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EFFECT OF LOCATION AND HARVESTING DATE ON YIELD AND 1,000-SEED WEIGHT OF DIFFERENT SUNFLOWER GENOTYPES

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ABSTRACT

The effect of harvesting date on yield and 1,000-seed weight in sunflower genotypes was studied in India and Serbia. Harvest period began seven days after pollination and was performed on 10 occasions. The genotypes had higher seed yields per head and larger 1,000-seed weights in Serbia. The highest seed yield per head was produced by the genotype Ha-121. The yield grew gradually until the midpoint of the period studied, but only the first three dates produced yields significantly lower than those from the dates after the three earliest ones. In Serbia, there was also a significant decrease of yield on latest harvesting dates. The genotype Ha-121 had the largest average of 1,000-seed weight. Harvesting dates revealed a quadratic regression, with some maximum yields being recorded at seed moisture levels of 40% or more, especially in Serbia. At both sites, 1,000-seed weight grew for the most part in a linear fashion until the very last of the harvesting dates. Some genotypes could be harvested very early without any major impact on 1,000-seed weight and yield, but the significant influence of location should always be taken into account in cases such as these.

Key words: sunflower, seed yield, 1,000-seed weight, seed moisture content.

INTRODUCTION

Sunflower breeding and seed production often require earlier harvesting. The growing conditions in Serbia also often make necessary the use of chemical desiccation in order to dry out the green portions of the plant and, by this way, easing the mechanized harvesting. The question arises as to how early could start harvesting sunflower crops without negative impact on yield components and seed quality. 1,000-seed weight is of particular importance in this context, because early harvesting and early desiccation have a greater negative impact on this trait than on seed yield, oil content or seed quality (Miklič, 2001).

Different authors have reported different results on the subject concerned. It has been found that seed yield increases until 40 days after flowering (Cardinali et al., 1982). Seed moisture content (mc) at the moment of harvesting is a still better indicator, however, due to the number of days between flowering and physiological maturity varies depending on environmental conditions. Many authors have studied premature harvesting and have reported a range of mc values at which the highest yields are obtained varies from 31.9% (Mironov, 1967) till 45.0% (Morozov, 1976) and below 60.0% (Semihnenko, 1966). With chemical desiccation, the yield in Serbian conditions will stop dropping when moisture content reaches 44.3%, however desiccation is a less radical measure than early harvesting, since the seed filling process continues for a period of time after the treatment (Miklič, 2001).

According to Chervet and Vear (1989), maximum 1,000-seed weight is achieved with mc at 18-41%, and the value increases at a rate of 0.9-2.2 g/day. Farizo et al. (1980) argues that maximum 1,000-seed weight is obtained when mc is in the 33-41% range. Borisonik et al. (1978) determined that seeds located at the periphery of the head achieve the highest 1,000-seed weight 38 days after flowering at 20-32% mc and that those found in the centre of the head do so 45 days after flowering with mc at 23.4%. Role et al. (1976)

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established that mc decreases daily by 0.88-1.45% (in drought) as well as that 1,000-seed weight increase steadily at a rate of 0.475 g/day (0.28 g/day in drought). In the growing conditions of Serbia, 1,000-seed weight increases at a steady rate until 40 days after flowering (Jančić and Pap, 1983). Although Djakov (1968) argues that environmental conditions during maturation have little effect on 1,000-seed weight, which is already largely predetermined at the end of the seed growth stage, the widely varying results such as those described above can only be a product of different weather conditions or the use of different genotypes in different studies.

The objective of the present study was to determine how the same set of sunflower genotypes performs in different growing conditions with respect to the dynamics of seed filling and the formation of yield and 1,000-seed weight.

MATERIAL AND METHODS

Sunflower genotypes Ha-121, Ha-191 and Ha-171, from the Institute of Field and Vegetable Crops in Novi Sad, were used in the study. A trial with three replicates was carried out at Hyderabad, Andra Pradesh, India in 2007 and at Rimski Šančevi in Serbia the following season. The usual crop management practices were used in the course of the trial.

