INFLUENCE OF SOWING PERIOD ON PRODUCTION RESPONSE OF SUNFLOWER IN CATCH-CROP GROWING.

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Summary

In the five-year period 1985-89 at the experimental farm of the Grosseto Centre of the Tuscan Regional Body for agricultural and forestal development situated at "Barbaruta", research was carried out into the productive possibilities of sunflower as a catch-crop in various sowing periods.

Every year, in irrigated cultivation and adopting an experimental scheme of a split-plot design with four replications, comparisons were made in two sowing periods, one after barley and one after durum wheat, between six sunflower hybrids characterized by differing lengths of biological cycle: the very early "Isa" and "Cerflor", the medium-early "Romsun HS 90", "Primasol" and "Florom 303" and "Gloriasol" with a medium cycle.

This research has pointed out the possibility of producing sunflower catch-crops, even sowing after durum wheat so long as there is adequate irrigation. The productive potential of the crop in general appeared to be good, even if the best results were obtained by sowing after barley. Concerning the choice of hybrid, "Gloriasol", characterized by a medium length cycle, was found to be the best in the cooler, rainier years, while the very early "Isa" hybrid in the warmer, drier ones.

Introduction

In Italy sunflower cultivation reaches its greatest extent in Tuscany where the area cultivated is more than a third of the total cultivated area. The considerable interest shown for the oil crop in this region has led also to considering the possibility of its use in catch-crop cultivation, obviously limited to those environments with greater water availability.

The recourse to one or two rescue waterings, together with the adoption of minimum tillage techniques which reduce water losses from the soil (Marzi et al., 1982; Miele, 1987), might in fact permit the successful cultivation of the crop, thanks also to the ability of the sunflower to make use of the water reserves occurring at depth in the soil (Boyer, 1976; Berengena and Henderson, 1980; Quaglietta Chiarandà et al., 1990); this possibility has already been partly demonstrated by research carried out in Puglia and Tuscany (Pacucci and Alba, 1977; Tarantino and Alba, 1978; Vannozzi and Paolini, 1978);

In order to single out the best sowing period for catch-crop cultivation and the correspondingly most suitable type of hybrid, with regard to its characteristics of biological and production cycle length, the research study described in this paper was carried out in the five-year period 1985-89 as part of the "Oil Plant" Project of the M.A.F., Subproject "Sunflower".

Materials and methods

In the five-year period 1985-89 on the experimental farm at the Grosseto Centre of the Tuscan Regional Body for agricultural and forestal development situated at "Barbaruta", a research study to evaluate the production possibilities of sunflower as a catch-crop in various sowing periods was carried out.

Every year, adopting an experimental split-plot design with four repetitions, comparisons were made in two sowing periods, one after barley and the other after durum wheat, between six sunflower hybrids of differing biological cycle length: the very early "Isa" and "Cerflor", the medium-early "Romsun HS 90", "Primasol" and "Florom 305" and "Gloriasol" with a medium cycle.

So as to obtain one factorial experiment only (years x sowing periods x hybrids), the autumn-winter cereals were sown every year on the plain located along the coastal strip of the middle Tyrrhenian Sea, in soils displaying similar physico-chemical and hydrological characteristics (Tab. 1).

Since the aim of the research was to identify the sowing period and the type of hybrid (i.e. the length of the biological cycle) most suitable for sunflower catch-crops, and also in order to check the production potential, an attempt was made to guarantee the crop the best environmental conditions. For this reason, in both periods, watering was carried out once after sowing so as to restore field water capacity in the ground down to a depth of 0 to 40 centimetres. Subsequent waterings were carried out so as to completely satisfy the water needs of the crop; for this purpose, when a third of the usable water was still present in the soil layer from 0 to 40 centimetres, 100% reintegration of maximum evapo-transpiration minus effective rainfall (i.e. over 10 mm in 24 hours) was implemented. The waterings were carried out separately for the two sowing periods and, for each, at the same time for the various hybrids being compared.

