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Research Article

Leaf growth traits and photosynthetic pigments of maize as influenced by water deficit stress

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Abstract

Glasshouse study was carried out to evaluate the impacts of water deficit stress (WDS) on leaf growth and photosynthetic pigments of four maize varieties at the Institute of Agricultural Research and Training, Ibadan. Seeds from 'TZPBSR-W', 'ILE1OB', 'ART98SW6OB' and 'DTESYNSTR' maize varieties were sown in sixty-four pots in a 4 x 4 factorial CR Design(r=4). The WDS treatments include 100%, 75%, 50% and 25% field capacities (FC). Data were taken weekly on specific leaf weight (SLW), leaf area (LA), leaf weight (LWT) and crop growth rate. At four weeks of WDS, extracts were obtained from 0.2 g cut leaf sample using 96% (v/v) ethanol. Light absorbance of the ethanolic leaf extract (cholorophyll-a (665 nm), chlorophyll-b (649 nm), total chlorophyll and the carotenoids (440 nm)) were read using spectrophotometer. From the results, WDS significantly reduced SLW, LWT, LA and CGR ($p<0.001$). The SLW ranged from 0.027±0.0 (g cm^{-2}) ('ART98SW6OB') to 0.034±0.0 (g cm^{-2}) ('DTESYNSTR'), while the LA ranged from 269.7±25.4 (cm^2) ('ART98SW6OB') to 220.9±20.9 (cm^2) ('ILE1OB'). Water deficit stress significantly reduced chlorophyll-b ($p<0.01$), chlorophyll-a and total chlorophyll ($p<0.001$) and the carotenoid ($p<0.05$). Chlorophyll-a ranged from 0.038±0.0 mg/g ('DTESYNSTR') to 0.050±0.0 mg/g ('TZPBSR-W'), chlorophyll-b ranged from 0.021 mg/g ('ART98SW6OB') to 0.040 mg/g ('TZPBSR-W'), total chlorophyll ranged from 0.063±0.0 mg/g ('ART98SW6OB') to 0.093±0.0 mg/g ('TZPBSR-W'), while the carotenoid ranged from 0.084±0.08 mg/g ('ART98SW6OB') to 0.115±0.09 mg/g ('TZPBSR-W'). The WDS and Variety interaction on photosynthetic pigments were significant ($p<0.05$). The Leaf growth traits, photosynthetic pigments and over all crop growth in maize are impaired when subjected to water deficit stress.

Keywords: leaf area; leaf weight; plant extract; specific leaf weight; total chlorophyll

Introduction

Leaf is an important plant component that plays significant role in process of photosynthesis and transpiration. Leaf growth influences interception of light for crop growth and yield in plants and according to Scott and Jaggard (1978) the final dry matter of a plant is a function of the amount of intercepted radiation. Hence, the more developed the leaf area, the higher the carbon sequestration and the faster the rate of plant growth (Roetman and Sterk, 1986). The leaf houses the stomata which control gaseous exchange, plant water content, nutrient uptake and cooling process in plant. Duration of greenness of crop (LAD) defined as the

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product of leaf area and the time period which leaf area is maintained determines the efficiency of crop photosynthetic ability. Photosynthesis pigments which include chlorophyll are presented in the form of porphyrin pigments (chlorophyll a, b and c), carotenoids, anthocyanins and flavones (Britton 1983; Brown *et al.*, 1991). The chlorophylls are contained in the chloroplast while the carotenoids are located in the chromoplast of the photosynthetic tissues of leaf. These photosynthetic pigments to a large extent determine the physiological status of plants (Jain *et al.*, 2013). Chlorophyll-a is the major light harvesting pigments which convert light energy to chemical energy, while chlorophyll-b is an accessory pigment which transfer its absorbed energy to chlorophyll-a (Costache, 2012). Carotenoid acts as antioxidant in plant under stress by preventing the chlorophyll and the thylakoid membrane from damage by absorbed energy during peroxidation (Havaux, 1998).

