in the onset of active leaf senescence was largely determined by the attainment of 50% anthesis or silking dates (growth duration), however, early maturity types were characterized by early onset of active leaf senescence particularly under the terminal drought situation of the late cropping season. This can be attributed to the unfavourable hydrothermal regimes of the late season. In crops, water deficits and increased air temperatures enhance leaf senescence (Sadras et al., 1991; Slafer, 1996). The sensitivity of leaf growth to water stress and hence changes in leaf area index (LAI) induced by sensecence may be one of the dominant factors controlling crop water relations under the gradual development of water stress of the late cropping season. Our study confirm the assertion of Bradford and Hsiao (1982) and Steduto and Hsiao (1998), that the restriction of leaf growth and the enlargement of canopy during early stage of crop cycle could therefore be components of defense mechanisms of a plant against intensifying water stress.

The magnitude of dry matter accumulation seemed to induce differences in supply and demand for assimilates during grain filling. Biomass development (source capacity) has major impact on cob initiation, grain filling capacity and grain size while floret survival is linked to assimilate supply to the ear (Slafer, 1996; Foulkes et al., 2001)., drought resistance is therefore determined by the ability to maintain source (Foulkes et al., 2001). Rajcan et al. (1999) reported the relation of large source: sink ratio as a characteristic of some elite lines of maize.

In the maize cultivars evaluated, late maturing lines and rainy season crop out-yielded late season crop in terms of number and weight of kernel produced per plant. Borias et al. (2003) obtained enhanced maximum plant leaf area and kernel number/plant under adequate soil moisture status. In plants, it is reported that pollination and subsequent ovary and seed development are linked with direct stress effects of high temperatures and soil moisture deficits which enhance plant water stress at pollination time (Zinselmeier et al., 1999; Pressman et al., 2002; Sato et al., 2002). In this study, fewer number of kernels/plant and ultimately reduced seed yield in maize was obtained in the late season maize. In addition, the reduction in the total number of kernels / cob (reduced sink size) was accompanied by increases in dry weights of the remaining kernels in late season maize. This can be attributed to harsh growing environment enhanced assimilate availability per kernel (small source-sink ratio) during whole grain filling period (Banziger et al., 1997). Concurrent stress reduces duration of kernel filling and offers drought escape in wheat although crop water use is enhanced by high temperatures (Wardlaw, 2002). The effect of drought on kernel number could be confounded by the association of high temperature reduction of period of grain filling.

Across cultivars, the magnitudes of chlorophyll a and b concentrations in leaf tissues declined in late season maize compared to the rainy season crops. Decreased leaf chlorophyll concentrations can be ascribed to restricted soil moisture and the enhanced rapid rates of leaf senescence which could also have masked cultivar traits and the expression of this growth character in the late cropping season. Leaf senescence is associated with loss of chlorophyll and declined photosynthesis capacity (Rajcan et al., 1999). The concentration of soluble carbohydrate in the stem internode and leaf tissues was greater in the late than in the early maturity cultivars. This trend Rajcan et al. (1999) attributed to a survival strategy in which the plants needs higher carbohydrate reserves to protect the leaves from destruction. Leaf senescence can accelerate at high leaf soluble carbohydrate concentration (Ceppi et al*.,* 1987) while Rajcan et al. (1999) reported accelerated leaf senescence at leaf soluble carbohydrate higher than 100 mg/gDM.

In this study, leaf soluble carbohydrate did not exceed 90 mg glucose equivalents g^{-1} dry matter. However, early senescence enhanced by moderate water deficit during grain filling period could have improved the remobilization of stored assimilates to seeds and hence the enhanced seed yield in the late cropping season. Smith (1998) reported that increased soluble carbohydrate concentrations in some ryegrass phenotypes were a consequence of excess photosynthates. This study supported the possibility that high-WSC concentrations may be a consequence of altered partitioning of carbon between structural and non-structural compounds. Cultivars which allocate high dry matter to stem reserves should therefore be better positioned to buffer grain yield formation and hence maintain harvest index under the terminal drought situation of the late season. The role of soluble carbohydrate (WSC) concentrations as an indicator of grain yield under drought is widely reported for a number of agricultural crops (Bidinger et al., 1977; Schnyder, 1993; Volaire et al*.,* 1998; Volaire & Lelievre, 1997; Volaire et al*.,* 1998; Foulkes et al., 2002). In rice, Yang et al. (2001) obtained increased remobilization of WSC stored in vegetative tissues to grain, this was attributed to water deficit enhanced senescence during the grain filling period.

Conclusion

Under the variable hydrothermal regimes of the rainy and late sowing seasons, among the maize cultivars evaluated, important differences were obtained in growth duration, dry matter production, stem assimilate reserves (WSC) and seed yield. Therefore, a desirable combination of traits associated with performance and adaptation looks promising in the maize cultivars evaluated, and cultivars with these attributes appeared to be better positioned to buffer grain yield formation under the variable soil water and thermal regimes of the sowing seasons. This attribute should be examined in maize cultivars common to the maize growing belt of the tropics (monomodal and bimodal rainfall pattern) particularly those characterised by terminal drought and/or drought at beginning of the growing season before the full establishment of rainfall. The usefulness of these traits to growers and breeders of maize adapted to drought prone environments should be exploited, and can contribute to expansion of cultivation and profitability of maize producers in Nigeria and elsewhere in the tropics.

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