Starting from the moment when irrigation after sowing had been carried out, the calculation of maximum evapo-transpiration was initiated. The latter was estimated on the basis of the daily evaporate from a class "A" pan (Eo "A"), corrected with the following crop coefficients (Kc):

Kc 0.4 - up to the fourth leaf 4 cm long (Schneiter and Miller's V5 stage) (Schneiter and Miller, 1981);
Kc 0.8 - up to flower bud (Schneiter and Miller's R2 stage);
Kc 1.1 - up to 15 days after the beginning of anthesis (the latter phase found in Schneiter and Miller's R5 stage);
Kc 0.8 - up to physiological maturity (Schneiter and Miller's R9 stage).

Due to the differing precocity of the experimental hybrids, the phenological phases for the definition of the Kcs were observed on the earliest of the hybrids, "Isa", for increasing Kcs and on the latest hybrid, "Gloriasol", for decreasing Kcs. The change of Kc was made in every case when the phenological phase under consideration was present in 50% of the plants.

The irrigation rate, kept constant throughout the irrigation period (Tab. 2), was calculated on the basis of the hydrological and physical characteristics of the soil (Tab. 1) so as to restore 2/3 of the water available to the plant for a soil depth of 40 centimetres. Irrigation was carried out when the crop had used all the water supplied by the previous irrigation, as a result of which the irrigation timetable varied according to the estimated consumption.

A localized irrigation system, which permitted highly efficient distribution and moreover prevented wetting the aerial parts of the plant so limiting the spread of cryptogamic diseases, was used in every case.

The ground intended for the trials was prepared with the minimum tillage technique after the cereal harvest. At tilling 150 kg/ha of nitrogen were distributed, while phosphorus (150 kg/ha) and potassium (100 kg/ha) were added in the summer preceding the preparation of the ground for the cereal crop. Sowing was carried out on the dates shown in Table 2, by parcel sowing machine and the density adopted, the same for all the hybrids, was 6 plants/m2. The plots, consisting of six rows of plants 60 cm apart, had an area in every case of 25.2 m2 (7 m x 3.6 m). Weed control was always carried out by hand.

On the crop were recorded values concerning the date of attainment of the principal phenological phases, expressed in days from emergence and referring to the moment in which 75% of the plants were seen to be in one of the above-mentioned phases.

At maturity observations were carried out on the height of the plant, the head diameter and the sterile part area sometimes present at the centre of the latter; the identification was then made of any parasitary symptoms occurring on the sunflower. At harvest the achene humidity and yield expressed in t.ha-1 at 0% humidity were determined. The weight of 1000-achene and their oil percentage content (by NMR method) were also determined. For the observations concerning the yield characters, the test area was limited in every plot to the four central rows, and furthermore eliminating from the latter the last three plants at each end.

The thermopluviometric trend, recorded during the five-year trial period, is shown in Figure 1.

All the data recorded underwent analyses of variance according to the arrangement in the field of the split plots.

Results and discussion

Year effect. All the characters examined were seen to be influenced by the climatic trend (Tabs. 3 and 4). In particular, the lower average temperatures and the higher rainfall that were recorded in 1989 in the months of July, August and September (Fig. 1), the latter so much so as to reduce the number of waterings (Tab. 2), caused a significant increase in the length of the biological cycle of the sunflower (Tab. 5) and especially in the period beginning of anthesis-physiological maturity. In this year also the biometric (Tab.

5) and yield characters (Tab. 6) appeared in general significantly greater; also the percentage of diseased plants, connected with the greater humidity present which encouraged the development of "White rot" (Sclerotinia sclerotiorum (Lib.) de Barry), was seen to be significantly higher. However the exceptions to this were the percentage of sterile area present in the head, which thanks to the climatic trend appeared to be almost absent, the 1000-grain weight, seen to be less with respect to the high number of achenes per plant, and the oil percentage in the achenes which was negatively influenced by the greater rainfall and by the occurrence of lower temperatures (Blanchet and Merrien, 1982), particularly during the grain-filling phase (Canvin, 1965).