Reduction in plant water potential has been reported to increase the level of Abscisic acid in the plant, resulting in early stomata closure. Reduction in rate of transpiration reduces carbon assimilation, photo-assimilate production and plant growth (Lahlou *et al.*, 2003; Tourneux *et al.*, 2003a). Non stomatal conductance limitation as a result of damage to photosynthetic system by water shortage has been reported by Noctor *et al.* (2014). Water stress had been reported to inhibit several photochemical activities and also reduce the activities of Calvin cycle enzyme during photosynthesis in plant (Monakhova and Chernyadev, 2002). Drought stress brings about changes in the ratio of chlorophyll "a"and "b" and carotenoid in plants (Anjum *et al.*, 2003b). Reduced chlorophyll content is an indicator of reduced photosynthetic activities in plants (Reddy *et al.*, 2004). Drought has been reported to reduce number of leaves and leaf area as a result of reduced cell tugor, leaf expansion and cell division (Chaves *et al.*, 2002; Anjum *et al.*, 2003a). Water deficit stress accelerates rate of leaf senescence, decrease canopy size, reduce photosynthesis and decrease yields (Nir *et al.*, 2018). Number of leaves per plant, leaf area and leaf growth rates, leaf total biomass and specific leaf weight (SLW) were severely reduced under water deficit stress, such reduction had been earlier reported in soybean by Zhang *et al.* (2004) and in wheat (Sacks *et al.*, 2009), maize (Anjorin *et al.*, 2017). Inhibitory effects of water deficit stress on leaf expansion, leaf development and reduced light interception consequently result in reduced dry matter production in plant (Nam *et al.*, 1998). Specific leaf weight (SLW in mg/cm^2) has been used as an indicator of leaf toughness in the studies of insect herbivory and eucalypt dieback (Landsberg, 1990). Specific leaf weight, leaf dry matter (Aggarwal and Sinha, 1984; Misra, 1995) had been widely used as selection parameters contributing towards drought tolerance for various crop plants in addition to grain yield. The objective of this study is to determine the impact of water deficit stress on leaf growth parameters and the photosynthetic pigments as they contribute to general maize growth.

Materials and Methods

Planting

Two seeds of the maize varieties were sown in sixty-four (64) plastic pots of 25 liters capacity filled with 20 kg of top soil. The soil was loamy sandy soil with 82% sand, pH (6.63), bulk density (1.36 g/cm^3), organic carbon (5.3 g/kg), nitrogen (0.1 g/kg), P (7.0 mg/kg), Ca (1.1 cmol/kg), Mg (1.8 cmol/kg), K (0.2 cmol/kg) , Na (0.4 cmol) and total acidity of 0.1 cmol/kg. Plants was watered regularly to the designated field capacity and soil potential with Quick and drawn tensiometer (Eijkelkamp.co). The emerged plants were later thinned down to one plant per pot two weeks after sowing. Basal fertilizer application was done using NPK-20-10-10, while hand weeding was done regularly when necessary.

Measurements were taken every week at seven days intervals, while the amount of watering requirement for each soil moisture treatment was added as at when required. Data were taken on.

Experimental design: The experimental design was a 4 x 4 factorial arranged in a complete randomized design of four replicates.

Treatments:

(i) Four simulated water deficit stress (WDS) rates equivalent to 25%, 50%, 75% and 100% field capacities constituted the main plot

(ii) Variety: four maize varieties ('TZPBSR-W', 'ILE1OB', 'ART98SW6OB' derived from open pollinated populations and 'DTESTRSYN' a drought tolerant maize variety), the varieties made up the sub plots.

(a) Leaf growth parameters

Specific leaf weight (SLW) was obtained by dividing the leaf weight of a plant with its leaf area (Pearce *et al.*, 1968). Leaf weight = leaf dry weight measured after drying using digital scale meter. Crop growth rate per plant (CGR) was calculated as (DMW)/ DT, where DMW = average dry matter weight of 1 plant in grams and DT = total growth period (time in days) (Fageria *et al.*, 2006), leaf area was obtained using meter rule, in centimeter-square by measuring the length and breadth of a fully expanded tagged leaf. The product was then multiplied by 0.75, which is the calibration factor for maize leaf (Francis *et al.*, 1969).

