UDC 575:633
DOI: 10.2298/GENSR1103427M
Original scientific paper

GERMINATION ENERGY AS A PARAMETER OF SEED QUALITY IN DIFFERENT SUNFLOWER GENOTYPES

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Mrđa J., J.Crnobarac, N. Dušanić, S. Jocić, and V. Miklić (2011): *Germination energy as a parameter of seed quality in different sunflower genotypes* - Genetika, Vol 43, No. 3, 427-436.

Using the standard method, we studied the germination energy of seed of seven different sunflower genotypes (five hybrids and two cytoplasmically male sterile female lines) developed at the Institute of Field and Vegetable Crops in Novi Sad. The seed was treated with the fungicides benomil, metalaxyl and fludioxonil and the insecticides thiamethoxam and imidacloprid and kept for a year in a storage facility. Analysis of variance showed that there were highly significant differences among the genotypes, chemical treatments, and storage periods. Highly significant differences were also recorded for all the interactions among the factors studied. On average, the highest germination energy was found in the hybrid H2

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(93.45%), whose values of this parameter were highly significantly higher than those of the rest of the genotypes, except for the hybrid H1. Also, each of the hybrids had highly significantly higher germination energy than either of the two lines, and the differences among the hybrids themselves were highly significant. Looking at the chemical treatments, the control had the highest germination energy by a highly significant margin (80.39%). The largest difference was observed in relation to the treatments with insecticides (5.48 and 9.56%). These treatments had highly significantly lower values of germination energy than those involving fungicides. Germination energy increased in the first nine months of storage, peaking at 81.29%. After that, there was a sharp drop to 68.94% after 12 months of storing. Differences among the different storage periods were all highly significant except for that between six and nine months of storage, which was not statistically significant.

Key words: chemical treatment, genotype, germination energy, length of storage, sunflower seeds

INTRODUCTION

The sunflower (genus *Helianthus*) is one of the most important oilseed crops on a global level, grown on a total of over 22 million hectares worldwide (ŠKORIC *et al*., 2008). In Serbia, sunflower is the most important oil crop with an annual acreage that has ranged from 146,000 to 201,000 ha in the past 20 years (SGRS, 2010). As the modern methods of agricultural production took root in the country, crop growers became increasingly aware of the importance of high quality seeds capable of quick and uniform germination in different environmental conditions.

The main goal of seed production is to obtain seeds of high quality that have good physiological, biochemical, and phytopathological characteristics (MILOŠEVIĆ *et al.*, 2010). The seed is one of the most important factors determining the viability of a plant. Use of good-quality, healthy, large, and viable seeds is of utmost importance in the maintenance of on optimum plant density in a crop (AHMAD, 2001). Indicators of seed vitality (germination energy and germinability as well as emergence in field conditions) play a direct role and are the key factor in determining plant number per hectare, which is one of the three main components of yield. Seed quality also affects the rate and uniformity of emergence as well as the rate of initial plant growth. The age by which seed maintains its ability to germinate and can be used for planting and production depends on its genetic makeup and the cultivar (TOMIĆ *et al.*, 1998). Seed longevity is especially important in oil crops. The weather conditions can have great influence on seed quality during the growing season (MIHAILOVIĆ *et al.*, 2002). Also, when seeds are kept at higher temperatures and higher relative humidity, their quality may become reduced (ŠIMIĆ *et al.,* 2006). The loss of vigor in sunflower seeds after four years of storage can be as high as 50%, and greater losses have been recorded at higher temperatures (ŠIMIĆ *et al.*, 2005). In the course of storage, CRNOBARAC and MARINKOVIĆ (1994) observed significant differences in germinability among different sunflower genotypes. A decrease of seed oil content during storage has been reported as well (VRBAŠKI *et al.*, 1996).

From the economic and environmental points of view, treating seeds with fungicides and insecticides is a good way of protecting field crops from diseases and pests in the early stages of plant development. When pesticide is applied directly onto the seeds, considerably smaller amounts of the chemical are needed than in the case of foliar or soil treatments across the entire field or in strips (MARJANOVIĆ-JEROMELA *et al.*, 2008).