On the contrary, in the first trial year, the higher temperatures and the low rainfall (Fig. 1), which made it necessary to irrigate as many as 10 times in the first sowing period (Tab. 2), had the opposite effect, causing a shortening of the phenological periods under consideration and a significant reduction in the values of both the head diameter (Tab. 5) and of the above-mentioned yield characters (Tab. 6).

Sowing period effect. Examining Tables 3 and 4 it can be seen that only the percentage of sterile area present in the head was not influenced by the sowing period. In fact all the characters examined (Tabs. 5 and 6) showed in general the significantly greater values with the first period. With the latter, due to the copious irrigation, it was found possible to obtain yield levels not far from those obtainable in a normal sowing period (Vannozzi et al. 1990), as also emerged from similar research also conducted in the same trial environment (Salera et al., 1988; Santamaria et al., 1991).

In the second sowing period, the existence during the vegetative phase of the sunflower of both high temperatures and high evaporative demand, caused in fact, together with a shortage of rainfall which notwithstanding the copious irrigation made its effect felt, a shortening in the length of the various phases of the biological cycle of the plant. Moreover in the above-mentioned period the insufficient radiation and temperature conditions during the grain-filling phase, were the principal factors limiting production (Lanza et al., 1988; Santamaria et al., 1991). On the other hand, the only character which showed statistically greater values in the trial sown after durum wheat, was the percentage of diseased plants. In this trial in fact more substantial attacks by Sclerotinia sclerotiorum occurred, particularly on the flower-head, as from the second half of September, connected to both the greater amount of rainfall and the average temperatures of about 18-20° (Zazzerini and Tosi, 1989; Tosi et al., 1991).

Concerning the length of the whole crop cycle, it should be underlined how in every case it was possible to carry out the sunflower harvest by the month of October (Tab. 2), with a humidity percentage in the achenes such as not to present problems for stockage and moreover still in time to carry out the main tilling of the ground for the subsequent crop.

Hybrid effect. The behaviour shown by the hybrids under comparison confirmed the diversity in their biological cycles (Tab. 5). Of them all, "Gloriasol" was seen to be the latest, as one would expect from its phenological characteristics, and showed the greatest length for all three periods under consideration. On the other hand, the cultivar "Isa" was seen to be the most precocious in the attainment of the flowering and physiological maturity phases. It is moreover of interest to note that "Romsun HS 90", which was third in precocity, showed a beginning of flowering-physiological maturity period of similar length to that of the less precocious hybrid, a fact which allowed it to complete very satisfactorily the delicate and important phases of setting and grain-filling.

Analyzing the biometric characters, statistical processing has demonstrated how on average in the five-year experimental period the significantly greater plant height (Tab. 5) was shown by the hybrids "Cerflor" and "Gloriasol", while the distinctly lower height by "Romsun HS 90". The latter showed however the greater head diameter and the highest value of the sterile part area. Concerning the yield characters (Tab. 6), "Gloriasol" appeared in every case, with the exception of the 1000-grain weight and the oil percentage in the achenes, to be the best. On the other hand, the latter two characters were seen to be significantly higher in "Romsun HS 90", although this hybrid showed the significantly lowest achene yield, so confirming that oil percentage is a character strictly tied to the genetic characteristics of every hybrid (Miller et al., 1982; Bedov, 1985; Skoric and Marinkovic, 1986). It should moreover be underlined how some cultivars, such as "Florom 305", "Cerflor" and "Primasol", which gave good achene yields, displayed, due to their low oil percentage, the significantly lowest unit yields of this latter. Instead the opposite behaviour was shown by "Isa": to an achene yield which was not high it countered a good oil percentage, which enabled the achievement of production levels of this latter character statistically similar to those of "Gloriasol".

