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COMPARATIVE PERFORMANCE OF THE NORMAL AND LATE SOWN SUNFLOWERS UNDER BRITISH CONDITIONS

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SUMMARY

Successful cultivation of the sunflower in the UK depends heavily on the sowing of suitable varieties at an appropriate time. Data from 66 open pollinated half-sib families of sunflower were analysed to determine the impact of the normal and late sowing dates on the expression of six metrical traits namely, height at 6 weeks after sowing, flowering time, height at the time of flowering, head diameter, seed set and area of seed set. Comparisons of the means revealed that the late sowing grew significantly faster and taller and took 7 days less to mature. The normal sowing, on the other hand, set significantly more seed. The two sowing dates did not differ critically for the remaining traits. The performance of the families was observed to be consistent across the sowing dates and there was little coincidence of family x sowing date interaction or family x micro environmental interaction for any of the traits. These observations were further supported by the significant and positive correlations between the sowings while the associations between traits did not differ much either. Only one out of the 15 inter-trait correlations was found to differ significantly. The important implications of these results are discussed and it is shown that early sown crop will be commercially more successful in the UK.

Key words: **Developmental characters, *Helianthus annuus*, quantitative traits, sowing dates.**

INTRODUCTION

One of the major problems that all breeders face during the production of crop varieties is the difference in the performance of the breeding material under experimental and commercial conditions. The factors that influence the experimental and commercial performances of the crop plants are the contrasting agronomic practices that are followed at the early and late stages of a breeding programme. In the early stages, experiments are often started in protected areas such as the glass-

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houses and the materials are protected from disease attack and environmental stress such as frost and/or drought. Controlled temperature also allows uniformity of germination and consequently the experiment is given the best possible start. Commercial growing, on the other hand, involves direct sowing in the field where seed may be sown at a more variable depth/density, germination may be slow and initial growth retarded due to low soil temperature and more variable moisture content across the field.

Sunflower breeding at Birmingham has followed exactly the same pattern as above. The genetic/breeding studies have involved sowing the experiments in the glass house which are later transplanted in the field. Generally, these experiments are sown in late May and the material is then ready to be transplanted outside during the first week of June. Contrary to this, commercial sunflower is sown around 1^{st} May where the crop is sown directly in the field and given an early start so that it can be harvested in early September, well before the onset of autumn. A late sown crop is assumed to lose out at the end of the season because wet and cold conditions could expose the ripening seed to *Botrytis/Sclerotinia* attack.

Toms and Pooni (1994) made comparisons between experimental and commercial densities and between single row and two row plots. Little difference was observed between the two types of plot or of density, especially when comparisons were made within the same sowing date, suggesting that sowing date effects were perhaps more important than those of plot size or density. Pooni, Virk and Hussain (1994) conducted a sunflower trial in 1992 in which they raised 66 families derived from an 11x11 half diallel set of crosses with selfs. This diallel was based on a set of restorer lines previously selected by Virk and Pooni (1994) for early maturity and high yielding ability. The present study, therefore, was conducted specifically to investigate the impact of sowing time on the performance of the 66 half-sib families mentioned before.

MATERIALS AND METHODS

The open pollinated seed of 66 half-sib families formed the experimental material for the present study. Two plots of each family were included in two sowings carried out on 11 May 1993 (normal sowing) and 3 June 1993 (late sowing). These sowings provided contrasting conditions during germination and early growth. The normal sowing was subjected to severe frosts during the month of May while the late sown sunflowers were exposed to above freezing temperatures all the time. The material was sown directly in a pre-prepared experimental field which had sandy loam soil fertilised with a complete fertiliser @ 56 g/m^2. The seeds were sown in rows 75 cm apart and the distance between hills within rows was kept at 15cm. Each plot consisted of a single row of 5 plants and the plots were completely randomised within each sowing. At each hill, 2-3 seeds were sown at a depth of 2.5 cm using a dibbler. The seedlings were thinned to one per hill at the 4 leaf stage and all plants were scored individually for the traits listed in Table 1. The performances of

Table 1: List of traits scored on the individual plants

Trait	Description
Plant height, H6	Measured in cm from the base to the top of the apical head of the plant six weeks after sowing
Flowering time, FT	Scored in whole days taken from sowing to pollen dehiscence on the main head
Height at flowering, HFT	Measured as H6 at the time of pollen dehiscence
Head diameter, HD	Distance in cm across the apical head at its widest point
Seed set, SS	Proportion of the apical head filled with seed scored on 0-10 scale where:0 = no seed set; 10 = complete seed set
Area of head set, AHS	Estimated for each plant in $cm^2 \times 10^1$ using the formula: $\pi(HD/2)^2(SS/100)$

the two sowings and of the various families within each sowing and across the sowings were compared using the t test and the ANOVA approaches of Snedecor and Cochran (1989), various correlations were estimated and tested following Steel and Torrie (1981), and the components of variances utilised to estimate the intra-class correlation as: $t = \sigma^2_{fams}/(\sigma^2_{fams} + \sigma^2_{plots} + \sigma^2_{within})$.