For downy mildew problem solution can be genetically (PANKOVIĆ *et al.*, 2007) or with seed chemical treatment. The most commonly used fungicide for the treatment of hybrid sunflower seed is metalaxyl, which controls the causal agent of downy mildew (*Plasmopara halstedii*). Metalaxyl is most often used in combination with another, systemic fungicide (MIKLIČ *et al.*, 2008; SHIRSHIKAR, 2005). In Serbia, the use of insecticides for sunflower seed treatment is of more recent date and does not have such a long tradition as the use of fungicides for the same purpose. Detailed analysis of the effects of particular insecticides can be found in SEKULIĆ *et al.* (1998). STANKOVIĆ and MEDIĆ (1997) studied germination energy and germinability in sunflower and maize seeds treated with insecticides and found that seed germinability decreased in all the treatments, although the decrease was not significant in every case. The same authors noted that the insecticides carbosulfan and imidacloprid had the least negative impact on seed quality and that all the chemicals used had a depressive effect after one year of storage.

The objective of this paper was to determine the effects of different chemical treatments and length of storage on germination energy in different sunflower genotypes.

MATERIALS AND METHODS

Our research was done on the seed of five sunflower hybrids (H1, H2, H3, H4 and H5) and two cytoplasmically male sterile female lines (L-1 and L-2), all of which were developed at the Institute of Field and Vegetable Crops in Novi Sad during 2007 and 2008. The fungicides benomil, metalaxyl and fludioxonil and the insecticides thiamethoxam and imidacloprid were used in the study, which included the following treatments: control (untreated seed); benomil + metalaxyl (B+M); fludioxonil + metalaxyl (F+M); fludioxonil + metalaxyl + thiamethoxam (F+M+T); and fludioxonil + metalaxyl + imidacloprid (F+M+I).

All of the seed was treated just before sowing. The rates were as follows: a.i. benomil - 300g/100kg seed; a.i. metalaxyl and a.i. fludioxonil - 300ml/100kg seed; and a.i. thiamethoxam and a.i. imidacloprid - 1000ml/100kg seed. Besides the above chemicals, the following was also applied to the seeds as part of the treatment: dye (300ml/100kg seed), gloss (150g/100kg seed), and water (500ml/100kg seed). In order to investigate the effects of the length of storage on germination energy, the seed was kept in a storage facility used for storing commercial seeds in which the storage conditions were dependent on external, weather conditions. The seed was kept in paper bags. The seeds from the storehouse were planted at three-month intervals as follows: 1. initial testing using freshly treated seeds; 2. planting after three months of storage, 3. planting after six months of storage, 4. planting after nine months of storage; and 5. planting after 12 months of storage. The testing was performed at the Laboratory for Seed Testing of the Institute of Field and Vegetable Crops in Novi Sad. Germination energy was determined using the standard laboratory method used for such purposes. In each genotype, 4 x 100 seeds were tested. Wet sterilized sand was used as the medium and the seeds were incubated in a germination chamber at a temperature of 25ºC and 95% relative humidity. Germination energy was assessed on the fourth day by counting the number of typical seedlings (ISTA, 2004).

The data was statistically processed by three-way ANOVA (*split–split-plot*) with genotype as Factor A, chemical treatment as Factor B, and storage length as Factor C. The processing of the data was done using a statistical software package and the least significant difference test (LSD) with significance levels of 1% (MEAD *et al*., 1996).

RESULTS AND DISCUSSION

Tables 1, 2 and 3 shows the effects of the genotype, chemical treatment, and storage length on the germination energy of the seed. The results of ANOVA showed that the three factors as well as all the interactions had a highly significant effect on GE ($P<0.001$).