(b) Leaf extraction and determination of photosynthetic pigments

Fresh leaves (0.2 g) was obtained from each plant and placed in 25 mL glass test tubes, 15 mL of 96% (v/v) ethanol was added to each tube. The tubes with the plant material were incubated in a water bath at a temperature of 79.8 °C until complete discoloration of samples, after about three to 4 h. The absorbance of chlorophylls a and b were measured at 665 and 649 nm, respectively. Total chlorophyll was determined according to Wintermans and Mots (1965) from the equations: The absorption peak of carotenoids was measured at 440 nm. Carotenoids were estimated using the following equation:

Ch-a=13.36A664 – 5.19 A649

Ch-b=27.43A649 – 8.12 A664

Chl (a + b) = 5.24A665+22.24A649-15/1000/F. W (mg/g F.W)

C x+c= (1000A440 –2.13Chl-a – 97.63Chl-b)/209

A = absorbance; Chl-a = chlorophyll a; Chl-b = chlorophyll b; C x + c = carotenoids were estimated on a UV-visible spectrophotometer (UV-Visible spectro 2060 plus) with the above equations, as described by Lichtenthaler (2008) and Porra *et al.* (1989) and modified by Yang *et al.* (1998) and Nayek *et al.* (2014).

Data obtained were subjected to analysis of variance using Statistical Tools for Agricultural Research (STAR, 2013). Means were separated using the Fisher's least significant difference at $p<0.05$.

Results

Table 1 presents the effects of water deficit stress (WDS) on leaf growth parameters and the photosynthetic pigments of four maize varieties. Water deficit stress (WDS) significantly reduced the leaf area (LA), specific leaf weight (SLW), leaf weight (LWT) and the crop growth rate (CGR) ($p<0.001$). Similarly, WDS significantly influenced the photosynthetic pigments (chlorophyll-a (Chl-a) ($p<0.001$), chlorophyll-b (Chl-b) ($p<0.01$), carotenoid ($p<0.05$) and the total chlorophyll content (T. Chl) ($p<0.001$). High moisture availability at 75% FC (292.5 cm^2) and 100% FC (325.4 cm^2) favoured large leaf area sizes, but significant reduction in maize leaf area was observed at 25% FC (144.8 cm^2). The LWT (12.64 g), SLW (0.038 g cm^{-2}) and CGR (0.51 g cm^{-2} day^{-1}) at 100% FC but least values (2.54 g, 0.018 g cm^{-2} and 0.10 g cm^{-2} day^{-1}) were obtained at 25% FC.

Across the varieties, leaf area ranged from 220.9 cm^2 (ART98SW6OB) to 269.7 cm^2 (ILE 1OB), there was no significant difference between LA of 'TZPPBSR- W' (247.7 cm^2) and 'DTESYNSTR' (237.4cm^2). The SLW ranged between 0.027 g cm^{-2} ('ART98SW6OB') and 0.034 g cm^{-2} ('DTESYNSYR'), there was no difference in SLW between maize variety ILE 1OB (0.029 g cm^{-2}) and 'TZPBSR-W' (0.029 g cm^{-2}). The four maize varieties were not significantly different in LWT and CGR, respectively. The WDS and V interactions for LA, LWT, SLW and CGR growth parameters were not significant (p<0.05).

Water deficit stress significantly reduced the photosynthetic pigments evaluated in this study. Maize variety (V), WDS and V interaction effects on the photosynthetic pigments were also significant. Chlorophyll-a, Chl-b, total chlorophyll and the carotenoid contents were highest but not significantly different at both 75 and 100% FC, the least values for the pigments were obtained at 25% FC. Maize variety 'TZPBSR-W' had more photosynthetic pigments compared to the other three maize varieties which were not significantly different from one another except for the carotenoid content which was lowest in 'DTESYNSYR'.

