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Agronomic, morphological, anatomical and physiological characteristics of tolerant and non-tolerant drought maize varieties

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The agronomic, morphological, anatomical and physiological characteristics of native and improved varieties of rain fed drought tolerant maize (DTV) and non-tolerant varieties (NDTV) was compared. Correlation analysis of each variety in terms of production characteristics and other variables was done. This was done in order to observe if some of the latter could be used as selection indices of productive plants. The study was conducted under irrigated conditions in Zacatecas, Mexico (2280 musl; 15.8°C mean temperature; 448 mm of annual rainfall average). The average of 10 fully competitive plants of each variety was evaluated. There were no differences between the DTV and NDTV as a group, but they differed when considering characteristics of each individual variety. It suggests that to find differences between these varieties, they should be studied individually. The indices for selecting productive plants in the early DTV native are: C-5: NGC, NRC, NL and W5G for both grain and stubble; in the DTV semi early native: C-7: high values of: NKR and low: EH, DMF, DS and PH for grain, also high values of: W5G, V5G, NSP and NPBT for stubble; in the DTV native semi early C-23, high values of: W5G and a low one of PL for grain, also high values of: W5G, V5G and EH and low of: ASY, NRC and ILE, for stubble.

Key words: *Zea mays* L., native varieties, rain fed, grain yield, stubble yield.

INTRODUCTION

More than 80 years ago, research on drought tolerance in maize had been conducted (Jenkins and Richey, 1931; Jenkins, 1932; Sayre, 1932; Moreno et al., 2001). In Mexico, more than 50 years ago, Moncada (1957) determined the drought tolerance of a group of corn varieties in Northeastern Mexico; Palacios (1959) selected in Chapingo, Mexico State, a drought resistant maize line for its behavior of "latency". This topic was thoroughly studied in this country from 1960 to 1990 (Luna and Gutiérrez, 1998). Currently, several researchers

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Table 1. Genetic material used in the present study, place of origin, donor and growth cycle.

Variety	Community and municipality	Donor	Cycle
C-19 NDTV	Col. R. Jaramillo, Ojocaliente	Didn´t give his name	Early
C-5 DTV	Col. G. Ortega, Sombrerete	Humberto Salazar	Early
V-209	Cieneguillas, Zacatecas	INIFAP and UAA-UAZ	Early
VS-202	Cieneguillas, Zacatecas	INIFAP and UAA-UAZ	Early
C-18 NDTV	Malpaso, Jerez	Didn´t give his name	Semi early
C-7 DTV	Zaragoza, Sombrerete	Martín Salazar	Semi early
C-23 DTV	La Florida, Valparaíso	J. Guadalupe Alba	Semi early
VS-201 DTV	Cieneguillas, Zacatecas	INIFAP and UAA-UAZ	Semi early

DTV = Drought tolerant variety; NDTV = Not drought tolerant variety; Early = 90-100 days to physiological maturity; Semi early = 100-120 days to physiological maturity (Veríssimo-Correa, 2008).

are doing work in Mexico to form varieties of maize tolerant to drought (Reyes-Mendez et al., 2007; Dávila, 2011; CIMMYT, 2012); however, they do it in tropical or subtropical regions, where recorded rainfall exceeds 500 mm during the growing season of maize, and with average temperatures exceeding 21°C. Very little research has been done to develop drought tolerant *varieties for rain fed crops in arid and semi-arid* temperate region of Central north of Mexico, where rainfall is generally 250 to 400 mm during the growing season of 100 to 120 days, with average temperatures ranging between 17.5 and 20.5°C (Medina et al., 1998).

The National Institute for Forest, Agricultural and Livestock Researching (INIFAP) formed the open-pollination varieties (OP), CAFIME and VS-201, released in 1957 and 1963, respectively, (Gámez-Vázquez et al., 1996), for dry land sowing in the arid and semi-arid temperate region of North central México. Several years later, it was determined that these varieties have drought tolerance characteristics (Gutiérrez et al., 1988). In 1975, other OP four varieties were released by the INIFAP also for rain fed crops in that region, and in 1991, another one was released.

In the arid and semi-arid temperate region of North central Mexico, 750,000 ha of rain fed maize are sown annually on average (SAGARPA, 2012); but for more than 20 years, there has not been maize breeding for this sowing system.

