INTERNATIONAL SUNFLOWER ASSOCIATION
ISA

Proceedings

18th International Sunflower Conference

MAR DEL PLATA & BALCARCE - ARGENTINA

February 27 - March 1 / 2012

ASAGIR
ASOCIACION ARGENTINA DE GIRASOL

ISA Board

Carlos FEOLI, Argentina - President

André POUZET, France - CEO

Nikolai BOCHKARYOV, Russia

Maria JOITA-PACUREANU, Romania

Johan POTGIETER, South Africa

Gerald SEILER, USA

Dragan SKORIC, Serbia

Gian Paolo VANNOZZI, Italy

Felicity VEAR, France

Leonardo VELASCO, Spain

Yalcin KAYA, Turkey

ASAGIR Board

PRESIDENT
Ricardo Negri, Capelle Hnos

VICE PRESIDENT
Orlando Vellaz, Advanta Semillas

SECOND VICE PRESIDENT
Guillermo Pozzi

SECRETARY
Juan Carlos Arana, OMHSA

TREASURE
Ramiro Costa, Bolsa de Cereales

PRO SECRETARY
Carlos Sosa, Pannar SA

PRO TREASURE
Fernando Cozzi, Cargill SA

Norma Huguet
Luis Arias, Cazenave y Asociados
Alicia Rupel, Bolsa de Cereales de Bahía Blanca
José María Dodds, Nidera Semillas
Marcelo Morini, ArgenSun
Armando Casalins, Federación de Acopiadores
Antonio Hall
Raúl Tomá, SRA
Santiago Sanchez, AGD
Horacio Urpi
Hernán Busch, Banco de Galicia
Jorge Harguindeguy, AACREA

Local Organizing Committee

Antonio Hall (President) *

Carlos Feoli (ISA President) *

Ezequiel Fonseca *

Archibaldo Salvador *

José Dodds *

Pablo Paoloni

Norma Huguet

Florencia Bedacarratz

Ramiro Costa

Carlos Sosa

Facundo Quiroz

Javier Mallo

Daniel Alvarez

Daniel Funaro

Mariano Martín Sposaro

Jorge Moutous

Marcelo Morini

Arnaldo Vázquez

Marisa Della Maddalena

Maria Carolina Alegre

* Executive Committee

International Steering Committee

Dr. Antonio Hall (Argentina)

Dr. Ruth Heinz (Argentina)

Dr. Luis Aguirrezabal (Argentina)

Dr. Loren Rieseberg (Canada)

Dr. Leonardo Velasco (Spain)

Dr. Felicity Vear (France)

Program Committee

Dr. Luis Aguirrezábal (co-chair)

Dr. Miguel Cantamutto (co-chair)

Dr. Antonio Hall

Dr. Ruth Heinz

Dr. Carlos Sala

Dr. Abelardo De La Vega

Ms. Amelia Romano

Dr. Mónica Poverene

Mr. Guillermo Pozzi

Dr. Pablo Calviño

Dr. Alberto Escande

Dr. María Eugenia Bazzalo

Dr. Andrés Zambelli

Dr. Sergio Alemano

Foreword

The International Sunflower Association (ISA) and the Argentine Sunflower Association (ASAGIR) are pleased to present this guide to the 18th International Sunflower Conference.

At the time the main objectives for the meeting were defined, organizers aimed to provide a forum for the international sunflower research community with interest in any aspect of science and technology relating to the crop (in its oil-seed and confectionery variants) that would allow all involved to:

- Update knowledge in all fields of sunflower research since the previous conference held at Córdoba, Spain, June 2008;
- Review recent technological advances in sunflower production and identify knowledge gaps that require attention;
- Analyze the status and expectations for current and prospective demands for sunflower products;
- Provide a venue for workshops and special-interest meetings focusing on unresolved research, market, and production issues;
- Provide new generations with an opportunity to interact with global leaders in sunflower research.