Table 1. Main effect of water deficit stress and variety on leaf growth parameters, crop growth and the photosynthetic pigments of four maize varieties; results of the *F*-tests for the effects of main factors and interactions

Source of variation	LA (cm^2)	LWT (g)	SLW ($g\ cm^{-2}$)	CGR ($g\ cm^{-2}\ day^{-1}$)	Chl-a (mg/g FW)	Chl-b (mg/g FW)	T.Chl. content	CRT (mg/g FW)
WDS								
25	144.8^{c}	2.54^{d}	0.018^{c}	0.10^{d}	0.031^{c}	0.019^{c}	0.050^{c}	0.075^{c}
50	213.1^{b}	6.74^{c}	0.032^{b}	0.25^{c}	0.041^{b}	0.025^{bc}	0.066^{b}	0.092^{b}
75	292.5^{a}	9.18^{b}	0.031^{b}	0.39^{b}	0.052^{a}	0.033^{a}	0.085^{a}	0.114^{a}
100	325.4^{a}	12.64^{a}	0.038^{a}	0.51^{a}	0.054^{a}	0.037^{a}	0.091^{a}	0.116^{a}
Variety								
'TZPBSR-W'	247.7^{ab}	7.86^{a}	0.029^{ab}	0.30^{a}	0.050^{a}	0.040^{a}	0.093^{a}	0.115^{a}
'ILE 1OB'	269.7^{a}	8.12^{a}	0.029^{ab}	0.31^{a}	0.045^{b}	0.029^{b}	0.074^{b}	0.105^{ab}
'ART98SW6OB'	220.9^{b}	6.70^{a}	0.027^{b}	0.27^{a}	0.042^{b}	0.021^{b}	0.063^{b}	0.093^{bc}
'DTESYNSYR'	237.4^{ab}	8.42^{a}	0.034^{a}	0.35^{a}	0.038^{b}	0.025^{b}	0.065^{b}	0.084^{c}
Water (W)	105503.2***	288.84***	0.0012***	0.46***	0.0018***	0.0010**	0.0056***	0.622*
Error (a)	2369.9	3.006	0.00	0.01	0.0000	0.0001	0.0002	0.028
Varieties (V)	6651.3*	9.0701	0.00	0.03	0.0006*	0.0011**	0.0032**	0.285**
W x V	2319.8	3.7650	0.00	0.01	0.0004*	0.0004*	0.0014*	0.175*
Error (b)	2080.3	3.4154	0.00	0.01	0.0001	0.0001	0.0005	0.054

*, **, *** significant at *p*=0.05, 0.01, 0.001. D.F= Degree of freedom. Means designated with same alphabets in the superscripts along same column are not significantly different according to Fisher's Least Significant Difference Test at p<0.05. LA= Leaf area, LWT=Leaf Weight, SLW=Specific Leaf Weight, CGR= Crop Growth Rate, Chl-a= Chlorophyll-a, Chl-b =Chlorophyll-b, T. Chl= Total Chlorophyll, CRT=Carotenoid content; WDS=water deficit stress

Table 2 presents the comparison of photosynthetic pigments of four maize varieties at each level of water deficit stress. The photosynthetic pigments (Chl-a, Chl-b, total chlorophyll content and the carotenoid) of the four maize varieties when WDS were at 50 and 25% FC were not significantly different. However, at 75 and 100% FC, Chl-a was optimum in 'ART98SW6OB' (0.055 mg/g), 'TZPBSR-W' (0.066 mg/g) and 'ILE1OB' (0.058 mg/g) though not significantly different while 'DTESYNSTR' (0.028 mg/g) had the least Chl-a content. At WDS 100% FC, Chl-a was higher in 'TZPBSR-W' (0.069 mg/g) than 'DTESYNSTR' (0.049 mg/g), 'ART98SW6OB' (0.048 mg/g) and 'ILE1OB' (0.052 mg/g) which were not significantly different at p<0.05.

Maize varieties 'TZPBSR-W' (0.056 mg/g) and 'ILE 1OB' (0.058 mg/g) was significantly higher had more Chl-b than 'DTESYNSTR' (0.028 mg/g) and 'ART98SW6OB' (0.024 mg/g) under 75% FC. Maize variety 'TZPBSRW' (0.057 mg/g) had more Chl-b at 100% FC than 'DTESYNSTR' (0.035 mg/g), 'ART98SW6OB' (0.025 mg/g) and 'ILE1OB' (0.032 mg/g) which were not significantly different.

