INVESTIGATIONS INTO SEED SET IN SUNFLOWERS.

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ABSTRACT

The effect of pollination treatment and head size on seed set was investigated on three varieties of irrigated sunflowers (Hysun 30, DeKalb 500 and Sunfola 68-3). The four pollination treatments were nil, self, cross and natural pollination. It was found that head size has a marked effect on seed set in Hysun and DeKalb. That is, the bigger the heads the better the seed set. No such correlation could be found with Sunfola. Hence seed sets in hybrids should only be compared in populations of similar head size. A number of head size classes are proposed to allow comparison between varieties. Using this system, it was found that Dekalb and Hysun (self, cross, natural) and Sunfola (cross, natural) all had similar seed sets ranging from around 60% to 90% depending on head size. The unpollinated Hysun heads showed a drop in seed set ranging from 6% to 19% for the smallest and largest head size classes respectively. However, the unpollinated DeKalb heads did not show a clear drop in seed set (and then only a comparatively small decrease of 8%) until the largest head size class. This means that DeKalb and Hysun are fully self fertile and that the limiting factor in setting seed in these hybrids is their self pollinating ability and not their self fertility. DeKalb is marginally better self pollinating than Hysun. As expected, Sunfola was not self fertile. However a small number (7%) of Sunfola heads had the ability to pollinate and fertilise themselves to give high seed sets.

INTRODUCTION

There have been many studies which have shown the importance of cross pollination for good seed set in open pollinated sunflower varieties (for example, Furgala, 1954; Free and Simpson, 1964; Cirnu and Sanduleac, 1969; Free, 1970; Guynn and Jaycox, 1973; Langridge and Goodman, 1974; and Palmer-Jones and Forster, 1975). However, very little work has been forthcoming on hybrid varieties and published results have often been quite confusing (Low *et al.*, 1978; Radford *et al.*, 1979; George and Shein, 1980; Langridge, 1980 and Forrester *et al.*, 1980). In the past, there has been little appreciation of the differences between self pollinating ability and self fertility nor of the effect of such things as head size and temperature etc. on seed set. In addition, the effect of pollination treatments on sunflower yield and oil content and quality has not been adequately studied. This paper deals with the effect of head size and pollination treatment on seed set while subsequent papers will deal with grain yield and compensation, oil content and oil quality under different pollination treatments and temperatures. The eventual aim is to develop a set of guidelines to aid plant breeders in increasing self pollination and self fertility to a level where low pollinator activity (due to unfavourable weather or other reasons) will not adversely affect oil yield or oil quality.

MATERIALS AND METHODS

Three varieties of sunflowers (Hysun 30, DeKalb 500 and Sunfola 68-3) were sown on the Liverpool Plains Field Station, Breeza, N.S.W. They were sown in two split sowings (5 Sept. and 12 Sept. 1980) to ensure an overlapping flowering period for all three varieties. Each variety had 40 rows (20 early, 20 late sown) 120 metres long and was replicated 5 times. The three varieties were all sown at 60,000 plants per hectare except that the Sunfola sowings were considerably thinned out by wireworms and hares, leaving an establishment rate of around 30,000 plants/ha. Fertilizer was applied at the rate of 50 kg N and 12 kg P per hectare. The trial was planted on raised irrigation beds and fully irrigated (1 pre-irrigation, 4 pre-flowering and 2 post-flowering irrigations). In addition, the plots received 111 mm of rainfall mostly in October and December. Sunfola flowered from 26 November to 9 December (14 days) and the average daily maximum and minimum screen temperatures during that period were 32.3°C and 15.8°C respectively (2 days over 36°C). Hysun and DeKalb flowered from 3 December to 14 December (11 days) with comparable maximum and minimum screen temperatures of 32.5°C and 14.9°C respectively (2 days over 36°C). Sunfola was harvested on 16 Jan. 1981 and Hysun and DeKalb were harvested 1 week later.

There were four pollination treatments, all having a total of 50 heads/variety with 10 heads/replication.