The local Program Committee, with the help of the International Steering Committee, has developed a program covering the whole spectrum of relevant topics from genes and genomics through to field agronomy, crop protection, and industry and market issues. The program comprises 14 plenary and 13 invited presentations, 14 short oral presentations, an exhibition of 160 posters that can be visited during each of the first three days of the meeting. In addition, there will be three associated workshops (Bird Damage, Breeding, International Sunflower Genome Initiative), a special-interest presentation of the Global Crop Diversity Trust, and facilities will be available on request for small groups who wish to discuss business or scientific topics.

On the last day of the meeting, the Conference Field Day will be held at the joint INTA-Universidad de Mar del Plata facility in Balcarce. This time the traditional Conference demonstration plots of hybrids from International Sunflower Association member countries and from the host country will be complemented by a broad range of demonstrations of production and management techniques, as well as demonstrations of research techniques in current use by Argentine sunflower research teams.

This Conference has been made possible by the work of many people, by the support of sponsors from both the public and the private sector (sponsors are recognized on the back covers of this guide) and last, but certainly by no means least, those responsible for the lectures, short oral presentations, posters, associated workshops and special interest meetings, and field and laboratory demonstrations that make up the rich and varied bill of fare for this Conference, as reflected in this guide. The Organizing Committee extends their heartfelt thanks to all these individuals and organizations.

ISA and ASAGIR trust that this guide will enable all attendees to have an interesting and fruitful 18th International Sunflower Conference.

Welcome

It has been 27 years since the 11th International Sunflower Conference was held in Mar del Plata, Argentina, March 10-13, 1985. Since then, very many things have changed in the world of sunflower science, technology, and crop production and management. As the global sunflower community reconvenes once again in the same city, its members will have the opportunity to review progress in the last four years, which has been substantial in many areas.

Mar del Plata, a vibrant city located by the sea, with a fishing port, good restaurants, an unusually good choice of golf courses, and kilometers of sandy beaches, together with Balcarce, provide excellent venues for the Conference lectures and Field Day, and will allow attendees to appreciate a unique combination of seas, hills and Pampas. It is a great pleasure for the Organizing Committee to be able to host attendees to this meeting, which we hope will be both enjoyable and fruitful.

Welcome to Argentina, to Mar del Plata and Balcarce, and to the 18th International Sunflower Conference.

| 02-VC-4 |

Modeling of environmental causes of hybrid by sowing date interaction in sunflower: a statistical approach

Igor Balalic,[1] Miroslav Zoric,[2] Jovan Crnobarac,[3] Vladimir Miklic V,[4] Velimir Radic[5]
[1]Institute of Field and Vegetable Crops, Maksima Gorkog 30, 21000 Novi Sad, Serbia, igor.balalic@ifvcns.ns.ac.rs
[2]Faculty of Technology, University of Novi Sad, Bulevar cara Lazara 1, 21000 Novi Sad, Serbia, crop.biometrics@gmail.com
[3]Faculty of Agriculture, University of Novi Sad, Trg Dositeja Obradovica 8, 21000 Novi Sad, Serbia, jovanc@polj.uns.ac.rs
[4]Institute of Field and Vegetable Crops, Maksima Gorkog 30, 21000 Novi Sad, Serbia, vladimir.miklic@ifvcns.ns.ac.rs
[5]Institute of Field and Vegetable Crops, Maksima Gorkog 30, 21000 Novi Sad, Serbia, velimir.radic@ifvcns.ns.ac.rs