Similarly, 'TZPBSR-W' (0.122 and 0.127 mg/g) had highest total chlorophyll content at both 75% and 100% FC's, respectively. The least total chlorophyll content was observed in 'DTESYNSTR' (0.084 mg/g) at 75% FC, while there was no significant difference in total chlorophyll content among 'ART98SW6OB', 'ILE1OB' and 'DTESYNSTR' at 100% FC. The carotenoid levels were significantly higher in 'TZPBSR-W', 'ILEIOB' and 'ART98SW6OB' than 'DTESYNSTR' at 75% FC. Similarly, 'TZPBSR-W' (0.143 mg/g) had highest carotenoid content at 100% FC, while 'DTESYNSTR' (9.98 mg/g) and 'ILE1OB' (10.09 mg/g) had least carotenoid contents though not significantly different (p<0.05).

Table 2. Comparison of photosynthetic pigments of four maize varieties at each level of water deficit stress

Photosynthetic pigment		Water deficit stress levels			
	Maize varieties	25% FC	50% FC	75% FC	100% FC
Chlorophyll-a (mg/g FW)	'DTESYNSTR'	0.030a	0.047a	0.028b	0.049b
	'ILE1OB'	0.027a	0.044a	0.058a	0.052b
	'ART98SW6OB'	0.030a	0.035a	0.055a	0.048b
	'TZPBSR-W'	0.038a	0.038a	0.066a	0.069a
Chlorophyll-b (mg/g FW)	'DTESYNSTR'	0.023a	0.030a	0.013b	0.035b
	'ILE1OB'	0.018a	0.025a	0.042a	0.032b
	'ART98SW6OB'	0.015a	0.021a	0.024b	0.025b
	'TZPBSR-W'	0.022a	0.027a	0.056a	0.057a
Total chlorophyll content (mg/g FW)	'DTESYNSTR'	0.052a	0.077a	0.041c	0.084b
	'ILE1OB'	0.045a	0.068a	0.100ab	0.084b
	'ART98SW6OB'	0.045a	0.056a	0.079b	0.073b
	'TZPBSR-W'	0.059a	0.065a	0.122a	0.127a
Carotenoid (mg/g FW)	'DTESYNSTR'	0.074a	0.105a	0.060b	0.099b
	'ILE1OB'	0.068a	0.098a	0.134a	0.101b
	'ART98SW6OB'	0.069a	0.078a	0.123a	0.121ab
	'TZPBSR-W'	0.089a	0.086a	0.140a	0.143a

† Means designated with same alphabets are not significantly different at $p<0.05$ according to Fisher's Least Significant Difference Test