Kakani et al. (2003) indicate that plants under stress through generations can lead to tolerant varieties through changes in the morphology and anatomy. This increases the ability to capture and conserve water and other resources, thereby increasing the tolerance to adverse factor that causes stress. In the above region, rain fed maize with drought stress has been cultivated for 800 years (Velasco, 1896; Rodríguez, 1977). Based on this, the Autonomous University of Zacatecas, Mexico, iniciated a Project in the month of January 2005, with the collection of native corn varieties in rain fed locations in the state of Zacatecas plateau (1900 to 2250 musl); the localities have representative ecological characteristics of arid and semi-arid temperate region of North central Mexico.

The varieties were tested for two years under the drought-irrigation scheme (Muñoz and Rodriguez, 1988) in a village of this region; based on the results, the following collections were selected: C-5, C-7 and C-23. This is because they showed greater drought tolerance than all the rest (Loera, 2008), according to their productivity under drought and drought susceptibility index, indicated by Fisher and Maurer (1978).

The aim of this work is to observe if these varieties can be distinguished from non-drought tolerant varieties, based on some agronomic, morphological, anatomical and physiological characteristics, as indicated by Williams et al. (1967), Muñoz (2003) and Kakani et al. (2003); in addition to that, these features could be used as selection index in breeding programs of rain fed maize in the Central northern Mexico.

MATERIALS AND METHODS

Genetic material

The studies were made with varieties shown in Table 1. In order to obtain more precise information, varieties were divided into two groups: Early and semi early, according to the classification of Verissimo-Correa (2008). In average of two tests conducted in 2005 and 2006 in Cieneguillas, Zacatecas, Mexico, with drought in the soil during the phenological stages of vegetative growth, flowering and grain filling, Loera (2008) found that the average grain yield of drought tolerant varieties with early vegetative cycle (DTV) (C-5, VS-202, V-209) was statistically higher than the non drought tolerant (NDTV) (C-19) variety by 40% and in yield stubble by 41%. The semi early cycle growth of DTV (C-7, C-23, VS-201) outperformed NDTV (C-18) by 37% in grain and by 41% in stubble yield. On the average of experiments treated under rain fed conditions in the year 2008 (425 mm of rainfall during the growing season) and 2009 (280 mm of rainfall during the growing season), in Valparaiso, Zacatecas, Mexico (1900 musl and 20.5 ^{o}C average temperature in the growing season), Luna et al. (2010) determined that the DTV with early vegetative cycle outperformed the NDTV in grain yield by 80% and in stubble yield by 23%; the VTS of semi early vegetative cycle outperformed grain and stover in NDTV by 28% and 10%, respectively. Varieties: C-5, C-7, C-18, C-19 and C-23 are native, while V-209, VS-201 and VS-202 are open pollinated varieties improved by INIFAP (Gámez-Vázquez et al., 1996).

Morphological and agronomic characteristics

Area of study

The research was carried out at the experimental field of the Agronomy Academic Unit of the Autonomous University of Zacatecas, Mexico, located at 22° 31' 28" N latitude, 102° 41' 10" W longitude and at 2280 musl. The climate is BS_1 (h_1)w(w) of the dry group. The average annual temperature is 15.8°C and precipitation of 448 mm; but between 60 and 70% is recorded during the dry growing season (July to September) (Medina et al., 1998). The soil used was loamy, has a depth of 0.8 to 1.0 m, 1.5% organic matter, pH 7.2 and has less than 4% slope (Zelaya, 2002).

Management of the seeding plot

Each variety occupied two rows of 5 x 0.75 m, with 16 plants each. According to the Experimental Zacatecas Field recommendation (Medina et al., 1998), the plants were sown on moist soil in 12 April, 2007; the management of the plot consisted of: fallow, tracking, tracing the grooves, manual seeding, fertilization with 80-40-00 dose, two spuds, watering enough to keep the soil moist and a manual weeding. There were no problems with pests or diseases.