ABSTRACT

- The analysis of agronomic crop trials is usually complicated by the presence of hybrid by environment interaction. In this study the effect of selected environmental variables on hybrid by sowing date interaction in sunflower, using statistical approach, were investigated.
- For the statistical modeling of interaction six environmental variables (minimum, maximum and mean temperatures, total precipitation, sunshine hours and relative air humidity) were used as input information in factorial regression model (FR). The calculation of environmental variables for each sowing date, were made according to approximate sunflower growth stages (six leaves, budding, flowering, physiological maturity). Three hybrids Miro, Rimi and Pobednik were grown during three vegetation periods and sown at eight sowing dates. The effects of environmental variables on the hybrid by sowing date interaction for seed yield and yield components (oil yield, oil content, 1000 seed weight) were tested.
- The results of individual FR model showed that all traits, except seed yield, were affected by the same number of environmental variables. Most of the variables exhibited the largest effect on interaction in flowering stage, indicating that this growth stage was most sensitive. Among the most important environmental variables were detected relative humidity, maximum temperature, and precipitation. Considering the stepwise FR model where variables were analyzed within particular growth stages, the largest percentage of explained interaction was obtained for 1000 seed weight (60 %) in physiological maturity. The second best model was obtained for oil yield in flowering stage. This model explained 54.4 % of interaction variance. Stepwise FR models in respect to the type of environmental variables (across sunflower growth stages) showed that the highest proportion of interaction variance was obtained for model which analyzed relative air humidity for oil yield (44.9 %) and oil content (34.1 %) in flowering stage. The significance of precipitation, sunshine hours, maximum and mean temperature for all traits in flowering stage was also stated.
- By planting sunflower earlier, plants are able to get full benefit of soil moisture and nutrient during the extended growing season, and obtain maximum yield and yield components.
- The results of this study could be of importance in determining the most advantageous sowing dates for certain sunflower hybrids. This could help in rationalizing the costs of the experiment, and in obtaining reliable information about the behavior of sunflower hybrids. It is of interest in sunflower production.

Key words: environmental variables-factorial regression-growth stage-sunflower

INTRODUCTION

In many trials in which a set of hybrids is grown in a range of environments, the hybrids do not evidence the same responses (or ranks) under all conditions. This phenomen is called hybrid by environment interaction. It is essential to find out which factors could explain the greatest proportion of interaction. In order to assess the physiological basis of interaction, analysis often include additional information such environmental variables (Denis, 1988, van Eeuwijk et al. 1996). Factorial regression (FR) is ordinary linear model which incorporates genetic and environmental informations that enhance physiological interpretation of interaction, as well main effects in parsimonious manner (van Eeuwijk et al., 1996; Brancourt-Hulmel et al., 1997, Vargas et al., 2001).

This investigation was undertaken to study the impact of environmental variables on hybrid by sowing date interaction in sunflower using statistical approach.

MATERIAL AND METHODS

To investigate the underlying physiological mechanisms of hybrid by environment interaction for seed yield, oil yield, oil content and 1000 seed weight, three sunflower hybrids (Miro, Rimi and Pobednik), breed at the Institute of Field and Vegetable Crops, Novi Sad, Serbia, were used. Hybrids were grown during three vegetation periods (2005, 2006, 2007) and sown at eight different sowing dates (SD) in 10-days interval (SD1-20th of March, SD2-30th of March, SD3- 10th of April, SD4- 20th of April, SD5- 30th of April, SD6-10 of May, SD7- 20th of May, SD8- 30th of May). The experimental setup was randomized complete block design with four replications. Seed yield (t/ha), oil yield (t/ha), oil content (%), and 1000 seed weight (g) were analyzed. The sunflower growth stages (V-vegetative and R-reproductive development) were determined according to Schneiter and Miller (1981) as follows: V4-6 leaves (stage 1), R1-budding (stage 2), R5.8-flowering (stage 3) and R9-physiological maturity (stage 4). Meteorological records were taken for minimum (mn), maximum (mx) and mean temperatures (mt), precipitation (pr), sunshine hours (sh) and relative air humidity (rh), from which environmental variables were calculated and averaged for the duration of particular growth stages: six leaves (mn1, mx1, mt1, pr1, sh1, rh1), budding (mn2, mx2, mt2, pr2, sh2, rh2), flowering (mn3, mx3, mt3, pr3 sh3, rh3), and physiological maturity (mn4, mx4, mt4, pr4, sh4, rh4) for each sowing date.

