Effects of genotype, season and nutrition on sunflower yield and hollow seededness in Gezira (Sudan)*

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ABSTRACT

A field experiment was conducted to study the effects of genotype, season and nutrition on sunflower seed yield and hollow seededness in Gezira. Five sunflower cultivars (Damazin-l, Hungarian-A, Rodio, Hysun-25 and Hysun-33), two nitrogen levels (0 and 129 kgN/ha) and two levels of phosphorus (0 and 129 kg P_20_5/ha) were used over two seasons (autumn and winter 2000) in a randomized complete block design with four replications. Data on 14 characters were collected. results showed that the percentage of empty seeds, self-compatibility1000 -seed weight and seed yield were significantly affected by and its interaction with season. The means of these characters were relatively higher in winter than in autumn season except for the empty seeds. The application of high doses of fertilizer had no significant effect on the percentage of empty seeds, and consequently lie phenomenon of empty seeds could be attributed mainly to genetical and seasonal effects. The genotypes mean seed yields ranged from 1127 to 1899 kg/ha, with Hysun-33 giving the highest yield. Simple and genotypic correlation analyses emphasized that seed yield was and positively correlated with days to flowering, harvest index , head diameter, seed number/head, self-compatibility, number filled seeds/head and percent seed set. Both analyses showed negative coefficients between seed yield and empty seeds. The percentage of empty seeds was positively and significantly correlated with plant height and number of heads/plant. The path analysis indicated that head diameter, percentage of seed set, days to flowering and seed weight

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were the most important traits related to seed yield where as percentage of seed set, harvest index, and days to maturity were the most important traits .contributing to high degree of self-compatibility in sunflower

INTRODUCTION

Sunflower (*Helianthus annuus* L.) proved to be a promising and potentially high-yielding oil crop with satisfactory seed yields of 0.5 -0.8 tonnes/feddan (l feddan 0.42 ha) in the rainfed clay plains of central Sudan (Skoric,1983). However, its yields declined rapidly due to lack of adapted, improved, high-yielding open-pollinated cultivars as will as the unavailability of the imported, expensive hybrid seeds. Furth ermore, the phenomenon of empty or unfilled or aborted or blanck or hollow seeds drastically reduces seed yield and oil content of this crop.

Hollow seededness has been ascribed to many causes; namely, self-incompatibility (Luciano et ale, 1965), insufficient pollinating insect, high relative air humidity, high temperature during flowering time (Marinkovic, 1992), and insufficient nutrients supply to the developing seeds (Khanna, 1972). In the Sudan, Nur (1978) related hollow seededness to the variation in plant height, head diameter and day maturity.

The objective of the present work were to (i) study the effects of genotype, season and nutrition on seed yield and hollow seededness of five sunflower cultivars grown in the Sudan during autumn and Winter seasons, and (ii) assess the association as will as the direct and indirect effects of some characters on self-fertility and seed yield of the crop.

MATERIALS AND METHODS

Five commercial sunflower cultivars; namely three open-pollinated Damazin-l, Hungarian—A and Rodio, and two hybrids: Hysun-25 and Hysun-33 were chosen for this study. Two levels of nitrogen (O and 129kg N/ha in the form of urea, 46% N) and two levels of phosphorus he(0 and 129 kg P_20_5/ha in the form of trible-superphoshate , 46% P_2O_5) were used. The experiment was laid out in a randomized complete block design with four replications at the Gezira Research Station, Wad Medani (latitude 14^0 24'N and longitude 33^0 29' E), Sudan.

The land was disc-ploughed, disc harrowed, levelled, ridged and divided into 4x5m^2 plots. Three seeds/hill were sown on the 25th of July and 22nd of November 2000 (autumn and winter seasons, respectively) in a spacing of 30 x 80 cm, and later thinned to one plant/hill. The crop was hand weeded, resown and irrigated as needed. The phosphorus was placed in furrows beside the row at planting and covered with soil, while nitrogen was broadcast before the second irrigation.