RESULTS

Effect on the overall performance

Given in Table 2 are the overall means of the normal and late sown families. These means show significant differences for four out of the six traits scored. Clearly, critical differences between the sowing dates were limited to the early growth traits and the largest t values are obtained for H6 and FT. Apparently, the normal sowing grew slowly and consequently took seven days longer to anther dehiscence relative to the late sowing.

Table 2: Average performance of the material in the normal and late sowings

Trait	Normal sowing	Late sowing	t
H6	22.81±0.35	30.44±0.58	7.91***
FT	119.53±0.25	112.23±0.26	10.22***
HFT	148.01±1.36	158.32±0.81	6.99***
HD	13.19±0.22	13.37±0.20	0.88
SS	7.42±0.10	6.89±0.11	2.01*
AHS	12.09±0.45	11.68±0.42	0.46

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

In fact, plants in the normal sowing remained shorter than those in the late sowing throughout their whole life. They were, on average, 10 cm shorter at the time of flowering, and as there was a very high correlation between HFT and height at the end of the season (Holtom, 1992; Virk and Pooni, 1994), this difference must have persisted right up to the end of the season. Other differences worth noting are those for HD and SS. There was significantly more seed set in the normal sowing but its head diameter was marginally smaller. Thus, critical differences were not detected between the overall means for any of the seed traits.

Effect on the variances

Mean squares (ms) obtained by the general linear model fitting procedure are given in Table 3. Both the families and sowing dates were treated as fixed effects and consequently these and the interaction ms were tested against the plots ms whenever the latter were significant, otherwise the within plots ms were used as error throughout. Results in Table 3 reveal that families differed significantly for all the traits, the sowing dates were significant for four traits and family x sowing date interaction was significant for FT only (see Table 3). This indicates that in general the families did not respond differently to sowing date in a critical manner. The components of the above ANOVA provided the following estimates of the intra-class correlation, t (see Falconer and Mackay, 1996, for details):

Trait	H6	FT	HFT	HD	SS	AHS
t	0.06	0.25	0.26	0.05	0.04	0.08

Two of these estimates (for FT and HFT) were very high but the others suggested that the remaining traits (H6, HD, SS and AHS) were moderately inherited in the present experiment.

Table 3: Combined analysis of variance for the normal and late sown materials

Trait	Mean squares				
	Families	Sowings	Fam x Sowing	Plots/fams/sowings	Within plots
	(65df)	(1df)	(65df)	(97df)	(800df)
H6	203.78***	15230.81***	112.81ns	135.43***	24.35
FT	223.31***	10632.25***	49.82***	34.36	30.01
HFT	3295.95***	24585.51***	668.36	575.26***	339.25
HD	22.79***	12.54	16.64	17.39	4.46
SS	6.82*	45.11***	4.60	4.64*	3.44
AHS	119.63**	1.53	71.58	82.98	64.32

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

The effects of sowing dates on the within plot ms were tested using the Bartlett's test of homogeneity (Snedecor and Cochran, 1989). A significant difference between the within plots ms would reveal that the families in each sowing showed markedly different response to sowing date because the sowings were planted adjacent to each other and therefore were unlikely to be exposed to large differences in soil type or agronomic practices in the experimental field. Table 4 shows that the χ^2 values were significant for two traits (HFT & SS). Thus, the within plots ms do not differ for the remaining 4 traits. Further, the ms of the normal sowing date was the smaller for SS and larger for HFT, indicating that neither sowing date was consistently more heterogeneous.

Table 4: Test of heterogeneity of the within plot mean squares

Trait	Normal sowing date		Late sowing date		χ^2
	ms	df	ms	df	
H6	24.97	350	23.87	450	0.20
FT	28.47	329	31.49	341	0.85
HFT	379.25	329	300.66	341	4.49*
HD	14.59	225	14.38	249	0.01
SS	2.84	218	3.98	245	6.45*
AHS	64.55	218	64.11	245	0.00

*p<0.05, ** p<0.01, *** p<0.001

Effect on correlation between sowings

The comparative performance of the families across the two sowings was further investigated using Pearson's (r) and Spearman's (r_{rank}) correlations. The former was calculated from the variances and the covariance between the family means while the latter utilised the variances and covariance of their ranks where the lowest family mean was given a score of 1 and the highest 66 (Steel and Torrie, 1980). Table 5 shows that all correlation coefficients were significant except r for HD and r_{rank} for SS. Further, all correlations were positive, suggesting that families generally showed similar performance across the sowing dates for most of the traits. However, all correlations were much lower than unity, indicating that genetic covariation in the material was rather low.