Fixed effect two-way model ANOVA on combined data was performed in order to determine the significance and relative magnitude of each source of variation. Linear FR model is presented by the following equation: $\bar{y}_{ij} = \mu + h_i + e_j + \sum_{k=1}^{K} \xi_{ik} z_{jk} + \bar{\varepsilon}_{ij}$ where μ is general mean of all hybrids and sowing dates, h_i is the main effect of the *i*th hybrid, e_j is the main effect of the *j*th sowing date. The interaction of *i*th hybrid and *j*th sowing date was is represented by the ξ_{ik} which are regression coefficients of hybrid sensitivity for a given environmental variable z_{jk}. The $\bar{\varepsilon}_{ji}$ is the average error. In order to test the effects of environmental variables, the model of individual FR was applied (Denis, 1988, van Eeuwijk, 1996). In addition two types of models were built by forward stepwise selection procedure. In the first one stepwise procedure was applied on the subset of environmental variables (across type of environmental variable), and second one was built by similar approach (across growth stages). FR models were implemented in R computing environment (R Development Core Team, 2009).

RESULTS AND DUSCUSSION

ANOVA for all examined traits showed that main effects and hybrid by sowing date interaction was highly significant, except for seed yield (hybrid as source of variation was not significant). Hybrid by sowing date interaction ranged between 7.1 % for oil content to 11.0% for oil yield (data not presented).

Table 1 presented the results of individual FR which estimates the effect of environmental variables on parsimonious way (i.e. in present case with only two degrees of freedom) to the total hybrid by sowing date interaction. Except seed yield, other traits were affected by the same number of environmental variables. Particularly, most of variables exhibited the largest effect (expressed as relative proportion of interaction variance) in the flowering indicating that this growth stage is the most sensitive. Among the most important environmental variables were detected relative humidity, maximum temperature, and precipitation.

Table 1. Individual contribution of environmental variables to the hybrid by sowing date interaction in sunflower. Highly significant ($P < 0.01$) and significant ($P < 0.05$) variables were retained.

Growth stage	Environmental variable	Seed yield	Oil yield	Oil content	1000 seed weight
Six leaves	mx1		4.7**		
	mn1		4.1**	9.0**	3.5*
	mt1		3.5*	4.4*	
	pr1				
	sh1				4.4**
	rh1				14.4**
Budding	mx2		3.6*	16.1**	6.5**
	mn2		2.5*	9.0**	4.2*
	mt2		3.4*	14.0**	3.7*
	pr2			11.6**	
	sh2			6.5*	
	rh2		3.3*	4.6*	13.4**
Flowering	mx3	20.2**,[a,b]	29.3**	22.6**	27.7**
	mn3				
	mt3	17.0**	22.9**	15.5**	24.9**
	pr3	20.4**	25.6**	13.0**	15.2**
	sh3	12.1**	17.5**	11.7**	16.1**
	rh3	29.2**	44.9**	34.1**	24.2**
Physiological maturity	mx4				
	mn4				
	mt4				3.8*
	pr4	4.6*	2.5*		11.4**
	sh4	5.6*	11.9**	9.1**	
	rh4	14.4**	26.5**	29.8**	12.0**

[a] relative contribution of environmental variable to the interaction term
[b] each term has two degree of freedom
$*P < 0.05$; $**P < 0.01$

In order to construct the more successful FR models in the terms of their effectiveness in the explanation of interaction, forward stepwise procedure was applied to the subset of environmental variables per particular growth stage. Similar to above presented results of individual FR, stepwise procedure selected the model for 1000 seed weight during the physiological maturity as the model with highest proportion of explained variance. This model contained four environmental variables (precipitation, relative air humidity, maximum and minimum temperature) and explained 60 % of interaction with eight degrees of freedom. The second best model was obtained for oil yield in flowering stage. This model explained slightly smaller proportion of interaction (54.4 %) than first ranked model and contained three environmental variables (relative air humidity, sunshine hours and precipitation) as the most important. Equally good models were constructed for oil yield (47.4%) and oil content (45.4%) in physiological maturity as well for oil content (46.2%) in flowering stage. The poorest models were obtained for first two stages of sunflower development (Table 2).