The first sunflower heads were harvested seven days after flowering and the harvesting continued from that point on at an average interval of 3.5 days. There were 10 harvesting dates in total, and three sunflower heads were taken from each replicate. Mc was determined immediately after harvesting using the low constant temperature oven method, at 103 ±2°C during 17 ±1 hours (ISTA, 2004). Seed yield per head and also determined right after the harvest and the measurements were adjusted to 9% mc. 1,000-seed weights were determined using eight replicates, each of 100 seeds and the results expressed to the nearest 0.01 g (ISTA, 2004).

Data were analysed using three-way ANOVA for a completely randomised design as well as regression analysis. Based on the coefficient of determination, function curves that best fit the original data were selected. The significance of differences was determined by the least significant difference (LSD) test with significance thresholds at $p< 0.1$ and 0.5 (Mead et al., 1996).

RESULTS AND DISCUSSION

The effects of location and harvesting date on seed yield per head of three sunflower genotypes are shown in Table 1. On average, the genotypes had higher seed yields when grown in Serbia (58.21 g). The difference between the yields from India and Serbia was highly significant (44.22 g) and primarily a result of poor pollination at the Indian site. The average seed yield per head produced by the genotype Ha-121 (41.29 g) was significantly the highest among the average yields of Ha-171 and Ha-191. Average yield increased gradually until the fifth harvesting date (45.42 g at 50% average mc). After that, the yield began to drop, with the decreases being statistically significant on some of the dates.

Looking at the location x genotype interaction, the lowest average yield in India was produced by the genotype Ha-171 (10.52 g). This value was highly significantly lower than the ones obtained with the genotype Ha-121 (by 6.58 g). The other differences were not significant. In Serbia, the highest yield per head was found in the genotype Ha-121 (65.48 g), with the difference relative to the other genotypes being significant. The difference between the yields of Ha-191 and Ha-171, on the other hand, was not significant.

Considering the location x harvesting date interaction, the highest average yield per head was obtained on the 10th harvesting date in India (19.06 g, with 10.75% average mc). However, as early as from the fourth harvesting date onwards (16.12 g at 54.17% average mc), there were no significant increases in yield recorded in the experiment. In Serbia, the highest average yield was recorded on the fifth harvesting date (77.18 g at 47.90% average mc), and the difference relative to the other treatments was significant. After the fifth date, the yield dropped, with the decreases being significant on some of the dates.

Analysis of the genotype x harvesting date shows that the genotype Ha-121 produced the highest average yield per head on the eighth harvesting date (48.74 g), while the genotypes Ha-191 and Ha-171 gave the best yields on the fifth date. All three genotypes gave the lowest average yields on the first three harvesting dates.

Table 1. Effect of location and harvesting date on seed yield per head in different sunflower genotypes (g)

Loca-tion (A)	Genotype (B)	Harvesting date (C)										Mean (AΔB)	Mean (A)
		1	2	3	4	5	6	7	8	9	10		
India	Ha-121	4.93	8.59	13.22	18.33	18.44	19.33	26.37	17.93	21.70	22.11	17.10	13.99
	Ha-191	6.59	8.18	9.50	15.13	14.68	19.03	18.53	14.50	15.38	22.12	14.37	
	Ha-171	3.04	6.94	3.92	14.90	7.85	12.09	11.96	13.33	18.18	12.96	10.52	
	Mean (AΔC)	4.85	7.91	8.88	16.12	13.66	16.82	18.95	15.25	18.42	19.06		
Serbia	Ha-121	61.98	70.44	61.29	69.93	75.17	67.50	59.53	79.54	54.71	54.71	65.48	58.21
	Ha-191	42.26	30.66	54.38	49.03	83.05	50.36	67.70	54.89	57.98	49.81	54.01	
	Ha-171	41.54	46.00	45.98	54.91	73.31	57.32	55.16	58.64	55.22	63.18	55.13	
	Mean (AΔC)	48.59	49.03	53.88	57.96	77.18	58.39	60.80	64.36	55.97	55.90	Mean (B)	
Mean (BΔC)	Ha-121	33.45	39.52	37.25	44.13	46.81	43.41	42.95	48.74	38.21	38.41	41.29	36.10
	Ha-191	24.43	19.42	31.94	32.08	48.87	34.69	43.11	34.70	36.68	35.96	34.19	
	Ha-171	22.29	26.47	24.95	34.90	40.58	34.71	33.56	35.99	36.70	38.07	32.82	
Mean (C)		26.72	28.47	31.38	37.04	45.42	37.61	39.88	39.81	37.20	37.48		