Tab. 1 Effect of genotype and interaction with the same chemical treatment and a different genotype on sunflower seed germination energy (%)

Chemical treatment (B)	Genotype (A)						
	L1	L2	H1	H2	H3	H4	H5
K	53.45	57.65	92.60	94.10	92.45	85.60	86.90
B+M	50.35	46.00	92.80	92.95	88.10	83.75	87.65
F+M	51.7	48.05	93.25	94.45	91.90	83.95	84.40
F+M+T	47.35	40.35	91.40	94.50	84.50	81.55	84.75
F+M+I	43.15	36.15	89.65	91.25	85.85	72.40	77.35
Mean (A)	49.20 e	45.64 f	91.94 a	93.45 a	88.56 b	81.45 d	84.21 c
	Genotype			Chemical treatment x Genotype			
$LSD_{0.01}$	2.07			3.30			

Among the genotypes, the highest average GE was found in the hybrid H2 (93.45%). This average was highly significantly greater than those of all the other genotypes except for the hybrid H1 (Table 1). The difference in average GE was the highest relative to the two lines – 44.25% with L1 and 47.81% with L2. Another point of note was that the hybrids invariably had significantly higher GE than the lines and that the differences among the hybrids other than H2 were all highly significant. The lines L-1 and L-2 were chosen for the study because they often had had problems with this parameter of seed quality. The idea was to determine what effects the factors under study have on this kind of seed material as compared to hybrids in which there are no such problems and to thus highlight the response of individual genotypes. Therefore, the differences observed in the present study are not differences between lines and hybrids in general but between specific lines and commercial hybrids. Genotype effects on stored seeds have also been reported by CRNOBARAC and MARINKOVIĆ (1994), who found that there were significant differences in seed germinability among different sunflower genotypes during storage. Similarly, ĐUKANOVIĆ (1999) found that the genotype was the most important factor in the alteration of maize seed characteristics that took place during storage in self-pollinated lines and hybrid combinations of this crop.

Tab. 2 Effect of storage length, and interactions with the same storage length and a different genotype on sunflower seed germination energy (%)

Length of storage (C)	Genotype (A)							Mean (C)
	L1	L2	H1	H2	H3	H4	H5	
0	44.50	41.20	90.50	90.50	89.70	83.75	79.75	74.27 c
3	53.20	45.80	92.85	93.20	85.95	79.15	86.85	76.71 b
6	53.05	53.85	94.90	96.45	90.25	84.70	90.55	80.54 a
9	54.10	52.65	95.95	96.75	93.85	87.40	88.35	81.29 a
12	41.15	34.70	85.50	90.35	83.05	72.25	75.55	68.94 d
	Storage length				Storage length x Genotype			
$LSD_{0.01}$	1.38				3.78			

GE was highly significantly greater in the control (80.39%) than in any of the treatments (Table 3). The difference was the largest between the control and the treatments with insecticides (5.48 and 9.56%), which also had highly significantly lower GE values compared to the treatments with fungicides. A negative influence of insecticide on sunflower seed quality has also been reported by MRĐA *et al.* (2008), while KUHAR *et al.* (2002) cite cases of reduced germinability in sweet corn seeds as a result of imidacloprid use. BAČA *et al.* (2008), on the other hand, did not find any negative influence of the use of imidacloprid and thiamethoxam on maize seed germinability in a four-year study. IVANOVIĆ *et al*. (1994) studied the influence of fungicide plus insecticide combinations in eight different maize genotypes and found that the same chemical could have a depressive effect in one genotype but a positive one in another. KASHYPA *et al.* (1994) determined that insecticide use extended the period of germination and reduced seed vigor.

Looking at the duration of storage, we can see that GE peaked nine months after the start of storage (81.29%), after which there was a sharp decrease to 68.94% after 12 months of storing. The differences between all storage treatments were highly significant, with the exception of that between six and nine months (Table 2). Similar results were obtained by RAJIĆ *et al*. (2005), who found that the GE and germinability of sugar beet seeds was significantly increased six months after harvesting. TATIĆ *et al*. (2008), furthermore, determined that the quality of soybean seeds was significantly influenced not only by the length of storage but by the method of storing as well. GHASEMNEZHAD and HONERMEIER (2009), on the other hand, found that storage duration had no effect on seed GE, which is in opposition to the findings of the present study.

Interactions between the chemical treatment and genotype showed that the GE of the hybrid H2 obtained in the control treatment (94.10%) was highly significantly higher than the GE of any of the other treatments except for those involving H1 and H3 (Table 1).