Measured variables

In 10 fully competitive plants of each variety, data were taken: GW= Grain weight in g; SW= Stover weight in g; DMF= Days from sowing to male flowering average; DS= Days from seeding to half silking; ASY= Floral asynchrony; GWCD= Grain weight per cob/DMF in g/day; SWD= Stubble weight/DMF in g/day; SP= Silking period in days; MFP= Male flowering period in days; EH= Ear height in cm (from the soil surface to the lower ear position); PH= Plant height in cm (from the soil surface to the tip of the tassel); NL= Number of main stem leaves; NSP= Number of shoots per plant; IDE= Diameter of the middle part of the ear internode in mm; ILE= Internode lenght of ear in cm; PL= Peduncle lenght in cm; TL= Tassel lenght in cm; NTPB= Number of tassel primary branches; DPM= Days from seeding to physiological maturity; GFP= Grain filling period in days (DPM – DMF); CL= Cob lenght in cm; DC= Diameter of the middle part of cob in mm; NRC= Number of rows of the cob; NKR= Number of kernels per row; NGC= Number of grains per cob (NRC x NKR); CD= Corncob diameter in the middle part in mm; CW= Corncob weight in g; W5G= Weight of 50 grains in g; V5G= Volume of 50 grains in cc; GD= Grain density (W5G/V5G); LG= Lenght of grain (DC-CD)/2. Variables were measured as indicated by the International Union for the Protection of New Varieties of Plants (UPOV) (Carballo, 2010). The results are presented as average of 10 plants.

Anatomical feature

Stomatal density

This work was were conducted in the greenhouse and plant pathology laboratory of the Academic Unit of Agronomy of the Autonomous University of Zacatecas. The stomatal density was measured as indicated by Briones and Delgado (1988) and Gutierrez and Luna (1992). For the study, developed seedling leaves in styrofoam cups with capacity of 500 mL in volume were used. To each beaker was added 115 g of a sterilized substrate composed of loamy soil mixed with 10% organic matter. The seed was sown in 3 cm depth. To each beaker was added 50 mL of water. Samples were taken from epidermal tissue of 10 plants (repetitions) of each variety; both at the beam and the underside, by a thin film of exactoden previously applied with a brush. Each sample taken from leaves was placed on a slide for stomata counting under a microscope of 40 magnifications.

Physiological characteristics

Seed germination at different osmotic pressures

Seeds of approximately the same size and age of each variety were germinated in Petri dishes at 0, 5, 10 and 15 atm osmotic pressure, to simulate drought stress (Michel and Kaufmann, 1973; Martínez, et al., 1999). A completely randomized design with five replications was used. The experimental unit was a Petri dish with 20 seeds per treatment. The seeds were placed between filter paper dusted with fungicide to prevent fungal damage. To each box was added 15 mL of sucrose solution in distilled water according to the treatment, except the 0 atm, consisting only of distilled water. The Petri dishes were put in an oven at 25°C. Five days after starting the experiment, the germinated seeds were counted.

Resilience of seedlings subjected to PWP

For this test, an experimental design in randomized complete blocks with five replications was used; the experimental unit was 10 styrofoam cups of 500 mL volume capacity, with one seedling in each. To each beaker was added 120 g of a sterilized substrate composed of loamy soil mixed with 10% organic matter. The seed was sown in 3 cm depth. To each beaker was added 50 mL of wáter; 30 days later were added again 50 mL of water to each beaker, to subsequently obtain the percentage of plantlets recovered, as indicated by Williams et al. (1967), Palmeros (1985) and Rojas (2003).

Transpiration index

For this test, the same methodology noted in the previous paragraph was used, respectively in the use of glasses, substrate, sowing, etc. Weights of vessels were taken from the first day after adding water to each glass. With these data, by substracting the initial weight from the everyday weight, the transpiration rate of each variety was determined (Gutiérrez and Luna, 1992).

Statistical analysis

In order to observe whether there was difference between drought tolerant varieties and non-tolerant ones, the variables measured in each study were subjected to analysis of variance; those variables that showed statistical significance, the mean test was done with the method of averages of Tukey ($p<0.05$). Also a simple correlation analysis between variables for each variety was carried out, in order to observe if some of them can be used as selection indices in breeding programs of regional drought tolerant varieties.