(a) Nil pollination — Fine muslin bags (37 cm long by 32 cm wide) were placed over the heads just prior to flowering. They were tied down at each corner to ensure that the head was facing downward during the flowering period. This was done to prevent the bag from rubbing the face of the head and also to prevent pollen from the top florets falling onto the bottom florets. The bags remained in this position throughout flowering without any hand pollination. After flowering, the strings at each corner of the bag were cut to allow the head to resume its normal position. The bags were left on the heads until harvest.

(b) Self pollination — Fine muslin bags were placed over the heads just prior to flowering. The heads were allowed to remain in their vertical position. The bags were removed every 2 — 3 days and the heads were hand pollinated with a 12 mm bristle paint brush with pollen from its own head. A separate brush was used for each head and cross contamination of pollen was kept to a minimum by housing each brush in its own envelope and by enclosing the envelopes in a plastic bag while walking through the flowering crop. Towards the end of flowering, it was found necessary to retain some pollen in the envelope in order to pollinate the central female stigmas after the male anthers had finished producing pollen. The bags were left on the heads until harvest.

(c) Cross pollination — Fine muslin bags were placed over the heads just prior to flowering. The heads were allowed to remain in their vertical position. The bags were removed every 2 — 3 days and the heads were hand pollinated with a 12 mm bristle paint brush with pollen from its own and other heads. One brush was used for all the heads of the same variety. Pollen was collected from other heads by collecting it in muslin bags tied over heads in full flower. The bags were left on the heads until harvest.

(d) Natural pollination — The heads were left unbagged during flowering allowing free access for all insect pollinators, chiefly honey bees *Apis mellifera* L. In addition, these heads received the same pollination treatment as the cross pollinated heads above. Fine muslin bags were then placed over the heads at the end of flowering and left on until harvest.

All bagged heads were sprayed with a mixture of endosulfan (0.07%) and fenvalerate (0.01%) just prior to and after flowering, to prevent infestations by *Nysius* spp. and *Heliothis* spp. In addition, the whole trial area was sprayed a number of times with the same mixture to prevent a build up of the previously mentioned insect pests and the secondary fungal head rot, *Rhizopus* sp. Any of the treated heads showing signs of head rot infection were discarded in this trial (a total of 4 Sunfola and 1 DeKalb). The heads were hand threshed and sorted into set and unset seeds. Head diameters were recorded on dried heads by measuring the distance between the outer rows of seeds (the dried floret remains having been removed). Two perpendicular diameters were taken on each head and averaged, to account for non-circular heads. Head areas were then computed and analysed as a two factor split plot analysis of variance with pollination treatment

being the split factor and variety the other. Unfortunately this type of analysis was not applicable to the seed set data due to the correlation between seed set and head size. For these data, seed sets were assigned to their appropriate head size class ranges and analysed as unpaired 't' tests. The head size classes used in this work are only arbitrary but reflect the greater impact of smaller heads on seed set. (Increments are in 50 cm^2 for heads smaller than 300 cm^2, in 100 cm^2 for heads between 300 cm^2 and 500 cm^2 and in 150 cm^2 for heads over 500 cm^2).

The graphical relationship between seed set and head area for each variety was examined by plotting seed set versus head area for those heads where pollination treatment did not significantly alter seed set. This involved the self, cross and natural pollination treatments for Hysun and DeKalb (150 heads each) and the cross and natural pollination treatments for Sunfola (99 heads). A linear regression was performed on the Sunfola data and both constants in the linear regression equation were tested for significance by a 't' test and the correlation coefficient computed. The curvilinear relationships obtained for the Hysun and DeKalb heads have not yet been analysed statistically.

RESULTS

Factors affecting head size. These data are listed in Table 1. In the analysis of variance, the interaction means were not significantly different but the variety and pollination treatment means were. Sunfola had the biggest heads at all pollination treatments and the nil pollination treatment had the smallest heads for all varieties.

Table 1. Effect of pollination treatment and variety on head size. Means followed by the same letter are not significantly different at the 5% level.