Tab. 3 Effect of chemical treatment, and interactions with the same storage length and a different chemical treatment on sunflower seed germination energy (%)

Chemical treatment (B)	Length of storage (C) 0	3	6	9	12	Mean (B)
K	77.68	82.11	83.71	84.21	74.25	80.39 a
B+M	75.36	79.32	82.29	82.14	67.75	77.37 b
F+M	77.29	79.39	81.68	81.04	71.82	78.24 b
F+M+T	72.18	73.54	78.64	80.93	69.29	74.91 c
F+M+I	68.86	69.21	76.36	78.14	61.57	70.83 d
	Chemical treatment			Length of storage x Chemical treatment		
$LSD_{0.01}$	1.15			2.98		

In the other treatments, H2 also had the highest values. The line L2 had the smallest GE values by a highly significant margin in all the chemical treatments except for the check, in the case of which the GE of L2 was highly significantly higher than that of the line L1 (by 4.20%). Storage length by genotype interactions revealed that the GE values of the hybrids were highly significantly higher than those of the lines. H2 had highly significantly higher GE than H1 after 12 months of storage (by 4.85%), and the same was the case when comparing H2 and the rest of the hybrids with all storage periods. GE of L1 became highly significant after 3 and

12 months of storing. GE values were the highest in the control treatment with all lengths of storage and the difference relative to treatments involving insecticides was highly significant. Similar findings indicating a negative influence of insecticide use on rapeseed seed quality were reported by MARJANOVIĆ-JEROMELA *et al*. (2008).

CONCLUSION

Our study has shown that the genotype, chemical treatment, and storage period as well as all their interactions have a highly significant effect on GE.

The highest GE was found in the hybrid H2 and the lowest in L2. The hybrids used in the study had highly significantly higher GE than the lines, and the differences in GE among the hybrids themselves were highly significant as well.

GE values in the check treatment were highly significantly higher than those in the treatments involving the use of chemicals, and the differences were the largest when insecticides were used. GE in these treatments was highly significantly lower than GE in treatments with fungicides.

GE increased until nine months after storage and was reduced after 12 months of storing. The differences among all the treatments were highly significant except for that between six and nine months of storage.

ACKNOWLEDGEMENTS

This study was supported by the Ministry of Education and Science, Republic of Serbia trough the Project TR-31025.

Received November 19th, 2010
Accepted November 17th, 2011

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ENERGIJA KLIJANJA KAO PARAMETAR KVALITETA SEMENA RAZLIČITIH GENOTIPOVA SUNCOKRETA

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I z v o d

U radu je standardnom metodom ispitivana energija klijanja semena sedam različitih genotipova suncokreta, dve citoplazmatski muško sterilne forme linije majke i pet hibrida, stvorenih u Institutu za ratarstvo i povrtarstvo iz Novog Sada. Seme je tretirano fungicidima: benomil, metalaksil i fludioksonil, kao i insekticidima: tiametoksam i imidakloprid i čuvano godinu dana u skladištu. Analizom varijanse utvrđene su visoko značajne razlike između ispitivanih genotipova, hemijskih tretmana i dužina čuvanja. Ustanovljene su i visoko značajne razlike za sve interakcije ispitivanih faktora. U proseku, najveću energiju klijanja imao je hibrid H2 (93,45%), čija je vrednost bila je statistički visoko značajno veća nego kod ostalih genotipova, osim u odnosu na vrednost kod hibrida H1. Takođe, može se zaključiti da su svi hibridi imali visoko značajno veću energiju klijanja semena od linija kao i da su između ostalih ispitivanih hibrida razlike bile visoko značajne. Kod hemijskih tretmana energija klijanja u kontroli bila je visoko značajno najveća i iznosila je 80,39%. Najveća razlika bila je u odnosu na tretmane sa insekticidima (5,48% i 9,56%). Vrednost ispitivanog parametra kod ovih tretmana bila je i visoko značajno manja u odnosu na vrednosti dobijene kod tretmana sa fungicidima. Energija klijanja povećavala se sve do devetog meseca kada je i zabeležena najveća vrednost (81,29%), a zatim dolazi do naglog pada nakon dvanaest meseci čuvanja gde je zabeležena vrednost od 68,94%. Između svih ispitivanih varijanti su bile visoko značajne razlike, jedino razlika između šest i devet meseci čuvanja nije bila statistički značajna.

Primljeno 19. XI. 2010.
Odobreno 17. XI. 2011.