To evaluate self-fertility of the sunflower cultivars in the absence of Insect pollinators, a technique using cotton bags was adopted. Three heads from each plot were covered with new cotton bags (30 x 35cm^2 x 18 strands of thread/cm), just prior to anthesis. At the end of the pollination and fertilization processes, the heads were covered with plastic mesh to reduce the birds damage in the winter season.

The following parameters were measured:

I. Days to 50% flowering: days from sowing to the time when 50% of the plants in a plot started to flower.

2. Plant height (cm): measured from the soil surface to the base of the head at maturity.

3. Days to maturity: days from sowing to the time when heads turned yellow and outer bracts brown.

4. Number of heads/plant including the head on the main stem.

5. Head diameter (cm): measured at maturity across the main head, including the area of disk flowers.

6. Harvest index (HI): (Seed yield per plant/ Biomass per plant) x I00.

7. Seed number/head: the total number of unfilled and filled seeds/head.

8. Number of filled seeds/head: sound and filled seeds /head.

9. Percentage of empty seeds (%ES) = (No. of unfilled seeds per head /Total no. of seeds per head) x 100.

I0- Percentage of seed set (%SS) = (No. of filled seeds per open-head/ Total no. of seeds per open-head) x 100.

11. Self-compatibility (SC): = (Number of filled seeds from bagged head/ Total number of seeds from bagged head) x 100.

12. 1000 - seed weight: three samples of 1000 sound filled seeds from heads harvested /plot were taken and weighed.

13. Seed yield: based on seed yield/plot (kg/m^2), and then converted to kg/ha.

14. Seed oil content: determined by the Soxhelet extraction method

The standard statistical analysis of variance procedures were for the data of each season, then the combined analysis of variance for the two seasons was carried out after testing the homogeneity of the error variance for each season. The means over seasons were used for computing the simple linear correlation coefficients, the genotypic correlation coefficients as well as for carrying out the stepwise multiple regression analysis and the genotypic path coefficient analyses.

RESULTS AND DISCUSSION

Self-compatibility is defined as the ability of the plant to set seed when self-pollinated. The percentage of seed set and degree of self-compatibility were significantly affected by season and genotype)Table 1). The two characters were higher in winter than in autumn. The mean percentage of seed set was 81% and 86% in autumn and winter, respectively, while mean self-compatibility percentage was 59% and 63% in autumn and winter, respectively (data not shown). High temperature and humidity (as in Sudan rainy season) had been found to have profound, deterimental effects on both characters (Pinthus 1959; Akhtar *et al.*, 1987). Hybrids gave higher seed set than open-pollinated cultivars (Table 2). Such differences could be explained by the heterogeneity of the open-pollinated cultivars.

The seed number/head, number of filled seeds/head and percent seed set were significantly affected by season, nitrogen and genotype (Table 1). The values for the three traits were relatively higher under nitrogen fertilization in case of hybrids and during the winter season (Table 2). The percentage of empty seeds was significantly affected by genotype and its interaction with seasons. The open-pollinated cultivars gave the highest mean percentage of empty seeds (e.g. Damazin { 20% }), while the hybrids gave the lowest (e.g. Hysun-33 .({%12}. The percentage of empty seeds was lower in winter than in autumn.

Table 1. Mean squares for seasons, genotypes, nitrogen, phosphorus and their interactions for some characters of five sunflower cultivars, grown at Gezira Research Station in autumn and winter seasons of 2000 (combined over season