Table 3 presents the comparison of the photosynthesis pigments of the four maize varieties at each level of water deficit stress. The Chl-a content in 'DTESYNSTR' was significantly higher at 75 (0.047 mg/g) and 100 (0.049 mg/g) % FC than Chl-a at 25 (0.028 mg/g) and 50 %FC (0.030 mg/g), respectively. There was no significant difference in Chl-a contents of 'ILE1OB' at 50 (0.044 mg/g), 75 (0.052 mg/g) and 100% FC (0.052 mg/g) but significantly higher than 25% FC (0.027 mg/g). Maize variety 'ART98SW6OB' produced significantly higher Chl-a at 75% FC (0.055 mg/g), followed by 100% FC (0.048 mg/g), but lowest Chl-a was recorded at 25% FC (0.030 mg/g). The differences in the quantity of Chl-a produced by 'TZPBSR-W' at 75 (0.066 mg/g) and 100% FC (0.069 mg/g) were non-significant but greater than Chl-a at 25 and 50% FC (0.038 mg/g), respectively. The quantities of Chl-b produced at 75% FC (0.030 mg/g) and 100% FC (0.035 mg/g) were similar but more than 25% FC and 50% (0.013 mg/g). Production of Chl-b reached the peak at 75% FC (0.042 mg/g), the Chl-b dropped sharply at 100% FC (0.032 mg/g) but lowest at 25 and 50% FC (0.025 mg/g), respectively. There was no significant difference in the chlorophyll-b produced by 'ART98SW6OB' across the WDS levels. The quantity of Chl-b produced by 'TZPBSR-W' at 100% FC (0.057 mg/g) and 75% FC (0.056 mg/g) were not significantly different but higher than 50% FC (0.027 mg/g) and 25% FC (0.022 mg/g), respectively. Maize variety 'DTESYNSTR' had highest total chlorophyll content at 100% FC (0.084 mg/g) but lowest at 25% FC (0.041 mg/g). Maize variety 'ILE 1OB' produced highest total chlorophyll content at 75% FC (0.100 mg/g) and declined sharply at 100% FC (0.084 mg/g) but lowest at 25% FC (0.045 mg/g). Similarly, 'ART98SW6OB' produced optimum total chlorophyll content at 75% FC (0.079 mg/g). There was no significant difference in total chlorophyll content of 'ART98SW6OB' at 50 (0.056 mg/g) and 100% FC (0.073 mg/g), but total chlorophyll content was lowest at 25% FC (0.045 mg/g). Maize variety 'TZPBSR-W' contained similar total chlorophyll contents at 75 (0.122 mg/g) and 100% FC (0.127 mg/g) but significantly more than total chlorophyll obtained at 25 (0.059 mg/g) and 50% FC (0.065 mg/g), respectively. The carotenoid content in 'DTESYNSTR' was highest at 100% FC (0.105 mg/g) while the least value was obtained at 25% FC (0.059 mg/g). The quantity of carotenoid content produced by 'ILE1OB' was optimum at 75% FC (0.134 mg/g), but dropped sharply at 100% FC (0.121 mg/g), while carotenoid content was lowest at 25% FC (0.068 mg/g). The carotenoid content in 'ART98SW6OB' was optimum at 75% FC (0.101 mg/g) but lowest at 25% FC (0.069 mg/g). Maize variety 'TZPBSR-W' had optimum carotenoid contents at both 75 (0.140 mg/g) and 100% FC (0.143 mg/g), but significantly more than carotenoid values obtained at 50 and 25% FC, respectively. Table 4 presented Pearson correlation comparison of some leaf growth parameters and the photosynthetic pigments of four maize varieties evaluated under varied water deficit stress condition in Ibadan. Leaf area showed positive and significant association with LWT (r=0.87***), SLW (0.43**), (Chl-a (r=0.53***), Chl-b (r=0.45**), CGR (r=0.81***) and CRT (r=0.50***). There was a positive and very strong correlation between LWT and CGR (0.93***), SLW (r=0.82***), Chl-a (r=0.58***), Chl-b (r=0.47***), carotenoid (r=0.53***) and the total chlorophyll content (r=0.51***). There was a very strong and positive association between CGR and SLW (0.76***), Chl-a (r=0.50***) and Chl-b (r=0.43**) and the CRT (r=0.45**). Chlorophyll-a associated positively and strongly with Chl-b (r=0.85***) and CRT (r=0.96***).

Table 3. Comparison of the water deficit stress at each level of varieties

Photosynthetic pigment	WDS level	'DTESYNSTR'	'ILE-I-OB'	'ART98SW6OB'	'TZPBSR-W'
Chlorophyll-a	25	0.028b	0.027b	0.030c	0.038b
	50	0.030b	0.044a	0.035bc	0.038b
	75	0.047a	0.058a	0.055a	0.066a
	100	0.049a	0.052a	0.048ab	0.069a
Chlorophyll-b	25	0.013b	0.018b	0.015a	0.022b
	50	0.023ab	0.025b	0.021a	0.027b
	75	0.030a	0.042a	0.024a	0.056a
	100	0.035a	0.032ab	0.025a	0.057a
Total chlorophyll content	25	0.041c	0.045c	0.045b	0.059b
	50	0.052bc	0.068bc	0.056ab	0.065b
	75	0.077ab	0.100a	0.079a	0.122a
	100	0.084a	0.084ab	0.073ab	0.127a
Carotenoid	25	0.059c	0.068c	0.069c	0.088b
	50	0.074bc	0.098b	0.078bc	0.086b
	75	0.105a	0.134a	0.123a	0.140a
	100	0.099ab	0.121ab	0.101ab	0.143a

Means designated with same alphabets are not significantly different at $p<0.05$ according to Fisher's Least Significant Difference Test.