Table 5: Pearson's (r) and Spearman's (r_{rank}) correlations between family means across the sowing dates

Trait	r	r_{rank}
H6	0.33**	0.36**
FT	0.55***	0.45***
HFT	0.63***	0.53***
HD	0.20ns	0.27*
SS	0.25*	0.22
AHS	0.33**	0.46***

*p<0.05, ** p<0.01, *** p<0.001

Effect on correlation between traits

Traits can be correlated due to both the genetic and environmental causes. Environmental correlations are detected when the same environmental factors affect more than one character simultaneously. This type of correlation is observed among the individuals of inbred lines or F_1 hybrids. In segregating populations, such as F_2 or backcross, correlation between individuals are caused by both genetic and non genetic factors. On the other hand, correlations among the family means are due primarily to genetic causes, particularly when the family size is large (Kearsey and Pooni, 1996). In the present study, correlations among family means can be expected to differ in the two sowings when the effect of the sowing date is large and it modifies the phenotypic relationship between the traits.

Table 6: Correlations between traits in the normal and late sowings

Trait	Sowing	FT	HFT	HD	SS	AHS
H6	Normal	-0.21#	0.16	0.45***	0.25	0.45***
	Late	-0.34**	0.40***	0.41***	0.46***	0.39***
FT	Normal		0.74***	0.37***	0.17	0.36***
	Late		0.53***	-0.04	-0.03	0.03
HFT	Normal			0.49***	0.15	0.47***
	Late			0.27*	0.36**	0.31**
HD	Normal				-0.24	0.95***
	Late				-0.17	0.96***
SS	Normal					-0.31*
	Late					-0.21

correlations between family means
*p<0.05, ** p<0.01, *** p<0.001

Results in Table 6 show that H6, FT, HFT, HD and AHS were significantly correlated with each other in one or both sowings. On the other hand, SS was critically correlated on just three out of ten occasions. Negative correlation between H6 and FT suggests that fast growing plants flowered comparatively earlier than the slow growing ones. Positive values of the remaining correlations simply indicate that taller plants were also generally late flowering and produced larger heads. Correlation between HD and AHS was almost absolute, while other correlations were much smaller than unity.

Comparisons across the sowing dates showed that correlations were significant with almost equal frequency; 9 correlations were significant in the normal sowing and 10 in the late sowing. However, there were some subtle differences between the sowing dates in that H6 and HFT were more strongly correlated with other traits in the late sowing while correlations involving AHS were significant more frequently in the normal sowing. Nevertheless, none of the correlations showed a significant difference between the sowings except the r between FT and HFT.

Effect on the range of family means

Finally, comparisons of the range of scores among the family means indicated that sowing date had little effect on the overall spread of the families (Table 7). The minimum and maximum scores differed significantly between sowing dates only on one occasion (maximum score for H6) and the range did not differ for any trait. In fact, the range covered by the minimum and maximum scores was virtually the same in both sowings for FT, HFT, HD and SS, suggesting that the sowing date had

Table 7: The minimum and maximum scores among the family means in the normal and late sowings

Sowing	H6	FT	HFT	HD	SS	AHS
			Minimum score			
Normal	15.00	104.40	78.00	9.20	5.00	4.48
Late	17.00	100.43	69.71	9.00	4.00	2.15
Difference	-2.00	3.97	8.29	0.20	1.00	2.33
			Maximum score			
Normal	32.60	130.75	196.33	18.70	9.00	25.31
Late	41.60	127.00	183.40	18.00	8.71	31.11
Difference	-9.00*	3.75	12.93	0.70	0.29	-5.80
			Range			
Normal	17.60	26.35	118.33	9.50	4.00	20.89
Late	24.60	26.57	113.69	9.00	4.71	26.16
Difference	-7.00	-0.22	4.64	0.50	-0.71	-5.27

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

no effect on the comparative performances of the families. For H6 and AHS, however, the family means displayed a larger range in the late compared to the normal sowing. However, these differences were not significant and it can be assumed that the range did not differ between sowings for any of the traits.

DISCUSSION

Differences between the overall performance of families can arise for several reasons. Although the sowings were located side by side to minimise the soil and other environmental differences, such effects can not be eliminated entirely. Similarly, inter-plant competition may also differ between the sowings, especially when the plants of normal sowing will have adequate time to achieve full growth while those sown late will have 23 days less to do so. In the present case, some of the differences between overall means however must be attributed to the major effects of sowing date because they are too large to be accounted for solely by relatively minor factors associated with the effects of location and the agronomic practices.