RESULTS AND DISCUSSION

Early varieties

Agronomic and morphological characteristics

In 12 of the 31 measured quantitative variables, analysis of variance found no statistical difference ($p<0.05$)

Table 2. Means comparison of the measured variables in rain fed maize varieties of Early Vegetative Cycle. UAA-UAZ. 2007.

Variety	SW	SWD	DMF	PH	PL	T L	NTPB	NSP	DPM
C - 5 DTV	512	6.19^{a}	82.9^{ab}	241^{a}	27.7^{ab}	37.5^{ab}	12.2^{c}	1.50^{a}	127^{a}
V-209 NDTV	480^{ab}	5.73^{ab}	83.9^{a}	216^{b}	23.2^{c}	40.6^{a}	18.9^{a}	1.00^{b}	123^{b}
VS-202 DTV	365^{c}	4.61^{b}	79.2^{bc}	217^{b}	23.6^{bc}	35.8^{b}	16.1^{ab}	0.10^{c}	119^{c}
C – 19 NDTV	387^{bc}	5.05^{ab}	77.0^{c}	242^{a}	28.2^{a}	37.0^{ab}	14.8^{bc}	0.10^{c}	126^{ab}
DSH (0.05)	99	1.21	4.3	20	4.4	3.7	3.2	0.45	3

Variety	GFP	CL	DC	NRC	NGC	W5G	V5G	GD	CD	CW
C - 5 DTV	44.7^{ab}	17.6^{a}	43.0^{ab}	13.0^{b}	416^{ab}	21.5^{a}	14.1^{a}	1.52^{b}	24.9^{a}	21.6^{a}
V-209 NDTV	38.8^{c}	14.6^{b}	41.6^{b}	14.9^{ab}	480^{a}	17.5^{b}	10.8^{b}	1.62^{a}	21.8^{bc}	13.8^{b}
VS-202 DTV	40.1^{bc}	15.3^{ab}	45.0^{a}	13.0^{b}	377^{b}	21.6^{a}	13.4^{a}	1.61^{ab}	24.3^{ab}	17.8^{ab}
C – 19 NDTV	49.0^{a}	13.7^{b}	42.6^{ab}	16.0^{a}	483^{a}	17.2^{b}	10.3^{b}	1.69^{a}	20.1^{c}	12.9^{b}
DSH (0.05)	5.2	2.7	3.3	2.1	86	2.4	1.8	0.12	2.6	5.4

SW = Stover weight, SWD = Stubble weight per day to male flowering, DMF = Days to male flowering, PH = Plant height, PL= Peduncle lenght, TL = Tassel lenght, NTPB = Number of tassel primary branches, NSP = Number of shoots per plant, DPM = Days to physiological maturity, GFP = Grain filling period, CL = Cob lenght, DC = Diameter of cob, NRC = Number of rows per cob, NGC = Number of grains per cob, W5G = Weight of 50 grains, V5G = Volume of 50 grains, GD = Grain density, CD = Corncob diameter, CW = Corncob weight. DSH = Honest significant difference. Values with the same letter in the same column are not statistically different (p <0.05).

Table 3. Correlation coefficients greater than 0.39 between grain weight per day (gwd) and other variables of rainfed maize varieties early vegetative cycle. UAA -UAZ. 2007.

Variety	EH	NL	NTPB	ILE	TL	CL	NRC	NKR	NGC	W5G	V5G	CW	DC	SP
C - 5 DTV		0.63		-0.46			0.65	0.56	0.87	0.65	0.63	-0.40		
V-209 DTV	-0.44		0.68										0.46	
VS-202 DTV					-0.59				-0.70					-0.67
C – 19 NDTV						0.43								

Variety	DMF	ASY	GFP	GD	DPM
C - 5 DTV	-0.43		0.56	-0.42	0.51
V-209 DTV					
VS-202 DTV					
C – 19 NDTV	-0.42	-0.79	-0.4		

EH = Ear Height, NL = Number of main stem leaves, NTPB = Number of tassel primary branches, ILE= Internode lenght of ear, TL = Tassel lenght, CL = Cob lenght, NRC = Number of rows per cob, NKR = Number of kernels per row, NGC = Number of grains per cob, W5G = Weight of 50 grains, V5G= Volume of 50 grains, CW = Corncob weight, CD = Corncob diameter, SP = Silking period, DS = Days to silking, DMF = Days to male flowering, ASY = Floral asynchrony, GFP = Grain filling period, GD = Grain density, DPM = Days to physiological maturity.

the analysis of variance (Table 2). In all the variables there is at least one value of DTV statistically equal to NDTV. There was no trend of similarity or difference between the values of at least 2 DTV that distinguishes them from the NDTV.