Table 2. Stepwise FR models including the environmental variables per growth stage. Highly significant ($P < 0.01$) and significant ($P < 0.05$) variables were retained in the model.

Growth stage	Environmental variable	Seed yield	Oil yield	Oil content	1000 seed weight
Six leaves	mx1		4.7**		9.6**
	mn1			9.0**	4.6**
	mt1	10.6**,[a,b]	7.9**		
	pr1		3.2*	9.1**	
	sh1	14.7**	17.0**	9.6**	
	rh1				14.4**
Budding	mx2		3.6*	16.1**	
	mn2		6.6**		7.2**
	mt2		4.1**	5.5*	
	pr2	8.6**			9.9**
	sh2	6.9**	13.4**		11.2**
	rh2				13.4**
Flowering	mx3			5.1*	27.7**
	mn3				
	mt3				4.1*
	pr3	5.3*	2.9*		3.6*
	sh3		6.6**	7.0*	
	rh3	29.2**	44.9**	34.1**	3.5*
Physiological maturity	mx4				8.3**
	mn4				7.4**
	mt4				
	pr4	20.2**	20.9**	15.6**	32.3**
	sh4				
	rh4	14.4**	26.5**	29.8**	12.0**

[a] relative contribution of environmental variable to the interaction term
[b] each term has two degrees of freedom
$^*P < 0.05$; $^{**}P < 0.01$

The second group of FR models was constructed with the aim of building the subsets of models in the respect to the type of environmental variable (across the sunflower growth stages). As expected, the highest proportion of interaction variance was obtained for model which analyzed the relative air humidity for oil yield and found as particulary important this environmental variable for flowering and physiological maturity stage. The explained interaction variance for oil yield in flowering was 44.9 %. Similar result was obtained for oil content in the same growth stage. The proportion of explained variance was 34.1 %. FR models which analyzed precipitation, sunshine hours, maximum and mean temperature, as environmental variables, showed also the imortance of these variables for all traits in flowering stage (Table 3).

Table 3. Stepwise FR models including the environmental variables per variable type. Highly significant ($P < 0.01$) and significant ($P < 0.05$) variables were retained in the model.

Environmental variable	Growth stage	Seed yield	Oil yield	Oil content	1000 seed weight
Maximum temperature	six leaves		2.9*		
	budding		2.8*	11.4**	3.1*
	flowering	20.2**,[a,b]	29.3**	22.6**	27.7**
	physiological maturity				5.2**
Minimum temperature	six leaves	5.9*	4.1*	9.0**	
	budding		6.5**	4.6*	4.0*
	flowering				
	physiological maturity				5.1**
Mean temperature	six leaves		4.2*		
	budding		5.5**	13.0**	
	flowering	17.0**	22.9**	15.3**	24.9**
	physiological maturity				10.1**
Precipitation	six leaves		3.1*	4.6*	
	budding		5.2**	16.2**	
	flowering	20.4**	25.6**	13.0**	15.2**
	physiological maturity				8.3**
Sunshine hours	six leaves				11.7**
	budding			13.7**	5.8**
	flowering	12.1**	17.5**	11.7**	16.1**
	physiological maturity		7.8**		4.9**
Relative air humidity	six leaves				19.8**
	budding				
	flowering	29.2**	44.9**	34.1**	24.2**
	physiological maturity		3.2*	7.3*	

