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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.

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Influence of seed processing on sunflower seed qualities

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ABSTRACT

- In sunflower seed production it is important to obtain a high quality end product. This depends not only on field conditions and cultural practices applied but also on seed processing. During processing, seed grades are obtained which differ in size and specific weight. This procedure improves seed quality in comparison with unprocessed seed. The objective of this study was to assess the effect of seed processing and grading on seed quality parameters in different sunflower genotypes.
- Effects of four seed grades (1. large and heavy, 2. large but light, 3. small and heavy, 4. small and light) on 1000-seed weight, husk, oil and protein contents, energy of germination, and germination rate were examined in three sunflower genotypes developed at Institute of Field and Vegetable Crops in Novi Sad. The seeds were first separated through sieves into large (3.5-5.0 mm) and small (2.6-3.5 mm) grades, which were then divided into heavy and light grades on a gravity table.
- The analysis of variance showed that seed grading had a highly significant effect on all parameters under study except the energy of germination. Effects of genotype and genotype x grade interaction were also highly significant. As expected, the average 1000-seed weight was higher in the larger and heavier seeds. The husk content, however, was increased in the large but light seeds (the highest average value was found in grade 2, the lowest in grade 3, 23.75% and 22.13%, respectively). The average oil content was increased in small and heavy seeds. The highest average oil content was found in grade 3, the lowest in grade 2 (42.45% and 40.47%, respectively). The protein content behaved in the opposite way, but only with respect to seed size. The small seeds had higher average germination rate and energy of germination than the large seeds, whereas differences in specific weight were not of major significance (the smallest average germination rate was found in grade 1, the highest in grade 4 (71.62% and 75.44%, respectively).
- Separation into grades showed a greater impact on seeds with lower quality, for example germination in Hybrid 1 varied from 47.25% to 59.75%, while in Hybrid 2 it varied from 94.25% to 97.25%, which was not significant. The tested genotypes reacted differently to seed grading - in some cases larger seeds had better germination rate, in others the situation was opposite.
- In light of the large differences in the impact of seed processing on seed quality of the different genotypes, it was concluded that it is important to know the characteristics of each genotype and how to adjust the seed processing parameters, especially in the case of seeds with lower qualities.

Key words: parameters of quality – seed – seed processing – seed grades – sunflower

INTRODUCTION

Seed processing is an important part of the sunflower seed production process through which seed quality can be significantly enhanced, but there is always a risk of impairing seed quality through mismanagement. Most important separations in the course of seed processing are linked with the geometric characteristics of seed (length, width, thickness), specific weight, and, in recent times, the optical properties of seed (Prole et al., 2010). Germination rate and energy are increased by seed processing (Šimić et al., 2009), especially if bottom sieves have cylindrical perforations of 2.5 mm (Munde et al., 2005). Some authors claim that large seeds have high germination rate (Robinson, 1974; Kaya and Day, 2008), but others have found that small seeds have better germination (Marinković et al., 1994; Farahani, 2011). Large seeds usually have thick hulls and are not well filled (Knowles, 1978) and the hull to seed ratio was found to be increased (Zimmerman and Zimmer, 1978). Large seeds have a thick pericarp not because of differences in cell number, but due to the large size of the scleroid cells in the middle layer. Water transfer to the seed is more efficient in small seeds, however, small seeds do not have better germination than large ones, they only germinate faster (Hernandez and Orioli, 1985). Low quality of large sunflower seeds results from a disturbance during the process of seed development, which can be connected with the membrane function (Saranga et al., 1998).

Correlations between oil content, protein content, germination rate and seed size are interpreted differently in the literature. Radić et al. (2009) found a positive correlation between germination rate and oil content and a negative correlation between germination rate and protein content. Lipid concentration was higher in small seeds than in big ones (which were poor germinators), whereas protein content was similar for all seeds (Reuzeau et al., 1992). Lofgren (1978) found a negative correlation between oil concentration and sunflower seed size, while Bajaj et al. (2009) clamed that the correlation between protein content and germination rate can be positive or negative depending on environmental conditions.

The aim of this study was to examine the influence of seed processing and grading on seed quality parameters in different sunflower genotypes.

MATERIALS AND METODS

Seed material for this study was produced in Serbia, by growers contracted by Institute of Field and Vegetable Crops. The contracted seed plots received all agro-technical measures required by the technology of sunflower hybrid seed production. Three NS hybrids were used in the study: hybrid 1, hybrid 2 and hybrid 3, which were produced in 2010. In the case of the last hybrid, we also used the seed produced in 2007, which was designated as hybrid 3/1. The hybrids were conventional Novi Sad oil hybrids. Old seed was deliberately used because of its inferior seed quality.