Interaction effect. Statistical processing has demonstrated the fact that generally (Tabs. 3 and 4) only the interactions years x sowing periods and years x hybrids were significant for all the characters under consideration. For both it seems appropriate, given the determining role of oil percentage, to examine the unit yield of the latter, given that this allows us to appreciate most satisfactorily with respect to that of the achenes, the productive potential of the crop. Observing Figure 2, where the interaction years x sowing periods is recorded in graphic form, one notes how in every year the trials sown in the two periods have been similarly affected by the different climatic trends. In general the statistically greatest yields were obtained sowing after barley, but in 1989 the highest values were recorded for the trial sown after wheat. The latter trial was moreover the one which showed, together with the trial sown in 1988 in the first period, the significantly highest oil yields. The reason for this behaviour, atypical of the crop, should be looked for in

the particular climatic trend which existed in the last experimental year (Fig. 1). During the latter, in fact, both average temperatures lower than the other years and higher rainfall (312.5 mm altogether in the months of July, August and September) occurred.

Concerning the interaction years x hybrids (Fig. 3), one observes how the significantly greater oil yield (for $P \leq 0.05$) was shown by "Gloriasol" in 1989. Moreover the same hybrid produced the best results also in 1986 and 1988. In the latter year, a statistically similar yield was shown also by the very early cultivar "Isa", which moreover appeared particularly productive for the years in which scanty rainfall and temperatures higher than the average (1985 and 1987) were recorded. The general trend of oil production has therefore highlighted how in the fresher and rainier years the hybrids characterized by a medium length biological cycle are to be preferred, while on the other hand for warmer and drier seasonal trends the best results are produced by the earlier cultivars.

Conclusions

The results obtained at the research centre during the five-year experimental period have indicated, first of all, the possibility of producing a sunflower catch-crop even sowing after the harvest of durum wheat.

The productive potential of the crop appeared generally good, even if the total volumes of water necessary for irrigating to fully satisfy the requirements of the crop were high.

The significantly greater yields were obtained by carrying out the sowing after the barley harvest. In fact also the oil percentage in the achenes was statistically higher in this period.

As regards the choice of hybrid, it was demonstrated how in general the statistically greatest quantities of oil were achieved with "Gloriasol" and "Isa". In particular in the cooler and rainier years "Gloriasol", characterized by a medium length biological cycle, was seen to be best, whereas with warmer and drier seasonal trends the very early hybrid "Isa" was best.

Fig. 1 - Mean monthly values of temperature and evaporation, and total monthly rainfall during the experimental period.