Source of variation	F	p
Location	1326.42	<.001**
Genotype	18.69	<.001**
Harvesting date	8.73	<.001**
Location x genotype	4.35	0.015*
Location x harvesting date	3.95	<.001**
Genotype x harvesting date	1.48	0.110ns
Location x Genotype x Harvesting date	2.24	0.005**

	A	B	C	AxB	AxC	BxC	AxBxC
$LSD_{0.05}$	2.40	2.94	5.38	4.16	7.60	9.31	13.17
$LSD_{0.01}$	3.18	3.89	7.11	5.50	10.05	12.31	17.40

Seed yield per head was significantly influenced by the mc at the moment of harvesting. This influence can be best represented through the use of quadratic regressions (Figure 1). The coefficients of determination were not high in all cases (in India they were generally higher (0.57-0.96), whereas in Serbia they ranged between 0.39 and 0.60). In all but one case, however, the coefficients were highly significant. With all three genotypes, the yield increase curves rose more sharply in the Serbian experiment than in the one conducted in India, indicating that seed yields increased at a faster pace in the former country. Consequently, the yields reached their maximum later in the season and at lower mc in India (30.31-15.83%) than in Serbia (41.47-31.20%).

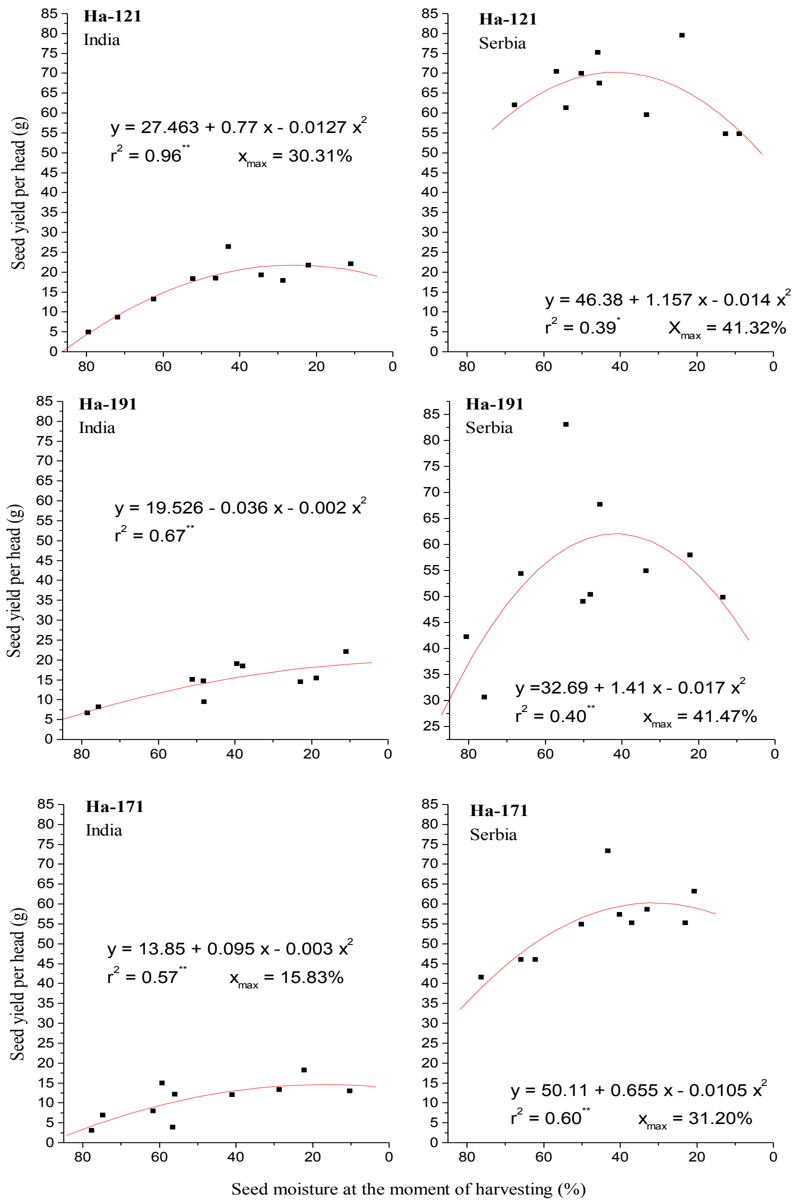

Figure 1. Effect of seed moisture content at the moment of harvesting on seed yield per head

The results above indicate that the yield formed faster in Serbia than in India and that the maximum yield was attained on the earlier harvesting dates with mc at 31-41% and no significant differences from the moment the mc reached 54% (India) and 48% (Serbia). This is in agreement with the findings of Crnobarac (1992), Morozov (1976), and Semihnenko (1966). In certain cases, some minor drops in yield were recorded on the very late harvesting dates. Rodrigues Pereira (1978) explains this phenomenon by dissimilation on account of the already accumulated reserves in the absence of the inflow of nutrients once the connection between the seed and the rest of the plant has been severed. The occurrence of diseases might play a role in this as well, especially in Serbian conditions.

