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Para o Desenvolvimento Ambiental, Cultural e Socioeconômico

Xosé Somoza Medina
(organizador)

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PRÓLOGO

La ciencia y la tecnología siguen siendo fuerzas impulsoras de las transformaciones sociales, culturales y ambientales de nuestro tiempo. Al mismo tiempo que responden a desafíos urgentes del presente, también iluminan caminos hacia futuros más sostenibles, más justos e inteligentes. Esta recopilación nace precisamente de ese impulso: el de pensar, crear y proponer soluciones a partir de la investigación científica y la innovación tecnológica, en diálogo con las realidades locales y los contextos globales.

Reunimos en ***Ciência e Tecnologia para o Desenvolvimento Ambiental, Cultural e Socioeconômico VI*** artículos de investigadores e investigadoras de distintas partes del mundo, comprometidos con la producción de un conocimiento riguroso, interdisciplinario y sensible a la complejidad de los temas contemporáneos. Los trabajos presentados abordan una amplia gama de cuestiones –desde la nanotecnología hasta la agricultura de precisión, desde la física aplicada hasta la expresión lingüística– conformando un panorama diverso que refleja los múltiples caminos de la ciencia en el siglo XXI.

Organizados en cuatro ejes temáticos –*Tecnología e Innovación en Salud e Industria*, *Ingeniería, Física Aplicada y Recursos Naturales*, *Sustentabilidad Agrícola y Transformaciones Climáticas*, y *Lenguaje, Cognición y Expresión Científica*– los textos aquí reunidos nos invitan a reflexionar sobre preguntas centrales de nuestro tiempo: ¿Cómo garantizar el acceso equitativo a las nuevas tecnologías médicas? ¿Cómo integrar soluciones de ingeniería a las urgencias ambientales? ¿De qué manera puede el avance agrícola responder al cambio climático sin agotar los recursos naturales? ¿Y cómo influye el lenguaje en la forma en que comprendemos y comunicamos el conocimiento científico?

Más que ofrecer respuestas definitivas, esta obra propone caminos para la reflexión y la acción, abriendo espacio para nuevas investigaciones, debates y colaboraciones. Cada autor y autora aporta una perspectiva única, y juntas estas voces amplían nuestra comprensión del papel transformador de la ciencia y la tecnología en el mundo contemporáneo.

Que este nuevo libro sea, para lectoras y lectores, una invitación a la curiosidad crítica, al pensamiento creativo y a la construcción de futuros posibles. Agradecemos a todos los involucrados por su confianza, dedicación y generosidad intelectual.

Xosé Somoza Medina

Universidad de León, Espanha

SUMÁRIO

CAPÍTULO 6

BREEDING DROUGHT RESISTANCE AND HEAT TOLERANCE TO MITIGATE CLIMATIC CHANGE EFFECTS ON CROPS

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ABSTRACT: The objective of this study was to assess the plant response to soil water deficit and heat in a group of bread wheat, triticale and barley varieties under glasshouse and outdoors conditions. Thirty-two bread wheats, two barleys and a triticale were included. A complete block design with three replicates was used. The experimental unit was a PVC tube 1 m tall and 10.5 cm diameter with an individual plant. Both experiments were planted in July 28, 2010. A fertilizer rate of 80-40-00 was applied to the soil. This showed that plants under water and heat stress in a glasshouse produced less biomass, dry weight of roots and shoot, and had lower root/shoot ratio than plants with less heat stress outdoors. The barley varieties produced greater biomass and dry weight of roots and shoot, and they had greater root/shoot ratio than the bread wheat and triticale varieties in glasshouse conditions with higher level of water and heat stress. The better performance of barley varieties in glasshouse conditions could be used as a valuable attribute of drought resistance and heat tolerance, and it could be used as a selection criterion in the plant breeding programs.

KEYWORDS: *Hordeum vulgare* L.; *Triticum aestivum* L.; *Triticosecale* Wittmack; dry weight of roots; dry weight of shoot.