[a] relative contribution of environmental variable to the interaction term

[b] each term has two degrees of freedom

*$P < 0.05$; **$P < 0.01$

Studying the effect of sowing date on seed yield in sunflower, Barros et al. (2004) came to the conclusion that rainfall in the later stages of sunflower development under Mediterranean conditions (in the South of Portugal), mostly contributed to year by sowing date interaction. Sunflower seed yield was influenced by solar radiation, which is received through the crop canopy. The reduction of solar radiation leads to a reduction of seed and oil yield in sunflower, as stated by Faramarzi and Korshidi (2008). Chimenti and Hall (1992) reported that water deficit during flowering and seed filling were critical for the formation of sunflower yield, since the lack of moisture during this period reduced the supply with assimilates required for reproductive growth and yield. De la Vega et al. (2001) found that minimum temperature and photoperiod played an important role in interaction for oil yield in sunflower.

Application of FR model on the four sunflower quantitative traits from the agronomic trial lead to physiological insight into environmental causes of the hybrid by sowing date interaction. The obtained results highlighted the importance of the relative air humidity as the most important variable for differential response of hybrids to the changes of sowing date. Furthermore, physiological maturity followed by flowering was observed as the most sensitive growth stage during the sunflower development

By planting sunflower earlier, plants are able to get full benefit of soil moisture and nutrient during the extended growing season, and obtain maximum yield and yield components.

ACKNOWLEDGMENTS
This work was supported by the Ministry of Science and Technological Development of the Republic of Serbia (Research Grant: TR-31025).

REFERENCES

Barros, J.F.C., de Carvalho M., and G. Basch. 2004. Response of sunflower (*Helianthus annuus* L.) to sowing date and plant density under Mediterranean conditions. Europ. J. Agron. 21:347-356.
Brancourt-Hulmel, M., Denis, J.B., and V. Biarnes-Dumoulin. 1997. Comparison of joint regression, AMMI model and factorial regression for efficiency and parsimony in plant breeding. p. 81-86. In: P. Krajewsky and Z. Kaczmarek (eds.). Advances in Biometrical Genetics. Proceedings of the Tenth Meeting of the EUCARPIA Section Biometrics in Plant Breeding. Poznan, Poland. 14-46 May 1997. Institute of Plant Genetics, Polish Academy of Sciences. Poznan, Poland.
Chimenti, C.A., and A.J. Hall. 1992. Sensibilidad del numero de frutos por capitulo de girasol (*Heliainthus annuus* L.): a cambios en el novel de radiation durante la ontogenia del cultivo. Actas Reunion Argentinas de Fisiologia Vegetal. Huerta Grande, Cordoba, 27-28.
de la Vega, A.J., Chapman, S.C., and A.J. Hall 2001. Genotype-by-environment interaction and indirect selection for yield in sunflower. I. Two-model pattern analysis of oil and biomass yield across environment. Field Crops Res. 72:17-38.
Denis, J.B. 1988. Two-way analysis using covariates. Statistics 19:123-192.
Faramarzi, A., and M.B. Khorshidi 2008. Planting date effect on yield and yield components of sunflower in Mizaneh region. Proc. 17th international Sunflower Conf., Cordoba, Spain, 325-328.
R Development Core Team, 2009. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, http://www.R-project.org.
Schneiter, A.A., and J.F. Miller.1981. Description of sunflower growth stages. Crop Sci. 21:901-903.
van Eeuwijk, 1996. Between and beyond additivity and non-additivity: The statistical modeling of genotype-by-environmental interaction in plant breeding. PhD thesis, Wageningen Agricultural University, Wageningen, Netherlands.
van Eeuwijk, F.A., Denis, J.B., and M.S. Kang.1996. Incorporating additional information on genotypes and environments in models for two-way genotype by environment tables. p.15-49. In: M.S. Kang, and H.G. Jr. Gauch (eds.), Genotype by environment interaction: new perspectives. CRC Press, Boca Raton, Fl, USA.
Vargas, M., Crossa, J., van Eeuwijk, F.A, Sayre, K.D., and M.P. Reynolds. 2001. Interpreting treatment × environment interaction in agronomy trials. Agron. J. 93, 949-960.