The results on the effects of location and harvesting date on 1,000-seed weight in the three sunflower genotypes studied are shown in Table 2. On the average, the genotypes had a higher 1,000-seed weight when grow in Serbia (34.20 g), and the difference relative to India was highly significant (5.77 g). The genotype Ha-121 had the highest average 1,000-seed weight (36.16 g), while Ha-171 had the lowest (26.35 g). In both cases the differences relative to the other treatments were highly significant. Looking at the harvesting dates, it can be observed that the value of this trait in both locations increased in an almost linear fashion until the last (10th) harvesting date and that the highest value by a significant margin was recorded on the 10th date (50.77 g at 12.56% average mc). On the harvesting dates preceding the last, there were several cases in which no significant differences in 1,000-seed weight were found between two adjacent dates.

Table 2. Effect of location and harvesting date on 1,000-seed weight in different sunflower genotypes (g)

Loca-tion (A)	Genotype (B)	Harvesting date (C)										Mean (AΔB)	Mean (A)
		1	2	3	4	5	6	7	8	9	10		
India	Ha-121	15.68	9.87	21.44	30.79	25.42	40.97	31.12	38.02	44.89	51.24	30.94	28.43
	Ha-191	14.42	7.54	18.04	32.13	31.02	42.17	34.98	44.50	49.39	54.59	32.88	
	Ha-171	10.55	9.06	10.62	14.51	15.64	19.74	29.09	33.14	31.82	40.48	21.46	
	Mean (AΔC)	13.55	8.82	16.70	25.81	24.03	34.29	31.73	38.55	42.03	48.77		
Serbia	Ha-121	18.04	25.17	32.34	31.70	34.11	41.40	51.98	60.11	58.53	60.40	41.38	34.20
	Ha-191	10.35	9.98	18.96	24.91	28.92	32.59	36.59	40.60	46.55	50.39	29.98	
	Ha-171	10.64	17.75	19.32	27.18	32.12	33.56	36.55	41.65	46.11	47.52	31.24	
	Mean (AΔC)	13.01	17.63	23.54	27.93	31.71	35.85	41.71	47.45	50.40	52.77	Mean (B)	
Mean (BΔC)	Ha-121	16.86	17.52	26.89	31.24	29.76	41.18	41.55	49.07	51.71	55.82	36.16	31.31
	Ha-191	12.38	8.76	18.50	28.52	29.97	37.38	35.79	42.55	47.97	52.49	31.43	
	Ha-171	10.59	13.40	14.97	20.85	23.88	26.65	32.82	37.39	38.96	44.00	26.35	
Mean (C)		13.28	13.23	20.12	26.87	27.87	35.07	36.72	43.00	46.21	50.77		