Correlation coefficients greater than 0.39 between the measured variables and weights of grain per day (Table 3) and stover (Table 4) showed no difference between the group of DTV and the NDTV, except cob lenght with grain weight per day. This suggests that it is not easy to differentiate a group of DTV early vegetative cycle from NDTV through agronomic and morphological characteristics as assessed here. As noted by some authors (Bartels and Salamini, 2001; Bruce et al., 2002; Muñoz, 2003; Mahajan and Tuteja, 2005), drought tolerance in maize is complex; assuming that is governed by several pairs of genes and mechanisms of tolerance, it may vary from one variety to another. Comparing only the DTV native C-5 with the NDTV C-19 (Table 4), it shows that C-5 had values greater than C-19 in features: SW, NSP, CL, W5G, V5G, CD and CW, and minor: NRC and GD.

Nilsen and Orcutt (1996) indicate that mechanisms of drought tolerance in plants can be improved by selection; so, if somebody would like to use the native variety of early growing season, C-5 is classified as drought tolerant (Loera, 2008). In a regional breeding program, some outstanding rates to be taken into account when selecting plants with high grain yield are: high values in NGC, NRC, W5G, V5G and NL (Table 3); for stover

Table 4. Correlation coefficients greater than 0.39 between stubble weight per day (swd) and other variables of rainfed maize varieties early vegetative cycle. UAA-UAZ. 2007.

Variety	NL	LE	IDE	TL	NTPB	CL	NRC	NKR	NGC	W5G	V5G	CW	CD	SP DS
C - 5 DTV		0.64	-0.45	0.50				0.76	0.56	0.92	-0.73	-0.53	-0.47	-0.50
V-209 DTV						0.74			0.49	0.46				
VS-202 DTV			-0.49			-0.45				-0.67	-0.65			
C – 19 NDTV			0.56	-0.64	-0.40	0.50				-0.73				
DMF		ASY	GFP	DPM										
-0.43			0.52	0.55										
			-0.79	-0.40										

NL = Number of main stem leaves, ILE = Internode lenght of the ear, IDE = Internode diameter of the ear, TL = Tassel lenght, NTPB = Number of primary branches in tassel, CL = Cob lenght, NRC = Number of rows per cob, NKR = Number of kernels per row, NGC = Number of grains per cob, W5G = Weight of 50 grains, V5G = Volume of 50 grains, CW = Corncob weight, CD = Corncob diameter, SP = Silking period, DS = Days to silking, DMF = Days to male flowering, ASY = Floral asynchrony, GFP = Grain filling period, DPM = Days to physiological maturity.

Table 5. Stomatal density (per mm^2) of studied varieties early vegetative cycle.

Variety	Stomatal density		
	Upper	Underside	Sum
C – 5	74^d	123^c	197^c
VS – 202	161^a	266^a	427^a
V – 209	87^c	112^d	199^c
C – 19	108^b	168^b	276^b
DSH (0.05)	5	5	12

Values with the same letter in the same column are not statistically different (p <0.05).

yield, high values: NGC, NRC and NL (Table 4).

Anatomical feature

The stomatal density did not differ in the DTV group early growing cycle from the NDTV (Table 5); but stomatal density of native DTV C-5 was significantly lower than the NDTV. It should be noted, that DTV C-5 had a lower stomatal density in the beam than the DTV V-209, but higher in the back. This coincides with Roth et al. (1986) and Bunce (2010), in the sense that stomatal density may vary from one variety to another, both in the beam and the underside.

Physiological characteristics

As in the above features, the physiological characteristics did not differ between DTV group of early growing cycle and NDTV (Table 6). The NDTV had a germination percentage of seeds with high osmotic pressures as high as the DTV C-5.