Source of variation	Df	Seed Number/ head	No. of Filled Seed/head	Seed-Set %	Empty Seeds (%)	Self-Compqti-Bility (%)	1000-seed Weight (g)	Seed yield (kg/ha)	Oil Content (%)
Season (S)	1	595791.1*	250984.8*	763.18**	500.13*	623.15	405.32* *	1000991**	566.56**
Nitrogen (N)	I	113928.9*	204561.5*	42.29	9.77	5365.71**	980.00* *	280326**	215.02**
S x N	1	40656.6	50091.01	1 0.01	16.42	116.45	59.37	799.60	2.884
Phosphorus (P)	1	93726.6*	9501.81	9.68	15.93	286.28	14.17	73432.87	10.983
S x P	1	222.05	2272.56	25.97	11.71	502.96	30.19	92339.26	11.881
N xP	1	39845.01	25326.06	14.93	29.88	1431.85	32.49	29426.86	3.341
S x N x P	1	56193.76	9625.51	30.05	89.79	1944.21**	0.426	56761.15	0.729
Genotypes (G)	4	115081**	372317 **	309.26**	310.2**	16578.5**	197.39* *	876445.4**	84.93
S x G	4	23977.81	5318.63	52.14*	48.83	1357.08**	134.86* *	218408**	8.665
N x G	4	12427.31	18458.93	34.62	8.2	1454.2**	4.331	49181.42	17.108**
S x N xG	4	15702.17	14233.80	29.59	14.40	732.6**	1I .026	11793.40	16.746*
P x G	4	73344.8**	13902.48	31.14	2.95	822.78**	35.177	14642.53	26.187*
S x P x G	4	27253.12	13799.23	23.37	13.28	752.81**	7.324	25939.26	16.738
N x P xG	4	3523.95	5374.95	10.96	17.78	1141.44*	I .636	69837.79	41.618
S x N x P xG	4	37846.91	24254.83	32.25	18.08	979.08**	10.739	21401.18	13.875

Table 2. Means of seed number/head (SN), no. of filled seeds/head (NF), % of empty seeds (ES), % of seed set (SS), self-compatibility (SC), 1000 -- seed weight (SW), and seed yield (SY) for the five cultivars , fertilizers and their interactions (combined over seasons).

Treatment	SN		NF		ES		SS		SC		SW		SY	
	Rank	Mean*	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean
Damazin-1, 0N0P	20	1008.1m	20	762.0 r	1	22.9 a	20	77.8 i	12	45.2 e	8	65.7 b c	20	1127.2 p
Hung-A, 0N0P	19	1066.5 l	18	688.1 p	7	17.2 cd	18	80.5h	16	37.6 h i	4	66.2 b	15	1282.5 m
Rodio, 0N0P	7	1246.9 f	9	985.8 i	10	15.9 e	11	84.1cd	17	36.5 i j	20	57.3 g	19	1215.6 o
Hysun-25, 0N0P	12	1170.3 h	8	993.5 h	12	15.3 e	9	84.7cd	2	87.7 a	15	60.2 f	16	1279.0 m
Hysun-33, 0N0P	2	1321.7 b	3	1133.0 c	19	11.7 hi	2	88.3ab	9	79.0 c	18	59.2 f	5	1605.8 e
Damazin-1, 0N3P	5	1275.2 d	19	825.6 q	5	17.7 c	14	82.3f	20	21.4 l	12	62.9 e	14	1614.9 l
Hung-A, 0N3P	18	1100.6 k	17	876.0 o	11	15.8 e	16	80.7gh	14	40.7 f g	16	60.1 f	17	1265.1 n
Rodio, 0N3P	14	1148.1 i	16	899.8 i n	6	17.3 c d	13	82.7ef	18	34.5 j k	19	57.8 g	18	1258.7 n
Hysun-25,0N3P	15	1146.1 i	10	979.9 i	15	12.8 g h	6	87.2b	1	88.7 a	17	59.9 f	13	1347.3 k
Hysun-33, 0N3P	10	1225.1 g	7	1112.1 d	18	12.1 h i	3	87.9ab	6	84.2 b	14	60.5 f	3	1673.6 c
Damazin-1, 3N0P	13	1166.3 h	14	921.5 m	3	19.3 b	17	80.7gh	16	33.8 k	1	70.7 a	10	1537.3 h
Hung-A, 3N0P	17	1108.7 j	15	914.9 m	9	16.0 e	10	84.3ch	11	66.6 d	3	66.6 b	9	1546.8 h
Rodio, 3N0P	11	1171.1 h	11	968.1 j	8	16.2 d e	12	83.8de	15	39.3 g h	10	63.9 d e	7	1578.1 I f
Hysun-25, 3N0P	16	1146.01 i	7	1014.0 g	17	12.3 h i	4	87.7ab	5	87.2 a	13	62.8 e	11	1415.2 I
Hysun-33, 3N0P	1	1329.9 a	2	1156.3 b	16	12.5 g h i	7	87.1a	4	87.2 a	9	64.9 c d	1	1892.5 a
Damazin-1, 3N3P	6	1266.4 e	13	949.1 l	2	19.5 b	15	81.8fg	13	41.8 f	5	66.2 b	12	1362.8 j
Hung-A, 3N3P	4	1276.8 d	6	1024.0 f	13	13.9 f	8	85.1c	10	67.8 d	2	69.6 a	6	1601.5 e
Rodio, 3N3P	8	1240.1 f	12	957.1 k	4	19.1 b	19	79.9h	7	80.2 c	11	62.9 e	4	1658.2 d
Hysun-25, 3N3P	9	1228.1 g	5	1057.2 e	14	13.6 f g	5	87.5ab	3	87.4 a	6	65.9 b c	8	1565.9 g
Hysun-33, 3N3P	3	1310.2 c	1	1189.0 a	20	11.41 i	1	88.6a	8	80.2 c	7	65.8 b c	2	1859.7 b