All seed was processed in the processing plant of Institute of Field and Vegetable Crops. After reception, the seed was pre-cleaned with a *Cimbria Heid* type Delta 145 pre-cleaner which had bottom sieves with cylindrical perforations of 2.6 mm and top sieves with circular perforations 8 mm in diameter. The seed was graded with a *Cimbria Heid* type ZS 500 cylinder grader, with the screens set to make two grades, small seeds of 2.6 -3.5 mm and large seeds of 3.5-5.0 mm. After that, both grades were run through a *Cimbria Heid* type GA 200 gravity table to separate heavy from light seeds. In that way we obtained four different seed grades:

Grade I   3.5–5.0 mm, heavy,
Grade II   3.5–5.0 mm, light,
Grade III   2.6–3.5 mm, heavy,
Grade IV   2.6–3.5 mm, light.

Thousand-seed weight was determined in eight replications, each replicate containing 100 seeds, and the results were expressed to the nearest 0.01g (ISTA, 2007). Husk content was determined in air-dry seeds and expressed in percents. Oil content was determined in naturally dried seeds using nuclear magnetic resonance (NMR), and it was expressed in percents. Protein content was determined by the standard Kjeldahl method, using VAP-50-Gerhardt apparatus. Germination energy and germination rate were determined by standard methods (ISTA, 2007).

The obtained results were statistically processed for *ANOVA* of the two-factorial trial, using the statistic package *STATISTIKA 10*. The least significant difference (LSD) test at significance levels of 1% and 5 % (Mead et al., 1996) was used to establish the significance of the obtained results.

RESULTS

The analysis of variance showed that, on average, seed grade exhibited highly significant effects on all examined parameters, except for germination energy. Effects of hybrid and grade x hybrid interaction were also highly significant.

The highest average 1000-seed weight was, quite expectedly, found in grade I, the lowest in grade IV. All differences were highly significant (Table 1). The highest 1000-seed average weight was recorded in hybrid 3, the lowest in hybrid 2. Hybrid 1 and hybrid 3 were not significantly different. The differences between seed grades were highly significant in all hybrids.

The highest average portion of husks was found in grade II, the lowest in grade III. The difference was statistically significant (Table 2). The large seeds had a significantly higher average portion of husks than the small seeds. In the case of the seeds of the same size, the lighter seeds had a higher portion of husks than the heavier seeds (the difference was non-significant with the large seeds, and highly significant with the small seeds). Hybrid 1 had the highly significantly highest average portion of husks, hybrid 2 the smallest portion which was significantly lower than that of hybrid 3 a highly significantly lower than those of other hybrids. Hybrids 1 and 2, the large seeds had a significantly higher portion of husks than the small seeds. In the category of large seeds, the heavy seeds had a higher portion of husks than the light seeds. The situation was reverse in the category of small seeds, mainly without significant differences. In hybrid 3, regardless of seed size, the light seeds had a significantly higher portion of husks than the heavy seeds. Considering the same weight categories, the small seeds had a larger portion of husks than the large seeds, but the differences were not significant.

Table 1. Effect of seed processing on 1000-seed weight (g) in 3 sunflower hybrids

Grade (G)	Hybrid (H)				Average
	1	2	3	3/1	(G)
I	64.54	56.01	63.74	62.16	61.61
II	57.96	52.49	58.64	57.34	56.61
III	51.58	41.88	51.00	49.79	48.56
IV	45.35	38.96	46.38	43.30	43.50
Average (H)	54.86	47.33	54.94	53.15	52.57
	G	H		G x H	
$LSD_{0.05}$	0.47	0.47		0.94	
$LSD_{0.01}$	0.63	0.63		1.25	

F-value	G	H	GH
	2418.73^{**}	474.93^{**}	7.64^{**}

Table 2. Effect of seed processing on husk content (%) in 3 sunflower hybrids

Grade (G)	Hybrid (H)				Average
	1	2	3	3/1	(G)
I	25.85	23.65	21.95	22.10	23.39
II	25.05	23.00	23.20	23.75	23.75
III	22.40	21.20	22.35	22.50	22.13
IV	22.50	21.30	23.40	24.10	22.83
Average (H)	23.95	22.29	22.73	23.11	23.03
	G	H		G x H	
$LSD_{0.05}$	0.42	0.42		0.83	
$LSD_{0.01}$	0.56	0.56		1.11	

F-value	G	H	GH
	23.87^{**}	23.36^{**}	15.52^{**}

The highest average oil content was recorded in grade III, the lowest in grade II. The differences were highly significant (Table 3). The large seeds had a highly significant average oil content compared with the small seeds. Considering the weight categories, the light seeds had a lower oil content than the heavy seeds, with non-significant difference between the values. Hybrid 3/1 had the highest average oil content, hybrid 1 the lowest, with significant or highly significant differences between the genotypes.