There was no difference in the recovery of seedlings subjected to Permanent Withering Point (PWP), or the Transpiration Index of seedlings; although in this last variable, NDTV had a numerically lower value. The failure to observe any difference between the DTV group of early vegetative cycle and NDTV, based on the variables evaluated in this study, suggests that studies should be done for each variety, comparing it with an already known variety which is susceptible to drought.

Semi early varieties

Agronomic and morphological characteristics

Unlike what was observed in the early growing season varieties, in the semi early vegetative cycle varieties, only in seven of the 31 quantitative variables measured was no statistical difference ($p<0.05$) between the varieties (Table 1); the range of values in these variables were: GW, 147-170 g; GWD, 1.63-1.89 mg; IDE, 18.2-19.8 mm; SP, 8.0-8.9; MFP, 11.5-12.6; NGC, 396-436; LG, 9.0-10.9 mm.

Like in the early growing season varieties, in the semi early vegetative cycle, drought tolerant varieties (DTV) did not differ as a group from non-drought tolerant variety (NDTV) in variables that showed significance ($p<0.05$) with the analysis of variance (Table 7); in all the variables there was at least a value of DTV, which is statistically equal to the NDTV. Comparing the DTV native C-7 with NDTV C-18 (Table 7), C-7 showed values higher than C-18 in characteristics: NL, NTPB, GFP, GD and CD, and minor: TL, CL and NKR. The DTV native C-23 had values greater than C-18 in: SWD, PH, NSP, ASY, CL, W5G and V5G, and minors: NRC and CW. Correlation coefficients greater than 0.39 between the measured variables and weights of grain per day (Table 8) and stubble (Table 9) showed no significant difference between the DTV group and the NDTV, except in the number of leaves and cob lenght with grain weight per day; also the cob lenght and

Table 6. Germination of seeds to different osmotic pressures (%), recovery of seedlings subjected to PWP (RSSD) (%) and rate of seedlings perspiration (mm) of studied varieties early vegetative cycle.

Variety	Osmotic pressure (atm)				RSSD	Transpiration rate
	0	5	10	15		
C – 5	100	89^{b}	60^{ab}	29^{b}	1^{a}	4.14^{ab}
VS – 202	100	83^{c}	36^{c}	2^{c}	1^{a}	4.52^{a}
V – 209	100	97^{a}	75^{a}	53^{a}	1^{a}	4.07^{ab}
C – 19	100	83^{c}	55^{b}	22^{b}	2^{a}	3.37^{c}
DSH (0.05)	5	15	16	2	0.50	

Values with the same letter in the same column are not statistically different ($p < 0.05$).

Table 7. Means Comparison of the measured variables in rain fed maize varieties, semi early vegetative cycle. UAA-UAZ. 2007.

Variety	SWD	DMF	EH	PH	NL	IDE	PL	TL	NTPB	NSP	DPM	ASY	GFP	CL
C - 7 VTS	5.69^{b}	90.5^{a}	113^{b}	237^{b}	14.6^{a}	15.3^{b}	21.4^{b}	40.0^{b}	24.3^{a}	0.21^{b}	134^{a}	1.25^{b}	43.9^{a}	16.9^{b}
C - 23 VTS	8.52^{a}	88.2^{ab}	132^{a}	258^{a}	13.2^{b}	18.4^{a}	26.6^{a}	42.6^{ab}	18.5^{b}	1.50^{a}	128^{b}	2.45^{a}	39.4^{b}	18.9^{a}
VS-201 VTS	5.81^{b}	87.0^{b}	119^{ab}	228^{b}	11.9^{c}	16.5^{ab}	23.0^{b}	37.9^{b}	21.1^{ab}	0.10^{b}	123^{c}	0.05^{c}	36.1^{b}	17.4^{ab}
C – 18 VNTS	5.13^{b}	89.8^{ab}	118^{ab}	237^{b}	12.3^{bc}	17.8^{ab}	24.2^{ab}	46.2^{a}	17.8^{b}	0.23^{b}	129^{ab}	0.35^{bc}	39.6^{b}	17.3^{ab}
DSH (0.05)	1.65	3.3	18	13	1.0	2.4	3.2	4.5	3.4	0.32	3	1.05		1.8