Source of variation	F	p
Location	80.53	<.001**
Genotype	77.54	<.001**
Harvesting date	170.79	<.001**
Location x genotype	45.47	<.001**
Location x harvesting date	3.29	0.001**
Genotype x harvesting date	2.09	0.010**
Location x Genotype x Harvesting date	2.26	0.005**

	A	B	C	AxB	AxC	BxC	AxBxC
$LSD_{0.05}$	1.27	1.56	2.85	2.21	4.03	4.93	6.98
$LSD_{0.01}$	1.68	2.06	3.76	2.92	5.32	6.52	9.22

The lowest 1,000-seed weight in India was produced by the genotype Ha-171 (21.46 g). This value was highly significantly lower than those obtained from the other two genotypes. In Serbia, the highest value of 1,000-seed weight by a highly significant margin was found in the genotype Ha-121 (36.16 g), while the genotype Ha-171, the same as in India, had the lowest 1,000-seed weight (26.35 g), also by a highly significant margin.

1,000-seed weight grew in a linear fashion until the last harvesting date in both locations and the highest value in India were recorded on the 10th date (48.77 g at 10.75% average mc). In Serbia the 1,000-seed weight recorded on the 10th harvesting date (52.77 g, with 14.37% average mc) was higher than the weights that were recorded on the first eight harvesting dates, whereas relative to the value obtained on the 9th date (50.40 g at 19.18% average mc) there was no significant increase. On the dates preceding the last harvesting date in both locations, there were several occasions on which there was no significant difference in 1,000-seed weight between adjacent dates.

1,000-seed weight of the genotypes increased over time and reached its peak on the 10th harvesting date. In the case of Ha-121 and Ha-191, the differences between certain adjacent harvesting dates were highly significant as a result of a sudden inflow of assimilates. With Ha-121, such differences were noted between the 2nd and 3rd, 5th and 6th, and 7th and 8th dates, whereas with Ha-191 highly significant differences were recorded in the period between the 2nd and 6th dates. With Ha-171, the increases of 1,000-seed weight were more gradual.

It was also determined that 1,000-seed weight was significantly affected by seed mc at the moment of harvesting. Similar results have been obtained by Oraki et al. (2011) on different water conditions during the maturity stage. This influence can be best represented by linear regressions (Figure 2). The regression coefficients were very high in all cases (from 0.941 to 0.998). With all three genotypes, the curves rose more sharply in the case of the Serbian site than the Indian one, indicating that 1,000-seed weight increased at a faster pace in Serbia.

Seed filling in India progressed at a slower pace initially and that mc decreased more slowly as a result. Later on, the seed filling process picked up speed, and so did the reduction of the relative mc percentage. This took place during the period of increased day length and high temperatures. The decrease of mc in the initial stages is not a result of moisture being released from the seed, as this begins to happen later on in the process. Rather, the decrease results from the reduction of the relative seed mc due to the inflow of assimilate (Alkio et al., 2002). In the initial stages of maturation in Serbia, the increase of seed yield and the decrease of the relative water content of the seed progressed at a faster pace. Later on, these two processes slowed down significantly with decreasing temperature and day length.