RESISTENCIA A LA SEQUÍA Y TOLERANCIA AL CALOR PARA MITIGAR LOS EFECTOS DEL CAMBIO CLIMÁTICO EN LOS CULTIVOS

RESUMEN: El objetivo del presente estudio fue evaluar la respuesta de la planta al déficit hídrico del suelo y calor en un grupo de variedades de trigo harinero, triticale y cebada en condiciones de invernadero e intemperie. Se incluyeron 32 genotipos de trigo harinero, dos cebadas y un triticale. Se empleó un diseño experimental de bloques completos al azar con tres repeticiones. La unidad experimental fue un tubo de PVC de 1 m de alto y 10.5 cm de diámetro con una planta individual. Los dos experimentos se sembraron el 28 de julio de 2010. Se aplicó la dosis de fertilización 80-40-00. Se determinó que las plantas sujetas a estrés hídrico y alta temperatura en invernadero produjeron menos biomasa,

peso seco de raíces y parte aérea, y tuvieron menor cociente de raíz/parte aérea que las plantas con menor estrés por calor en condiciones de intemperie. Las variedades de cebada produjeron mayor biomasa, peso seco de raíces y parte aérea, y tuvieron mayor cociente raíz parte aérea que las variedades de trigo harinero y triticale en condiciones de invernadero con mayor nivel de estrés hídrico y por calor. El mejor comportamiento genético de las variedades de cebada en condiciones de invernadero puede considerarse como un atributo de resistencia a sequía y tolerancia a calor, y podría utilizarse como criterio de selección en los programas de mejoramiento genético.
PALABRAS CLAVE: *Hordeum vulgare* L.; *Triticum aestivum* L.; *Triticosecale* Wittmack; peso seco de raiz; peso seco de parte aérea.

1 INTRODUCTION

Global food security is being haunted by the rapid increase in population and drastic changes in the climate (Lesk *et al*., 2016). In the wake of changing climate, drought, and heat stress have become the most important limiting factors to crop productivity and ultimately to the food security. Severe droughts cause substantial decline in crop yields through negative impacts on plant growth, physiology, and reproduction (Barnabas *et al*., 2008). Average global combined temperature of land and ocean surface has increased by 0.85 °C between 1880 and 2012 (IPCC, 2014). An average increase of at least 0.2 °C per decade is projected from now onwards. The rising concentration of the greenhouse gases is becoming a major cause of the global warming. Over the past 250 years a 30 and 150 % rise in the concentration of the CO_2 and methane has been observed (Friedlingstein *et al*., 2010). Drought and heat stresses limit plant growth and productivity more than any other environmental factor. For instance, global wheat production was simulated to decline by 6 % for each degree Celsius rise in temperature (Asseng *et al*., 2015). Although increasing temperatures are also beneficial for crop production in some cooler regions of the world, overall impact on global food security is still negative (Challinor *et al*., 2014). Plants are subjected to the drought conditions when either the water supply to the roots is limited or the loss of water through transpiration is very high (Anjum *et al*., 2011). The severity of the damage caused by the drought is generally unpredictable as it is driven by various factors including, the rainfall patterns, moisture holding capacity of the soil, and water losses through evapotranspiration. Drought and heat stresses interfere with growth, nutrient and water relations, photosynthesis, assimilate partitioning and ultimately cause a significant reduction in crop yields. The present research work was pursued to assess the response of a group of bread wheat, barley and triticale genotypes under drought and heat stress in glasshouse and outdoors conditions.

2 MATERIALS AND METHODS

Two experiments in large tubes were carried on at Colegio de Postgraduados at Montecillo, Municipality of Texcoco, State of Mexico (19º 29’ N, 98º 54’ O, elevation 2250 m above sea level) in the summer-fall growing season 2010. Thirty-two genotypes of bread wheat representing a historical sample of old and modern bread wheats from Mexico and the United States of America, and a triticale and two barley genotypes were included (Table 1).

Table 1. Germplasm used for the experiments.