DC	NRC	NKR	W5G	V5G	GD	CD	CW
46.9^{ab}	13.4^{a}	30.4^{b}	21.4^{b}	13.2^{b}	1.63^{a}	29.0^{ab}	26.5^{a}
44.5^{b}	11.0^{b}	36.0^{a}	25.1^{a}	17.3^{a}	1.46^{b}	23.0^{c}	19.4^{b}
49.2^{a}	14.4^{a}	30.3^{b}	22.9^{ab}	14.8^{b}	1.53^{ab}	30.8^{a}	29.9^{a}
45.7^{ab}	13.2^{a}	32.6^{a}	21.5^{b}	14.6^{b}	1.48^{b}	26.0^{bc}	25.4^{a}
4.4	1.9	3.5	2.9	2.1	0.13	3.6	5.2

SWD = Stubble weight per day to male flowering, DMF = Days to male flowering, EH = Ear height, PH= Plant height, NL = Number of main stem leaves, IDE = Internode diameter of the ear, PL = Peduncle lenght, TL= Tassel lenght, NTPB= Number of tassel primary branches, NSP= Number of shoots per plant, DPM = Days to physiological maturity, ASY = Floral asynchrony, GFP = Grain filling period, CL = Cob lenght, DC = Diameter of cob, NRC = Number of rows per cob, NKR = Number of grains per row, W5G = Weight of 50 grains, V5G = Volume of 50 grains, GD = Grain density, CD = Corncob diameter, CW = Corncob weight. DSH = Honest significant difference. Values with the same letter in the same column are not statistically different ($p < 0.05$).

Table 8. Correlation coefficients greater than 0.39 between grain weight per day (gwd) and other variables of rain fed maize varieties Semi early vegetative cycle. UAA-UAZ. 2007.

Variety	EH	PH	NL	TL	PL	NSP	CL	NRC	NKR	NGS	W5G	CW	SP	MFP
C - 7 DTV	-0.62	-0.54		-0.54	-0.47	0.40			0.85	0.51		0.40		
V-23 DTV				-0.41	-0.47			-0.43			0.54		0.40	
VS-201 DTV					0.48				0.55	0.70	-0.52	-0.59		-0.85
C – 18 NDTV	0.59		0.47				0.79	0.58	0.69	0.68	0.58		0.41	

DS	DMF	ASY	GFP
-0.57	-0.59		
		-0.52	0.61

EH = Ear height, PH = Plant height, NL = Number of main stem leaves, TL = Tassel lenght, PL = Peduncle lenght, NSP = Number of shoots per plant, CL = Cob lenght, NRC = Number of rows per cob, NKR = Number of kernels per row, NGC = Number of grains per cob, W5G = Weigh of 50 grains, CW = Corncob weight, SP= Silking period, MFP= Male flowering period, DS = Days to silking, DMF = Days to male flowering, ASY = Floral asynchrony, GFP = Grain filling period.

days to male flowering, with stubble weight per day. Similar with the varieties of early growing season, in the semi early vegetative cycle, it is not easy to differentiate the DTV group from the NDTV, through agronomic and

Table 9. Correlation coefficients greater than 0.39 between the weight of stover per day (wsd) and other variables of rain fed maize varieties semi early vegetative cycle. UAA -UAZ. 2007.

Variety	EH	PH	ILE	PL	NTPB	NSP	CL	DC	NRC	NKR	NGC	W5G	V5G	CW
C - 7 DTV		-0.54	-0.50	-0.70	0.55	0.59						0.71	0.70	0.41
C-23 DTV	0.50		-0.54					-0.40	-0.59			0.58	0.51	
VS-201 DTV				0.62	-0.55				0.56	0.40	0.73	-0.67	-0.46	-0.59
C – 18 NDTV					-0.45		0.44							
CD	**SP**	**MFP**	**DS**	**DMF**	**ASY**	**GFP**	**GD**							
						0.40								
	-0.40				-0.74									
-0.41		0.80	-0.54			0.82	-0.43							
	0.51		0.53	0.51										

EH = Ear height, PH = Plant height, ILE = Internode lenght of the ear, PL = Peduncle lenght, NTPB = Number of primary branches of tassel, NSP = Number of shoots per plant, CL = Cob lenght, DC = Diameter of cob, NRC = Number of rows per cob, NKR= Number of kernels per row, NGC= Number of grains per cob, W5G= Weight of 50 grains, V5G= Volume of 50 grains, CW= Corncob weight, CD = Corncob diameter, SP= Silking period, MFP= Male flowering period, DS = Days to silking, DMF = Days to male flowering, ASY = Floral asynchrony, GFP = Grain filling period, GD = Grain density.