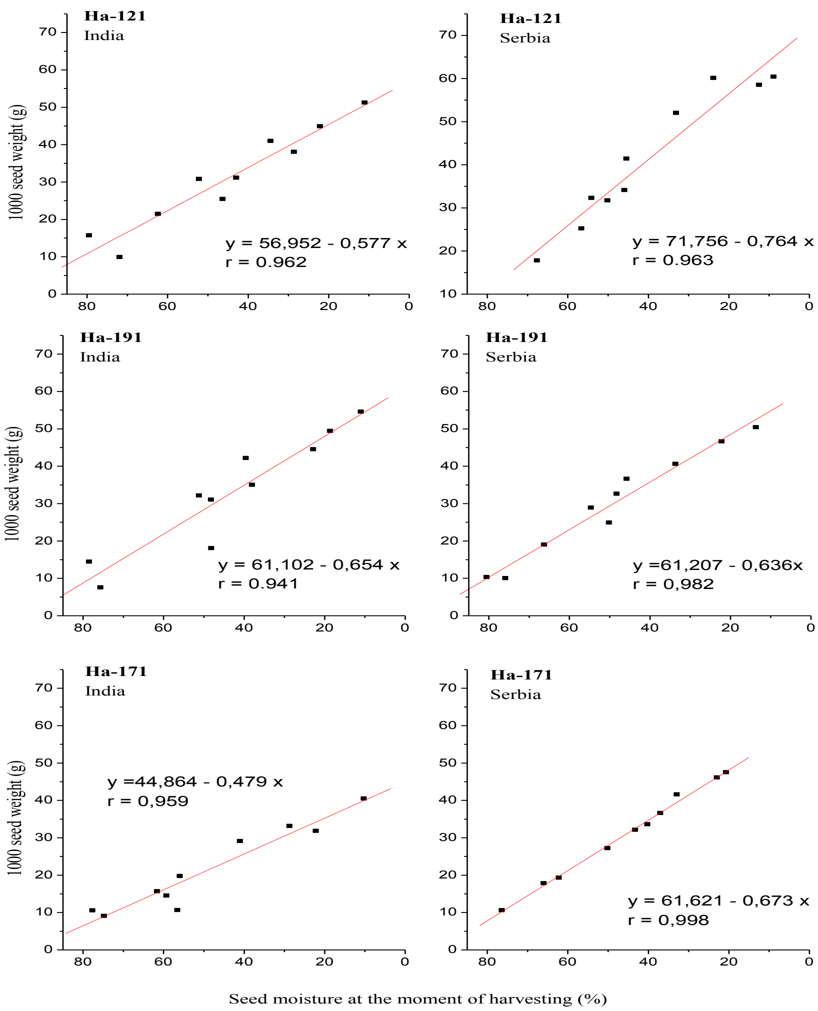

Figure 2. Effect of seed moisture content at the moment of harvesting on 1,000-seed weight

The last harvesting date occurred 38 days after pollination, so the findings about the linear increase of 1,000-seed weight are in agreement with those reported by Jančić and Pap (1983). In most individual cases, there was no significant increase of 1,000-seed weight once the seed mc came close to 20%. This is in agreement with the results of Chervet and Vear (1989) and Borisonik et al. (1978) but not with those of Farizo et al. (1980). The daily increase in the value of this trait was within the range reported by Chervet and Vear (1989) but higher than the value obtained by Role et al. (1976).

CONCLUSIONS

The genotypes had a higher seed yield per head and a larger 1,000-seed weight when grown in Serbia.

The yield increased gradually until the midpoint of the observed period. However from the fifth harvesting date onwards, no significant increase was observed.

The 1,000-seed weight increased in an almost linear fashion until the last harvesting date.

Yield and 1,000-seed weight were significantly affected by mc at harvesting.

Some genotypes could be harvested very early without affecting 1,000-seed weight and yield.

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