Means followed by the same letter(s) within a column are not significantly different at 0.05 probability level according to Duncan's Multiple Range Test

The application of high doses of nitrogen and phosphorus fertilizers had no significant effect on the percentage of empty seeds, and, consequently, under the conditions of this study, the empty seeds phenomenon could be attributed mainly to genetical and seasonal effects.

Seed yield and 1000 seed weight were highly and significantly affected by season, nitrogen, genotype and the interactions of genotype with season (Table l). Winter seed yields were generally higher than autumn yields. In general, mean seed yields of the genotypes ranged from 1127 to 1899 kg/ha which were quite comparable to the world average of 1247 kg/ha (FAO, 1999). Hybrids gave the highest yieds (e.g. Hysun-33 gave a mean seed yield of 1728 kg/ha). Among the open-pollinated cultivars, Rodio gave the highest mean seed yield (14 27kg/ha).

Oil content was significantly affected by season, nitrogen, genotype
and most of the interactions. The mean percent oil content for the combined data ranged from 40% to 50% for Rodio, and Hungarian-A, respectively (data not shown).

Character association

The simple linear correlation coefficient analysis showed that seed yied was positively and significantly associated with days to 50% flowering, head diameter, harvest index, seed number/head, number of filled seeds/head, percent seed set, 1000-seed weight, selfcompatibility and oil content (Table 3). But, the genotypic correlation coefficient analysis identified only head diameter, harvest index, seed number/head and percent seed set as the most important traits positively associated with seed yield. Both analyses showed that seed yield was negatively related to percentage of empty seeds
(r = 0.58** and -0.15 for simple and genotypic correlations, respectively).

The presentage of empty seeds was positively and significantly correlated with plant height and number of heads/plant but negatively and significantly correlated with days to 50% flowering, harvest seed number/plant, number of filled seeds/head, percentage, seed set percent autogamy, 1000 seed weight and oil content.

Table 3. Simple (upper diagonal) and genotypic (lower diagonal) correlation coefficients of 15 pairs of characters studied for two seasons (combined data).