Pedigree	Year of release	Country of origin	Plant genetic characteristics
Old Mexican landraces			
Kentana 48	1948	Mexico	Tall (rht), bread wheat
Yaqui 50	1950	Mexico	Tall (rht), spring
Temp. M-87/Col.1718 CPRST-13-13T (F_4)	1998	Mexico	Tall
Yaqui 48	1948	Mexico	Tall, (rht), awnless
Old parental green-revolution lines			
Gabo	1945	Australia	Tall, (rht), bread wheat
Marroqui	1948	Morocco, North Africa	Tall, (rht), bread wheat
Pre-breeding genotypes of the green-revolution			
Nainari 60	1960	Mexico	Tall, (rht), bread wheat
Penjamo 62	1962	Mexico	Tall, (rht), spring
Bajio 67	1967	Mexico	Tall, (rht), spring
Tobari 66	1966	Mexico	Tall, (rht), bread wheat
Green-revolution genotypes			
Decade 1970’s			
Salamanca S-75	1975	Mexico	Semi-dwarf
Cleopatra VS-74	1974	Mexico	Semi-dwarf
Tanori F-71	1971	Mexico	Semi-dwarf
Jupateco F-73	1973	Mexico	Semi-dwarf
Yecora Rojo	1975	USA	Semi-dwarf
Decade 1980’s			
Galvez M-87	1987	Mexico	Semi-dwarf
Mexico M-82	1982	Mexico	Tall
Tonichi S-81	1981	Mexico	Semi-dwarf
Seri M-82	1982	Mexico	Semi-dwarf
Genaro T-81	1981	Mexico	Semi-dwarf

Opata 85 (Cheel)	1985	Mexico	Semi-dwarf
Decade 1990's			
Verano S-91	1991	Mexico	Semi-dwarf
Romoga F-96	1996	Mexico	Semi-dwarf
Juchitepec	1996	Mexico	Semi-dwarf
Borlaug M-95	1995	Mexico	Short
Modern			
Nahuátl F-2000	2000	Mexico	Semi-dwarf
Rebeca F-2000	2000	Mexico	Semi-dwarf
Era F 2000	2000	Mexico	Semi-dwarf
Tlaxcala F-2000	2000	Mexico	Semi-dwarf
Summit	2005	CA, USA	Semi-dwarf
Blanca Grande	2005	CA, USA	Semi-dwarf
Other bread wheats			
Cal Rojo	-	Los Altos, CA, USA	Tall
Triticale			
Triticale 118 (Spring)	-	CA, USA	Tall, spring
Barley			
Lenetah (Barley, spring, two-row)	-	Idaho, USA	Tall, two-row, spring
Cleopatra (Barley, spring, six-row)	-	Mexico	Tall, six row, spring

Experiments were sown in July 28, 2010 in wet soil; one experiment was placed in a glasshouse and the another one was set up outdoors. Seeds of 35 mg weight were used for all genotypes. A complete randomized block design with three replicates was used. The experimental unit was an individual plant grown in a large PVC tube (1 m tall and 10.5 cm diameter) filled out with soil. Soil used was a silt-loam, rich in organic matter with 33.9 % field capacity, 20.5 % permanent wilting percentage, 9 % organic matter, 6.9 pH and 1.5 dSm^{-1} electric conductivity. Nitrogen and phosphorous were applied to the soil at a rate of 80 and 40 kg ha^{-1}, respectively. Plants grown in glasshouse conditions were watered every other day up to flowering and plants grown outdoors were exposed to rainfall (462 mm) and they were added with water as needed up to flowering. Soil born pests and diseases were prevented with the application of Quatz® IV, Twin-Chain (Alterna-agro, s.a. de c.v., Mexico) at a dosage of 1L ha^{-1} 25 days after sowing. Neither pests nor diseases were observed on the aerial plant organs.

At physiological maturity whole shoot was removed and placed in paper bags to be oven dried for 72 h at a temperature of 70 °C. Dry weight of shoot (DWS, g) was determined for all plants. Plant roots in large tubes were left in a glasshouse until the soil dried up. Then, plastic bags with soil and roots were placed on a table and length of the longest root (LR, cm) was measured from the soil surface to the root tip with a wooden ruler. Roots were separated from soil and they were taken to an oven and dry weight (DWR, mg) was determined. Plant biomass (BM = DWR + DWS, g) and root/shoot ratio (RSR = DWR / DWS) were calculated. Maximum and minimum temperatures were recorded by using a data logger (Hobo® model H08-004-02, United States) placed at 1.8 m height from the soil surface in both experiments. Rainfall occurred in the outdoors experiment was measured with a gauge (Young Tipping Bucking Rain Gauge, model 52202/52203, United States) (Table 2). Data were analyzed using the SAS Program for Windows version 9.4 (SAS, 2012). Least significant difference (Lsd Tukey, P≤0.05) was calculated for the comparison of means.

Table 2. Monthly weather statistics during the growing season.