Variety Means		Pollination Treatment Means	
	Head Area (cms^2)		Head Area (cm^2)
Sunfola	372a	Cross	353a
Hysun	311b	Self	345a
DeKalb	298b	Natural	339a
		Nil	271b

Interaction Means (NS)

	Head Area (cm^2)			
	Nil	Self	Cross	Natural
Sunfola	292	389	408	400
Hysun	257	337	338	310
DeKalb	264	309	313	306

Effect of head size on percentage seed set. These data are listed in Table 2 and Figure 1. The data for Sunfola clearly indicates no correlation between head size and seed set. However, there is a curvilinear relationship between head size and seed set for both Hysun and DeKalb. The exact mathematical relationship has not yet been computed, but generally up to head areas of about 3 — 400 cm^2, the bigger the head, the better the seed set.

Table 2. Effect of head size on percentage seed set (unbracketed figures) in three varieties of sunflowers. Figures in brackets are the number of heads used to determine the mean. Means, in the same row, followed by the same letter are not significantly different at the 5% level.

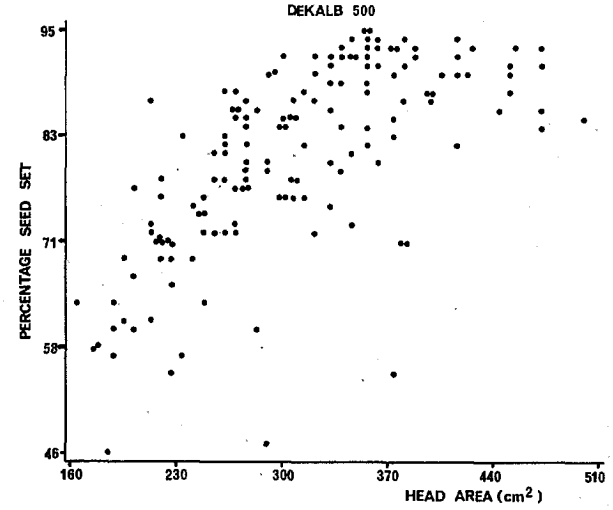
		Head Area Classes (cm^2)						
		100 — 150	151 — 200	201 — 250	251 — 300	301 — 400	401 — 500	501 — 650
Hysun	— Nil		59.8a(6)	67.1b(23)	73.3c(6)	69.2bc(14)		
30	— Self			72.2a(9)	81.6b(7)	87.1b(22)	88.3b(11)	
	— Cross			72.3a(7)	81.3b(12)	86.2c(15)	89.9d(9)	
	— Natural			74.0a(10)	83.0b(13)	89.9c(17)	89.8c(6)	
DeKalb	— Nil	45.7a(3)	54.9b(7)	64.2c(12)	74.6d(13)	78.6d(15)		
500	— Self		56.8a(4)	70.3b(7)	79.5bc(11)	85.0c(23)	88.8c(5)	
	— Cross		59.8a(4)	74.0b(10)	79.8bc(11)	85.0cd(18)	89.4d(7)	
	— Natural			66.7a(10)	80.5b(16)	88.5c(18)	89.6c(5)	
Sunfola	— Nil	31.5a(2)	22.6a(10)	15.5a(8)	31.8a(9)	30.0a(8)	35.2a(3)	34.8a(4)
68-3	— Self			33.2a(5)	40.4a(8)	41.1a(15)	27.8a(14)	29.1a(7)
	— Cross		77.0a(3)	71.5a(4)	82.5a(2)	77.6a(14)	76.8a(10)	80.5a(14)
	— Natural			86.4a(5)	82.8a(5)	84.4a(17)	82.8a(11)	84.0a(10)