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15
X1		-0.19	0.74**	0.16	0.44**	0.27*	0.11	0.32*	0.35**	-0.36*	-0.02	-0.05	0.17	0.65**	0.45*
X2	0.15		0.03	0.31*	0.01	-0.30*	0.15	0.21	-0.41**	0.44**	-0.37*	-0.43**	0.12	-0.19	-0.57**
X3	0.16	0.23		0.51**	0.14	-0.14	-0.12	-0.27	-0.10	0.10	-0.40*	-0.52**	0.15	0.25	0.20
X4	0.14	0.33	0.26		0.10	-0.23	-0.32*	-0.54**	-0.51**	0.39*	-0.48**	-0.41**	0.25	-0.17	-0.34**
X5	0.78**	-0.21	0.19	-0.58**		0.34*	0.29	0.41**	0.31*	-0.30*	0.25	0.24	0.55**	0.71**	0.02
X6	-0.32	-0.52*	-0.80**	-0.54*	-0.13		0.07	0.54**	0.40*	-0.44**	0.30*	0.46**	0.31	0.52**	0.29*
X7	0.11	-0.22	-0.12	-0.28	0.72**	0.90**		0.67**	0.55**	-0.46**	0.32*	0.21	0.04	0.46**	0.14
X8	0.04	-0.13	-0.19	-0.19	0.52*	0.76**	0.30		0.81**	-0.77**	0.56**	0.56**	0.05	0.65**	0.44**
X9	-0.07	-0.16	-0.29	-0.30	0.49*	0.79**	-0.09	0.22		-0.93**	0.46**	0.44**	-0.29	0.62**	0.57**
X10	-0.07	0.12	0.24	0.22	-0.62**	-0.96**	-0.02	-0.22	-0.21		-0.45**	-0.45**	0.03	-0.58**	-0.53**
X11	-0.05	0.27	-0.24	-0.24	0.24	0.94**	0.24	0.26	0.39	0.34		-0.18	0.81**	0.29*	0.28*
X12	-0.03	0.08	0.19	0.26	0.86**	0.70**	-0.47*	-0.15	0.12	0.20	-0.38		0.02	0.31*	-0.12
X13	-0.05	-0.32	-0.60*	-0.16	0.39	0.77**	0.20	0.29	0.35	-0.30	0.40	0.16		0.45**	0.31*
X14	0.27	0.12	0.36	-0.10	0.65**	0.62**	0.89**	0.27	0.51*	-0.15	-0.29	0.44	0.24		0.36*
X15	-0.21	0.53*	-0.48*	-0.46	-0.07	-0.98**	0.41	0.44	0.53*	-0.47*	0.35	0.11	0.63**	0.55**	

*,** Significant at 0.05 and 0.01 probability levels , respectively.
X1: Days to flowering; X2: Plant height; X3: Days to maturity; X4: No of heads/plant; X5: Head diameter; X6: Harvest index; X7: Seed number/head; X8: No. of filled seeds/head; X9: % seed set; X10: % empty seed; X11: % autogamy; X12:1000-seed weight; X13: Self-compatibility; X14: Seed yield; X15: Oil content .

Stepwise multiple regression

The multiple coefficient of determination analysis revealed that %51of the variation in seed yield could be explained by the variation in head diameter alone, and 68% of that variation could be explained by both head diameter and percentage of seed set (Table 4). About %76of the variation in seed yield could be accounted for by head diameter, percentage of seed set and days to 50% flowering. These three variables plus the 1000 seed weight accounted for 80% of the variation in seed yield. On the other hand, the percentage of seed set, harvest index and days to maturity accounted for 75% of the variation in self compatibility (Table 4). The seed set percentage alone accounted for 65% of the variation.

Table 4. Multiple correlation (R) and multiple coefficient of determination (R^2) obtained when the mean seed yield and mean self-compatibility are used as dependent variables in a stepwise multiple regression analysis and the order in which independent variables were introduced into the equation (combined data).