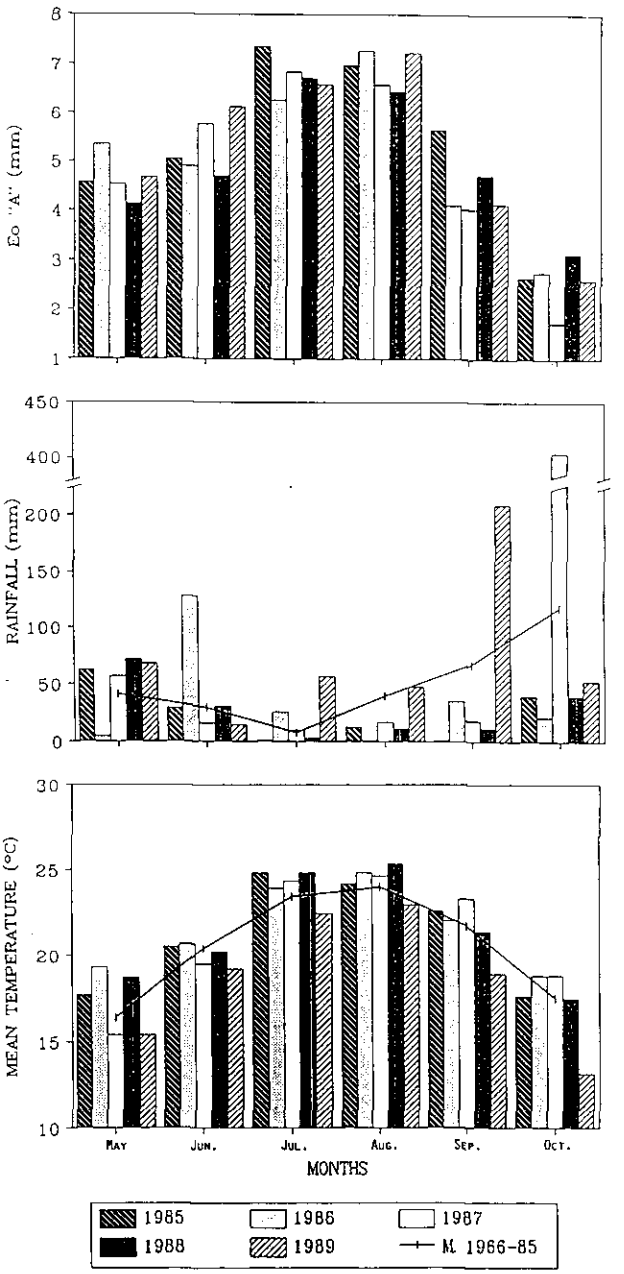


Fig. 2 - Interaction years x sowing periods.

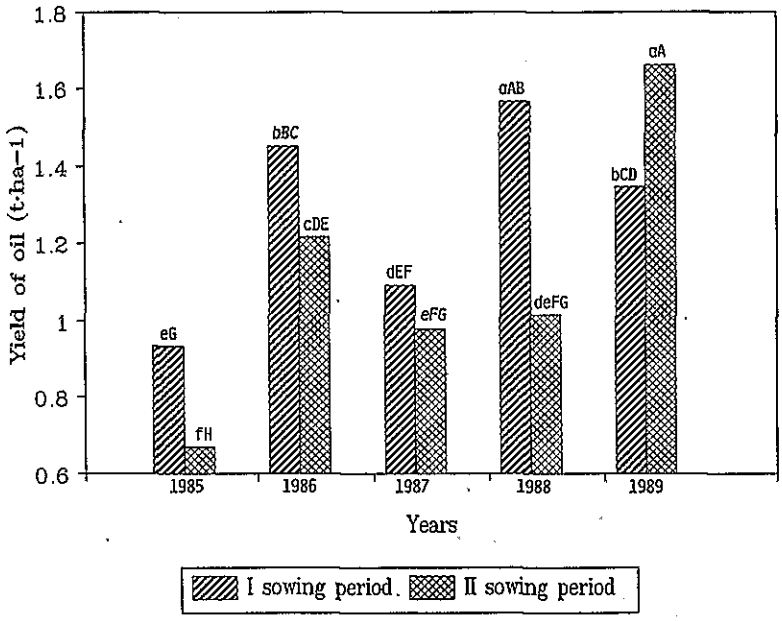
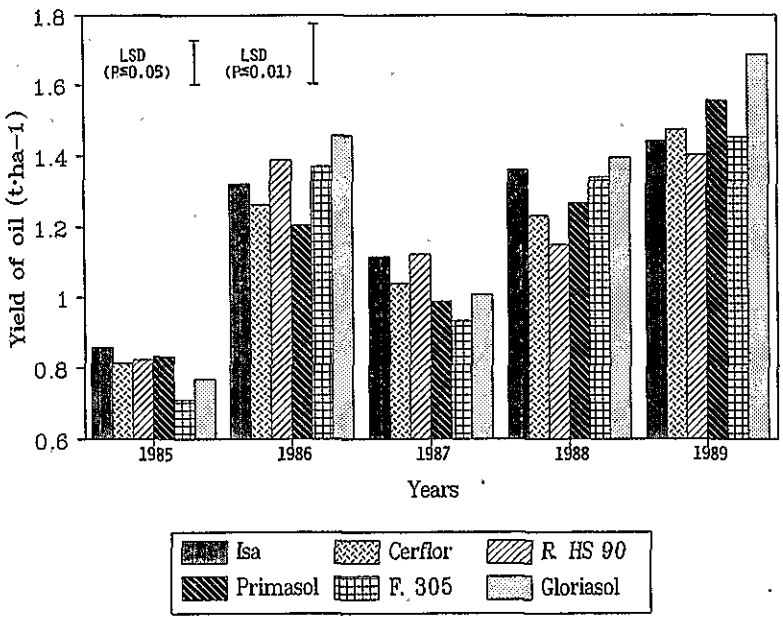


Fig. 3 - Interaction years x hybrids.