Table 4. Pearson correlation coefficients of leaf growth parameters and leaf photosynthetic pigments of four maize varieties evaluated under varied water deficit condition in Ibadan

	LA	LWT	CGR	SLW	Chl-a	Chl-b	CRT
LWT	0.87***						
CGR	0.81***	0.93***					
SLW	0.43**	0.82***	0.76***				
Chl-a	0.53***	0.58***	0.50***	0.45***			
Chl-b	0.45**	0.47***	0.43**	0.33*	0.85***		
CRT	0.50***	0.53***	0.45**	0.40**	0.96***	0.83***	
T. Chl	0.51***	0.55***	0.48***	0.41**	0.96***	0.96***	0.93***

* ** *** significant at p=0.05, 0.01, 0.001. LA= leaf area, LWT=leaf weight, SLW=specific leaf weight, CGR= crop growth rate, Chl-a= Chlorophyll-a, Chl-b=Chlorophyll-b, T.Chl= total chlorophyll, and CRT=carotenoid content.

Discussion

Increased water deficit stress resulted in significant reduction in leaf growth traits and the photosynthetic pigments of maize plant evaluated in this study. Optimum leaf growth was observed at 100% FC this is because adequate moisture enhances cell enlargement, mitotic cell division and growth. On the other significant reduction observed in all the leaf growth traits and the overall crop growth especially at 50 and 25% FC could be attributed to inadequate water availability. Water deficit stress resulting for inadequate water availability has been reported to impair plant growth due to reduced turgour require for mitotic cell enlargement and division (Specht *et al.*, 2001; Anjum *et al.*, 2011). Reduction in leaf growth due to increased water deficit becomes inevitable for plant adaptation to harsh condition most especially when rate of water loss via the leaf surface exceeds rate of water absorption (Munamava and Riddoch, 2001). Therefore, as the leaf expansion reduces due to increase water deficit stress, the rate of interception of photosynthetic active radiation reduces resulting in reduced dry matter production and final leaf weight. Significant reduction in the specific leaf weight/ leaf thickness observed at 50 and under severe water deficit stress at 25% FC in this study had been previously reported by Guendouz *et al.* (2016). High specific leaf weight has been linked with increasing apparent leaf photosynthesis, thicker leaves have more cells and more chloroplast and high mesophyll conductance Thompson (1996). In this study, a very strong association was observed between SLW, leaf weight (r=0.82) (leaf dry matter) and CGR (r=0.76) and the photosynthetic pigments. All the pigments evaluated in study reduced as the WDS increased. This finding agreed with the earlier investigators which studied the performances of plant under water deficit environments. Reduction in chlorophyll content as influenced by water stress has been earlier reported in cotton by Massacci *et al.* (2008) and in sunflower plants Kiani *et al.* (2008). Drought stress brings about changes in the ratio of chlorophyll "a" and "b" and carotenoid in plants (Anjum *et al.*, 2003b). Reduced chlorophyll content leads to reduced photosynthetic activities in plants (Reddy *et al.*, 2004). The maize varieties under evaluation however showed variation in the photosynthetic pigments content in response to the intensity of the water deficit stress especially at both 75% FC and 100% FC, respectively. The maize varieties showed variation under the mild (50% FC) and severe water deficit stress (25% FC) conditions for the leaf growth traits, however significant differences in the concentration of the photosynthetic pigments under 25 and 50% FC were not observed among the maize varieties.

Conclusions

Estimation of photosynthetic pigments and measure of leaf growth parameter in a plant is a measure of its photosynthetic activity and general plant productivity. Result obtained from this study clearly revealed the detrimental impact of increased water deficit on leaf growth traits and photosynthetic pigments of maize exposed to varying levels of water deficit stress. The water deficit stress and variety interaction were not significant for all the evaluated leaf growth traits, while WDS and variety interaction was only significant under high moisture conditions of 100 and 75% FC for the photosynthetic pigment. Identification of drought tolerant maize varieties in this study using leaf growth and photosynthetic parameters may be a bit difficult due to smaller maize population size. However, information from larger maize population, biochemical, molecular analysis and remote sensing may assist to further identifying drought tolerant genotypes. Finally, adequate moisture availability enhances leaf growth and photosynthetic pigments formation in maize plant.

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Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

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