One of the most important differences from the commercial point of view is for flowering time because it affects seed formation, seed development, seed maturity and harvest time. Although the results show that the late sowing took less time from sowing to flowering than the normal sowing, the normal sowing still flowered during the first week of September while the late sowing bloomed around 20th September. The late sown crop therefore runs a higher risk of being exposed to deteriorating weather at the end of the season and thus is more likely to fail compared with the crop sown in early May. Difference in plant height on the other hand reflects a genuine influence of the warmer weather which the late sown crop would encounter right from the time of sowing.

Otherwise, the two sowings show no plausible differences for other statistics such as family mean correlations, rank correlations or the range among the family means. Similarly, there is little family x sowing date interaction or difference between the within plot variances, and a modest to high level of heritable variation existed in the material for most traits.

CONCLUSION

The main conclusion of the study is that only early sown sunflowers are likely to be commercially successful in this country. Although the late sown crop catches up with the early sown material in terms of plant development and produces better growth, it is unlikely to be successful because it is always prone to severe losses due to frost and bad weather at the end of the season. It also follows that early maturing varieties are essential for the sunflower to be grown as a minor crop in the UK. Any variety which matures after mid September and takes more than 130 days from sowing to harvest will be too risky to grow as a commercial crop because its harvest will always be in doubt. Further, recommended varieties must also have thin necks and small heads so that they dry out quickly, before *Botrytis* can take hold and start to grow on the maturing head.

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COMPORTAMIENTO COMPARATIVO DE SIEMBRAS NORMALES Y TARDÍAS DE GIRASOL EN CONDICIONES BRITÁNICAS

RESUMEN

El éxito del cultivo de girasol en el Reino Unido (UK) depende mayormente de la siembra de variedades adecuadas en la fecha apropiada. Los datos de un largo número de familias de girasol en polinización libre fueron analizadas para determinar el impacto de siembras tardías en la expresión de seis caracteres, altura a las 6 semanas después de siembra, fecha de floración, altura en la floración, diámetro del capítulo, semilla llena y área de semilla llena. Las comparaciones de las medias revelaron que en la siembra tardía las plantas crecieron más rápidas y más altas y maduraron 7 días antes. La siembra normal, por otra parte, tuvo significativamente más semilla llena y las dos fechas de siembra no se diferenciaron críticamente para los restantes caracteres. Con la excepción de estas diferencias, el comportamiento de las familias fue consistente para las dos siembras y hubo poca coincidencia de la interacción familia x fecha de siembra o la interacción familia x microambiente por cualquiera de los caracteres. Estas observaciones fueron respaldadas por las correlaciones significativas y positivas entre las fechas de siembra mientras que las asociaciones entre caracteres no difirieron mucho. Solo una de 15 correlaciones entre caracteres se encontró que se diferenciaba significativamente. Las implicaciones más importantes de estos resultados se discuten y se muestra que el cultivo sembrado más temprano será comercialmente más exitoso en el Reino Unido.

COMPARAISON DES PERFORMANCE DES SEMIS NORMAUX ET TARDIFS DE TOURNESOL, EN GRANDE BRETAGNE

RÉSUMÉ

Le réussite de la culture du tournesol au Royaume Uni dépend fortement du semis de variétés convenables à la bonne période. Les données relatives à un grand nombre de familles en fécondation libre ont été analysées pour déterminer l'impact des semis tardifs sur l'expression de six caractères quantitatifs, c'est à dire: la taille six semaines après le semis, la date de floraison, la taille à floraison, le diamètre du capitule, la production de graines et la surface de fructification. La comparaison des moyennes montre que les semis tardifs se développent significativement plus vite, ont une taille plus élevée et une durée de maturation raccourcie de 7 jours. D'autre part, le semis normal produit significativement plus de graines et les deux dates de semis ne diffèrent pas de façon décisive pour les autres caractères. Excepté pour ces différences, la performance des familles était cohérente avec les dates de semis et quel que soit le caractère considéré li y avait peu de concordance pour les interactions (famille x semis) ou (famille x micro environnement). Ces observations sont renforcées par les corrélations significatives et positives entre les semis alors que les associations entre caractères diffèrent peu. Seule une corrélation entre caractères parmi les quinze étudiées, s'est avérée significative. Les conséquences les plus importantes de ces résultats sont discutées et il est montré que le semis précoce sera commercialement le mieux adapté pour cette culture au Royaume Uni.