Tab. 1 - Physical, chemical and hydrological characteristics of the trial soils.

Soil characteristics		Values				
		1985	1986	1987	1988	1989
Sand (%)		21	27	19	21	23
Silt (%)		44	43	44	43	42
Clay (%)		35	30	37	36	35
pH (in water)		7.68	7.52	7.75	7.67	7.47
Total lime (De Astis) (%)		13.26	12.78	13.49	13.27	13.48
Total nitrogen (Kjeldahl) (%)		1.71	1.87	1.73	1.67	1.69
Assimilable phosphorus (Olsen) (ppm)	P_2O_5	12.96	12.95	13.16	12.85	13.25
Assimilable potassium (ppm)	K_2O	414	423	417	411	421
Organic matter (Lotti) (%)		1.93	1.85	1.91	1.93	1.88
Soil dry bulk density ($t \cdot m^{-3}$)	0-50 cm	1.24	1.21	1.23	1.24	1.25
Field capacity "in situ" (w/w)	0-25 cm	31.9	33.2	32.2	32.1	31.9
	25-50 cm	32.1	33.6	33.0	32.1	31.9
Relationship between tension (bar) - soil moisture (w/w)	- 0.3 bar	43.9	44.9	43.1	44.3	44.4
	- 0.5 bar	36.3	37.1	36.0	36.6	36.7
	-15.0 bar	16.6	17.7	17.2	16.7	16.9

Tab. 2 - Sowing and harvest dates, irrigation rates and number of waterings.

Operations on the crop	Sowing periods	Years				
		1985	1986	1987	1988	1989
Sowing date	I	14/06	26/06	18/06	15/06	22/06
	II	5/07	10/07	15/07	7/07	8/07
Harvest date	I	15/10	26/10	20/10	28/10	26/10
	II	25/10	31/10	28/10	31/10	30/10
Irrigation rates (mm)	I and II	49.8	50.7	50.5	50.9	50.0
Number of waterings	I	10	8	8	9	6
	II	9	7	6	8	5
Total irrigation rates (mm)	I	498	406	404	458	300
	II	448	355	303	407	250

Tab. 3 - Significance of variance for some phenologic and biometric characters, and for affected plants percentage. (*) Significant at the 0,05 probability level; (**) significant at the 0,01 probability level; (n s) not significante at the 0,05 probability level.

Sources of variation	Period em.-b.a.	Period b.a.-p.m.	Period em.-p.m.	Plant height	Head diameter	Head's ster. part area	Affect. plants % (Sclerotinia)
Years	* *	* *	* *	* *	* *	* *	*
Sowing periods	* *	* *	* *	* *	* *	n s	* *
Hybrids	* *	* *	* *	* *	*	* *	n s
Years x sowing periods	* *	* *	* *	* *	* *	* *	n s
Years x hybrids	* *	* *	* *	*	*	* *	n s
Sowing periods x hybrids	n s	*	* *	n s	n s	*	n s
Yea. x sow. per. x hybr.	*	*	n s	n s	n s	n s	n s

Tab. 4 - Significance of variance for some yield characters. (*) Significant at the 0,05 probability level; (**) significant at the 0,01 probability level; (n s) not significante at the 0,05 probability level.

Sources of variation	No achenes·m^{-2}	1000 grain weight	Yield of achenes	Oil in achenes	Yield of oil
Years	* *	* *	* *	* *	* *
Sowing periods	* *	* *	* *	* *	* *
Hybrids	* *	* *	* *	* *	* *
Years x sowing periods	* *	* *	* *	* *	* *
Years x hybrids	* *	* *	* *	* *	* *
Sowing periods x hybrids	*	* *	n s	n s	n s
Yea. x sow. per. x hybr.	n s	n s	*	n s	n s

Tab. 5 - Average effect of year, sowing period and hybrid on phenologic and biometric characters, and on affected plants percentage.