Table 10. Stomatal density (per mm^2) of studied varieties semi early vegetative cycle.

Variety	Stomatal density		
	Upper	Underside	Sum
C – 7	71^c	98^d	169^c
C – 23	101^a	153^a	254^a
VS – 201	94^b	144^b	238^b
C – 18	74^c	104^c	178^c
DSH (0.05)	5	5	12

Values with the same letter in the same column are not statistically different ($p <0.05$).

and morphological characteristics as valued in this work. Anyway, if somebody would want to use the native variety of semi early vegetative cycle, C-7 is classified as drought tolerant (Loera, 2008). In a regional breeding program, some outstanding rates that should be taken into account when selecting plants with high grain yield are: high values of: NKR and low: EH, DMF, DS and PH (Table 8); for stover yield, high value: W5G, V5G, NSP and NTPB, also low values of PL (Table 9); for selection in the native variety C-23, for grain yield should be considered high values of W5G and low PL; for stover yield, high values of: W5G, V5G and EH, also low values: ASY, NRC and ILE.

Anatomical feature

The stomatal density did not differentiate the DTV group of semi early vegetative cycle from the NDTV (Table 10); however, the NDTV C-18 stomatal density was greater than the DTV C-7 and significantly lower than the native DTV C-23, both at the beam and back. The NDTV (C-18) had a number of stomata per square millimeter equal to the DTV C-7 in the beam and in total, and is greater than C-7 on the underside. As in the early vegetative cycle varieties, these results agree with those reported by Roth et al., (1986) and Bunce (2010), in the sense that the stomatal density may vary from one variety to another, both at the beam and back.

Physiological characteristics

Again, these features were not different between the DTV group semi early vegetative cycle and NDTV (Table 11). The NDTV had a germination rate of seeds with high osmotic pressures as high as some of the DTV; it also showed the same recovery rate of seedlings subjected to PWP and the same transpiration index of seedlings. As noted for the early growing season varieties, in the semi early vegetative cycle ones, studies must be done for each drought tolerant variety, comparing it with an already known variety which is susceptible to drought, in order to know the characteristics that differentiate them

Table 11. Germination of seeds to different osmotic pressures (%), recovery seedlings subjected to drought (RSSD) (%) and rate of transpiration (mm) of the studied varieties with semi early vegetative cycle.

Variety	Osmotic pressure (atm)				RSSD	Transpiration rate
	0	5	10	15		
C – 7	100	86[a]	50[a]	27[a]	2[a]	4.62[a]
C – 23	100	90[a]	36[a]	3[b]	1[a]	4.43[ab]
VS – 201	100	89[a]	46[a]	4[b]	1[a]	4.04[b]
C – 18	100	90[a]	38[a]	18[ab]	2[a]	4.07[b]
DSH (0.05)	5	15	16	2	0.50	

Values with the same letter in the same column are not statistically different (p <0.05).

and mechanisms that allow the respective drought tolerance.

Conclusions

The drought tolerant varieties (DTV), both early vegetative cycle and semi early ones, did not differ as a group from the non drought tolerant (NDTV) used as control, in the agronomic, morphological, anatomical and physiological features assessed in this study. There were differences only when comparing the drought tolerant varieties individually from the non drought tolerant ones.

Some features that could be considered to select plants with high grain yield and stubble in the DTV native early growing season C-5 are: NGC, NRC, W5G and NL. In the variety C-7, for grain yield: high values of NKR and low values of EH, DMF, DS and PH; for stover yield, high values: W5G, V5G, NSP and NTPB; in variety C-23, for grain yield: high values of W5G, and low values of PL; for stover yield, high values of: W5G, V5G and EH, also low values of: ASY, NRC and ILE.

The DTV early C-5, showed a greater stomatal density than the NDTV C-19. The DTV semi early C-7 had a lower stomatal density than the NDTV C-18 on the underside, and also a higher transpiration rate.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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