Table 3. Effect of seed processing on oil content (%) in 3 sunflower hybrids

Grade (G)	Hybrid (H)	Average

	1	2	3	3/1	(G)
I	36.21	42.37	41.60	43.16	40.83
II	37.26	42.03	40.37	42.22	40.47
III	38.88	44.08	41.95	44.88	42.45
IV	40.39	43.42	41.15	43.93	42.22
Average (H)	38.18	42.97	41.27	43.55	41.49
	G	H		G x H	
$LSD_{0.05}$	0.44	0.44		0.88	
$LSD_{0.01}$	0.59	0.59		1.17	

F-test	G	H	GH
	41.19^{**}	245.17^{**}	7.41^{**}

In all hybrids within the same weight category, the small seeds had higher oil content than the large ones, with occasional highly significant differences. In the case of hybrid 1, within the same size category, the light seeds had a higher oil content than the heavy ones, The situation was reverse in the other hybrids, with differences that were generally non-significant.

The highest average protein content was found in grade I, the lowest in grade III. The differences between the genotypes were mostly highly significant (Table 4). The large seeds had a higher protein content than the small ones. In the former category, the heavier seeds had a higher protein content, while the latter category had the reverse situation. Hybrid 1 achieved the highest average protein content, hybrid 3/1 the lowest, the difference was highly significant. In most cases, the large grades had a higher protein content than the small ones and the heavy grades generally had a higher content than the light ones.

Table 4. Effect of seed processing on protein content (%) in 3 sunflower hybrids

Grade (G)	Hybrid (H)				Average
	1	2	3	3/1	(G)
I	24.78	21.11	23.81	20.36	22.52
II	23.41	20.96	22.92	19.25	21.63
III	22.14	19.77	22.46	18.89	20.82
IV	21.71	19.24	22.21	22.51	21.42
Average (H)	23.01	20.27	22.85	20.25	21.60
	G	H		G x H	
$LSD_{0.05}$	0.28	0.28		0.56	
$LSD_{0.01}$	0.37	0.37		0.75	

F-test	G	H	GH
	51.15^{**}	245.43^{**}	33.63^{**}

Grade III had the highest average germination energy, grade I the lowest. A significant difference was found only in this case (Table 5). The small seeds had a higher average germination energy than the large seeds. In the category of large seeds, the light seeds had a higher germination energy than the heavy ones. The situation was reverse in the category of small seeds, wits non-significant differences in both categories. Hybrid 2 had the highest average germination, hybrid 1the lowest. All differences were highly significant. In the small-seed category in hybrids 1 and 2, the heavy seeds had a higher germination energy than the light ones. The situation was reverse in the other hybrids. In the large-seed category of hybrids 2 and 3, the heavy seeds had a higher germination energy than the light ones. The situation was reverse with the other hybrids.

Table 5. Effect of seed processing on germination energy (%) in 3 sunflower hybrids

Grade (G)	Hybrid (H)				Average
	1	2	3	3/1	(G)
I	48.75	96.00	77.00	57.00	69.69
II	53.00	94.25	74.00	61.00	70.56
III	45.75	97.00	78.75	69.25	72.69
IV	41.75	91.75	80.25	72.25	71.50
Average (H)	47.31	94.75	77.50	64.88	71.11
	G	H		G x H	
$LSD_{0.05}$	2.42	2.42		4.84	

$LSD_{0.01}$	3.23	3.23		6.47	
F-test	G	H	GH		
	2.29^{ns}	555.88^{**}	9.07^{**}		

Grade IV had the highest average germination rate, grade I the lowest. Highly significant differences were recorded between the former grade and the two small grades (Table 6). In several instances, the small grades had significantly higher germination rates than the large ones. Within the small grades, the light grade had a higher average germination rate than the heavy one, but the difference was not significant. Hybrid 2 had the highest average germination rate, Hybrid 1 the lowest, with highly significant differences among the hybrids. With the exception of Hybrid 1, the small grades had a higher germination rate than the large ones. In the case of the small grades of Hybrids 1 and 2, the heavier grade had a higher germination rate. The situation was reverse with the other hybrids and grades. In the case of the larger grades of Hybrid 2 and 3, the heavier grade had a higher germination rate, and the situation was reverse with the other hybrids and grades. The differences were generally non-significant.