Treatment	Period em.-b.a. (days)	Period b.a.-p.m. (days)	Period em.-p.m. (days)	Plant height (cm)	Head diameter (mm)	Head's ster. part area (%)	Affect. plants (Sclerotinia) (%)
Year							
1985	48.4 dD	34.6 eE	83.0 eE	153 cBC	156 cC	2.2 cC	2.5 c
1986	53.1 aA	36.3 dD	89.4 cC	159 bAB	171 bB	4.4 aA	9.5 ab
1987	49.8 cC	38.7 cC	88.5 dD	148 cdCD	160 cC	2.6 bcBC	3.2 bc
1988	50.8 bB	41.1 bB	92.0 bB	143 dD	172 bB	2.8 bB	4.0 bc
1989	48.4 dD	46.1 aA	94.5 aA	166 aA	200 aA	0.3 dD	11.2 a
Sowing period							
I	51.6 aA	40.7 aA	92.2 aA	160 aA	175 aA	2.0	3.0 bB
II	48.7 bB	38.1 bB	86.8 bB	148 bB	168 bB	2.2	9.2 aA
Hybrid							
Isa	47.9 dD	39.2 bB	87.2 fF	157 cC	167 c	1.5 dC	5.5
Cerflor	49.5 cC	38.7 cC	88.3 eE	166 aA	170 ac	1.9 cBC	6.0
Romsun HS 90	49.4 cC	39.9 aA	89.3 dD	122 dD	175 a	2.9 aA	7.5
Primasol	50.9 bB	38.8 cBC	89.7 cC	157 cC	175 a	2.1 cB	5.0
Florom 305	50.6 bB	39.9 aA	90.5 bB	159 bcBC	174 ab	2.3 bAB	6.0
Gloriasol	52.3 aA	39.7 aA	92.0 aA	163 abAB	169 bc	1.9 cBC	6.0

Means followed by the same letter do not differ significantly at the 5% level (small letters) and the 1% level (capital letters) according to Duncan's multiple range test.

Tab. 6 - Average effect of year, sowing period and hybrid on yield characters.

Treatments	Number of achenes (no·m-2)	1000 grain weight (g)	Yield of achenes (t·ha-1 0% hum.)	Oil in achenes (% of d.m.)	Yield of oil (t·ha-1)
Year					
1985	3733 eE	51.1 cC	1.90 dD	41.9 dD	0.80 dD
1986	4552 cC	59.4 aA	2.70 bB	49.4 aA	1.33 bB
1987	4150 dD	52.7 bcBC	2.19 cC	47.3 bB	1.03 cC
1988	4913 bB	53.5 bBC	2.56 bB	50.2 aA	1.29 bB
1989	6197 aA	54.2 bB	3.31 aA	45.4 cC	1.50 aA
Sowing period					
I	4892 aA	55.2 aA	2.65 aA	47.9 aA	1.28 aA
II	4526 bB	53.2 bB	2.41 bB	45.7 bB	1.11 bB
Hybrid					
Isa	4451 cB	55.7 bB	2.49 bAB	48.6 abAB	1.22 abAB
Cerflor	5256 aA	50.4 dD	2.60 abA	44.6 dD	1.16 bB
Romsun HS 90	4145 dC	57.4 aA	2.37 cB	49.4 aA	1.18 bB
Primasol	4708 bB	53.6 cC	2.51 abAB	46.2 cC	1.17 bB
Florom 305	4524 bcB	57.4 aA	2.62 aA	44.0 dD	1.16 bB
Gloriasol	5172 aA	50.5 dD	2.60 abA	48.1 bB	1.26 aA

Means followed by the same letter do not differ significantly at the 5% level (small letters) and the 1% level (capital letters) according to Duncan's multiple range test.

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