Environment	**May**	**June**	**July**	**August**	**September**	**October**
Glasshouse						
Maximum temperature (°C)	35.8	34.1	31.3	30.1	30.2	30.4
Minimum temperature (°C)	11.1	12.6	12.5	11.9	11.4	7.1
Outdoors						
Maximum temperature (°C)	33.7	32.9	27.3	26.8	26.4	25.4
Minimum temperature (°C)	6.3	8.6	10.1	9.2	8.2	0.5
Precipitation (mm)	10.5	49.2	208.6	149.5	44.3	0.0

3 RESULTS AND DISCUSSION

Soil moisture deficit after flowering caused water stress in the glasshouse and outdoors plants. Water stress in the glasshouse plants was increased by the higher mean maximum and minimum air temperatures (32 and 11.1 °C) than in the outdoors plants (28.8 and 7.2 °C). Exposure of bread wheat plants to suboptimal (below 2 °C) or super optimal (25 °C) temperatures may reduce grain yields by inducing pollen sterility (Sánchez *et al.*, 2014).

Genetic variability among genotypes of bread wheat, barley and triticale for all measured plant traits was significant, except for the length of the longest root in the outdoors plants. The range of variation among genotypes for biomass, dry weight of roots, dry weight of shoot, root/shoot ratio and length of the longest root was higher (12.7, 37.5, 12.2, 10.3 and 2.2-fold) in the glasshouse plants than in the outdoors plants (2.4, 9.0, 2.3, 9.7

and 1.9-fold) (Table 3). The fold range variation for dry weight of roots and shoot, observed in this study was greater than that determined in seedlings of durum wheat grown in phytoagar gel in laboratory conditions, where the range fold for dry weight of roots and shoot was 1.7 and 1.5, respectively (Sanguineti *et al*., 2007). Differences in root and shoot growth between these experiments and the laboratory experiment of Sanguineti *et al*. (2007) were due to the longer growth period given to the glasshouse and outdoors plants; this allowed a greater root and shoot development at physiological maturity. The lack of difference in length of the longest root among genotypes in the outdoors experiment was probably due to the high level of precipitation and greater soil moisture availability before flowering of plants.

Table 3. Fold range, significance of F and mean, minimum and maximum values for total biomass (BM), dry weight of roots (DWR), dry weight of shoot (DWS), root/shoot ratio (RSR) and length of the longest root length (RL) in the glasshouse and outdoors plants.

Genotype	**Glasshouse**					**Outdoors**				
	BM (g)	**DWR (g)**	**DWS (g)**	**RSR**	**RL (cm)**	**BM (g)**	**DWR (g)**	**DWS (g)**	**RSR**	**RL (cm)**
Mean	4.48	0.08	4.4	0.018	38.8	17.9	0.3	17.6	0.020	46.9
Minimum	1.52	0.02	1.50	0.004	24.7	10.9	0.1	10.8	0.006	34.8
Maximum	19.05	0.75	18.3	0.041	54.7	25.7	0.9	25.2	0.058	67.8
Fold range	12.7	37.5	12.2	10.3	2.2	2.4	9.0	2.3	9.7	1.9
Significance	**	**	**	**	*	*	**	*	*	ns
CV (%)	43.3	65.3	41.8	52.1	33.2	25.9	66.4	26.2	72.9	25.7

F value: *(P≤0.05); **(P≤0.01); ns=no significant.

Genetic variability in root and shoot traits among species showed that barley had 80, 90, 79 and 60 % higher BM, DWR, DWS and RSR, and 11 cm extra length of the longest root than bread wheat, and 68, 69, 68 and 2 % greater BM, DWR, DWS and RSR than triticale in the glasshouse plants (Table 4). Unexpectedly, in the outdoors experiment, triticale had 43 and 48 % greater DWR and RSR than barley, and 28, 43, 27 and 39 higher BM, DWR, DWS and RSR than bread wheat (Table 4). The higher BM, DWR, DWS and RSR in barley than bread wheat and triticale in the glasshouse was similar to that observed among barley, bread wheat, durum wheat, triticale and oat by the 2-leaf stage in a growth cabinet (López-Castañeda *et al*., 1996). However, the outstanding behavior of triticale in the outdoors experiment as compared with bread wheat and barley may be ascribed to less heat stress as air temperatures outdoors were cooler than in the glasshouse plants.

Table 4. Biomass (BM), dry weight of roots (DWR), dry weight of shoot (DWS), root/shoot ratio (RSR) and root length of the longest root (RL) in the glasshouse and outdoors plants.