Table 6. Effect of seed processing on seed germination rate (%) in 3 sunflower hybrids

Grade (G)	Hybrid (H)				Average
	1	2	3	3/1	(G)
I	54.00	96.75	78.00	57.75	71.62
II	59.75	94.25	77.00	61.00	73.00
III	53.75	97.25	79.25	71.00	75.31
IV	47.25	94.75	83.00	76.75	75.44
Average (H)	53.69	95.75	79.31	66.62	73.84
	G	H		G x H	
$LSD_{0.05}$	2.33	2.33		4.66	
$LSD_{0.01}$	3.11	3.11		6.22	
F-test	G	H	GH		
	5.15^{**}	482.39^{**}	12.30^{**}		

DISCUSSION

Sunflower has its specific characteristics that have a significant impact on seed quality. Sunflower head flowers in rings, the flowering lasts for several days so that we have seeds of different age in the same head. Due to differences in the length of grain filling, different position in the head, and various seed sizes caused by competition, seeds from the same sample may differ significantly in quality and other parameters (Atlagić, 1989; Miklič et al., 2004). Typically, outer seeds are larger than those from the inside, and especially those from the center of the head. If, for example, unfavorable conditions for pollination occur during the flowering of the third and fourth ring, which causes poorer fertilization, the pollinated seeds in this region of the head will become very large, primarily due to a lack of competition. In the course of seed processing, various seed grades are formed and seeds from the same seed head become separated. Seed grading is important for farmers because it simplifies the procedure of adjustment of seeder machines, and also, it gives an opportunity to improve seed quality.

Considering the fact that the content of husks affects the germination rate, it is important that this study confirmed that large seeds have on average an increased husk content, which is consistent with the findings of Knowles (1978) and Zimmerman and Zimmer (1978). However, the confirmation comes only from hybrids 1 and 2, but not from hybrid 3. We assume that the differences in germination rate found between the various grades were mostly due to differences achieved among the seed grades in husk content. The grades with lower husk contents had higher germination rate and germination energy. Regarding the oil content, the situation was reverse in relation to the husk content. The highest oil content was found in grade III (small and heavy seeds), the lowest in grade II (large and light seeds). This was in agreement with the results of Vollman and Rajčan (2009), who argued that the high oil content in the modern hybrids was first achieved indirectly, via the reduction of the husk content. Increased oil content in small seeds was also recorded by Lofgren (1978) and Reuzeau et al. (1992).

The large seeds had a higher average protein content than the small seeds, but the impact of weight was not the same for the large and small seed grades. Differences were registered even for the same hybrid (3 and 3/1), not only in the average values of protein content (which was expected in light of the different impact of environmental factors in different production years), but also between the corresponding grades in the hybrid coming from different years. So, hybrid 3/1 had a highly significantly larger portion of proteins in grade IV compared with grade III, and hybrid 3 had a reverse situation. Similar differences caused by environmental factors were reported by Bajaj et al. (2009).

Undoubtedly, most important results in the practical application of seed grading are improvements in germination rate and energy of individual seed lots. On average, the small seeds had a higher germination energy and rate than the large seeds, which is consistent with the results of Marinkovic et al. (1994) and Farahani (2011), but not with the results of Robinson (1974) and Kaya and Day (2008). The impact of seed weight is certainly more difficult to explain because different hybrids behave differently. In the case of the seed with good germination (hybrids 2 and 3), there were no significant differences in germination rate between the seed grades, however, highly significant differences were found in the hybrids which have low seed germination (hybrids 1 and 3/1). Obviously, seed processing may render grades that meet quality standards, which secures economic benefits from seeds that would otherwise have to be rejected. The differences between hybrid 3 and 3/1 indicate that, even within the same hybrid, seeds from the same lot differed in vitality when left in storage to deteriorate with age. This phenomenon should be recognized and tried to be exploited by applying grading by weight and size, as in our case, or by applying more recent grading methods such as optical separation or separation based on electrical conductivity.

Due to the large difference in the impact of seed processing on seed quality in different genotypes, it is necessary to know the characteristics of each genotype and how to adjust the seed processing parameters, especially in the case of seeds with lower qualities.

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