Character	Order		
	Seed yield		
Head diameter	1	O. 7 16**	0.513
Percentage of seedset	2	O. 826**	0.683
Days to 50% flowering	3	0.873**	0.761
-1000seed weight	4	O. 930**	0.797
	Self-compatibility		
Percentage of seed set	1	0.807**	0.651
Harvest index	2	O. 83 8**	0.702
Days to maturity	3	0.846**	0.747

**Significant at 0.01 probability level.

Path coefficient analysis

Genotypic correlation coefficients were used to perform the path coefficient analysis for seed yield and self-compatibility (Table 5). The variables used in the path coefficient analysis were chosen by the stepwise multiple regression analysis.

Table 5. Path coefficient analysis of the direct and indirect effects the different yield components and their genotypic correlation coefficients with seed yield and self-compatibility in sunflower (combined data).

Character	Seed yield effect via				
	Head diameter (X1)	% Seedset (X2)	Days to50% flowering (X3)	100- seed weight (X4)	Genotypic correlation with seed yield
X1	0.657	0.079	-0.173	0.084	0.647**
X2	0.321	0.162	0.016	0.012	0.511*
X3	0.509	-0.012	-0.223	-0.003	0.271
X4	0.553	-0.019	0.007	-0.098	0.443
	Self-compatibility effect via				
	Seed set (%) (X1)	Harvest Index (X2)	Days to Maturity (X3)	Genotypic correlation -with self Compatibility	
X1	0.425	-0.204	0.180	0.401	
X2	0.383	-0.226	0.612	0.769**	
X3	-0.010	0.181	-0.766	-0.595**	

*, ** Significant at 0.05 and 0.01 probability levels, respectively.
+Direct effects are underlined.

Head diameter can be a good selection criterion as it can easily be measured and had strong and highly significant positive correlation with seed yield. This relationship was confirmed by the path analysis as head diameter had a considerable direct effect on seed yield (Table 5) Such finding is confirmed by the work of Alba and Greco (1979), Sheriff and Appadurai (1985) and Ahmed *et al*. (1991).

The large negative direct effect of days to flowering and the small negative direct effect of seed weight on seed yield indicated that the environment (different sowing dates over seasons) may strongly influence the maturation process and seed development. Also, the negative indirect effects, on seed yield, of both traits (days to flowering and seed weight) through the percentage of seed set showed that late flowering, insufficient pollination and insufficient assimilate supply to the developing seeds may cause seed abortion. But, these negative indirect effects were simultaneously compensated by the positive high indirect effect of head diameter for both traits.

Sunflower plants have a system of self-incompatibility, which may be a major cause for the unfilled or partially filled seeds. Thus, a path coefficient analysis was carried out to obtain information about direct and indirect effects of the examined characters on self-compatibility (Table 5).

The percentage of seed set had considerable positive direct effect and also had minor positive indirect effect through days to maturity on self - compatibility. Its negative, indirect effect through harvest index reduced their positive association with self-compatibility. These findings emphasized the fact that, at the time of pollination, many factors influence the success of subsequent self-fertility or seed set such as date of planting and the impact of source-sink relationships on self-fertility. These results are in line with those reported by Pinthus (1959)and Fick (1983).

In spite of the highly significant and strongly positive correlation between self-compatibility and harvest index, the latter had a negative direct effect. The negative direct effect of harvest index was compensated for by the positive indirect effects of days to maturity and percentage of autogamy.

Days to maturity showed highly significant, but negative correlation with self-compatibility. It had highly negative direct effect and poorly negative indirect effect through the percentage of seed set on self-compatibility. These results revealed that date of planting (autumn and winter planting dates) had a direct effect on the date of flowering. Thus, the process of pollination and fertilization were greatly affected by the environment. Therefore, distinct weather changes increase the self-incompatibility and the incidence of empty seeds. These results are similar to those of Gowda and Giriraj (1989); Miller and Fick.(1997).

In conclusion, the present study indicated that growing early maturing cultivars with high degree of self-fertility and reasonably large head size and heavy seeds could result in high seed yield and in reduction of blank or empty seeds in sunflower.

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