Species	Glasshouse					Outdoors				
	BM (g)	DWR (g)	DWS (g)	RSR	RL (cm)	BM (g)	DWR (g)	DWS (g)	RSR	RL (cm)
Barley	18.19	0.55	17.64	0.0308	48.9	24.0	0.4	23.6	0.016	48.3
Triticale	5.80	0.17	5.63	0.0302	43.3	23.7	0.7	23.0	0.031	48.5
Bread wheat	3.58	0.05	3.53	0.0123	37.9	17.1	0.3	16.8	0.019	46.7
Lsd ($P \leq 0.05$)	1.2	0.08	1.09	0.0041	7.6	2.7	0.1	2.7	0.008	7.1

Finally, the results outlined here show the importance of roots and shoot in the response of plants to water and heat stress. There is no doubt that the roots have a direct connection with the shoot in a such way that the perception of soil water deficit triggers the signals to the shoot. So, that the plant may react quickly performing the necessary physiological adjustments to ensure survival and accumulation of dry matter in the reproductive organs.

4 CONCLUSIONS

Glasshouse plants experienced greater level of water and heat stress than outdoors plants; glasshouse plants produced lower biomass dry weight of roots and shoot, and they had lower root to shoot ratio than outdoors plants. Barley produced greater biomass, dry weight of roots and shoot, and had root to shoot ratio than bread wheat and triticale in glasshouse conditions with high water and heat stress, but in outdoors conditions with less heat stress triticale was the outstanding species.

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SOBRE O ORGANIZADOR

Xosé Somoza Medina (1969, Ourense, España) Licenciado con Grado y premio extraordinario en Geografía e Historia por la Universidad de Santiago de Compostela (1994). Doctor en Geografía e Historia por la misma universidad (2001) y premio extraordinario de doctorado por su Tesis "Desarrollo urbano en Ourense 1895-2000". Profesor Titular en la Universidad de León, donde imparte clases desde 1997. En la Universidad de León fue Director del Departamento de Geografía entre 2004 y 2008 y Director Académico de la Escuela de Turismo entre 2005 y 2008. Entre 2008 y 2009 ejerció como Director del Centro de Innovación y Servicios de la Xunta de Galicia en Ferrol. Entre 2007 y 2009 fue vocal del comité "Monitoring cities of tomorrow" de la Unión Geográfica Internacional. En 2012 fue Director General de Rehabilitación Urbana del Ayuntamiento de Ourense y ha sido vocal del Consejo Rector del Instituto Ourensano de Desarrollo Local entre 2011 y 2015. Ha participado en diversos proyectos y contratos de investigación, en algunos de ellos como investigador principal, con temática relacionada con la planificación urbana, la ordenación del territorio, las nuevas tecnologías de la información geográfica, el turismo o las cuestiones demográficas. Autor de más de 100 publicaciones relacionadas con sus líneas de investigación preferentes: urbanismo, turismo, gobernanza, desarrollo, demografía, globalización y ordenación del territorio. Sus contribuciones científicas más importantes se refieren a la geografía urbana de las ciudades medias, la crisis del medio rural y sus posibilidades de desarrollo, la evolución del turismo cultural como generador de transformaciones territoriales y más recientemente las posibilidades de reindustrialización de Europa ante una nueva etapa posglobalización. Ha participado como docente en masters y cursos de especialización universitaria en Brasil, Bolivia, Colombia, Paraguay y Venezuela y como docente invitado en la convocatoria Erasmus en universidades de Bulgaria (Sofia), Rumanía (Bucarest) y Portugal (Porto, Guimarães, Coimbra, Aveiro y Lisboa). Ha sido evaluador de proyectos de investigación en la Agencia Estatal de Investigación de España y en la Organización de Estados Iberoamericanos (OEI). Como experto europeo en Geografía ha participado en reuniones de la Comisión Europea en Italia y Bélgica. Impulsor y primer coordinador del proyecto europeo URBACT, "come Ourense", dentro del Programa de la Unión Europea "Sostenibilidad alimentaria en comunidades urbanas" (2012-2014). Dentro de la experiencia en organización de actividades de I+D+i se pueden destacar la organización de diferentes reuniones científicas desarrolladas dentro de la Asociación de Geógrafos Españoles (en 2002, 2004, 2012 y 2018).

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