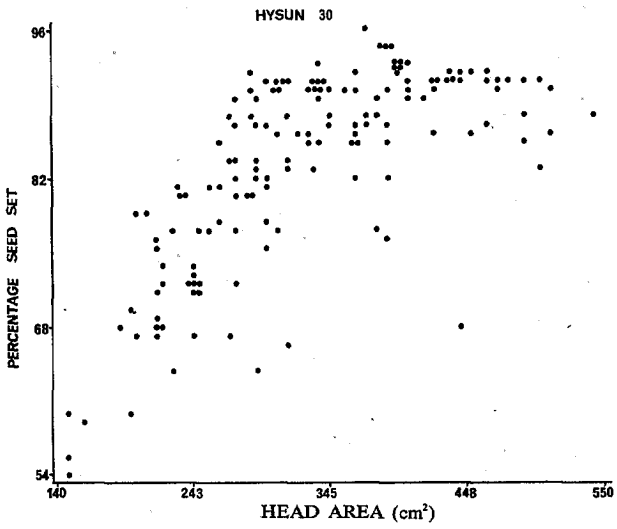
Effect of pollination treatment on percentage seed set. These data are listed in Table 3. In Sunfola, there was no difference between the nil and self treatments at all head sizes. The cross and natural treatments caused a dramatic increase in seed set, with both treatments generally giving similar seed sets. This means that Sunfola is neither self pollinating nor self fertile and that it is essential for transfer of pollen from head to head, to obtain a good seed set in this variety. However, it must also be noted that a small number of Sunfola heads (3 out of 46 in the nil pollinations treatment and 7 out of 50 in the self) had seed sets over 70%. This means that some Sunfola heads do possess the genetic potential to be self pollinating and/or fertile. In Hysun, there were no differences in the self, cross or natural pollination treatments. However, the nil pollination had marginally lower seed sets ranging from a 6% drop for the smallest heads (201 — 250 cm^2) to a 9% drop for 251 — 300 cm^2 heads to a 19% drop for 301 — 400 cm^2 heads. This means that Hysun is fully self fertile but that it lacks the ability to fully pollinate itself and that this inability assumes greater importance as head size increases. DeKalb showed a similar trend in that the self, cross and natural pollination treatments gave equivalent seed sets. However, in this variety the expected reduction in seed set in the nil pollination treatment was not clearly evident until larger head sizes were reached. In fact, in heads below 300 cm^2 there were no consistent differences between any of the four pollination treatments. Only in heads over 300 cm^2 was there a clear cut reduction in seed set and this was only an 8% reduction compared to a 19% drop in the equivalent Hysun head size class. Hence DeKalb is fully self fertile and its inability to pollinate itself is only really manifested in larger heads.

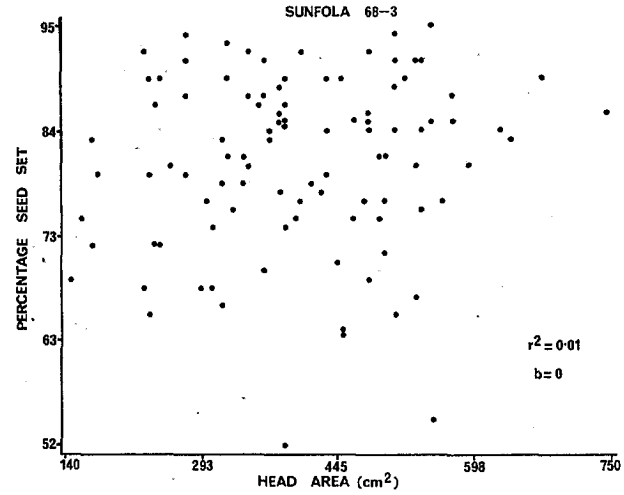
Table 3. Effect of pollination treatment on percentage seed set (unbracketed figures) in three varieties of sunflowers. Figures in brackets are the number of heads used to determine the mean. Means, in the same column, followed by the same letter are not significantly different at the 5% level.

		Head Area Classes (cm^2)						
		100 — 150	151 — 200	201 — 250	251 — 300	301 — 400	401 — 500	— 501 — 650
Hysun	— Nil		59.8(6)	67.1a(23)	73.3a(6)	69.2a(14)		
30	— Self			72.2b(9)	81.6b(7)	87.1bc(22)	88.3a(11)	
	— Cross			72.3b(7)	81.3b(12)	86.2b(15)	89.9a(9)	
	— Natural			74.0b(10)	83.0b(13)	89.9c(17)	89.8a(6)	
DeKalb	— Nil	45.7(3)	54.9a(7)	64.2a(12)	74.6a(13)	78.6a(15)		
500	— Self		56.8a(4)	70.3ab(7)	79.5.ab(11)	85.0b(23)	88.8a(5)	
	— Cross		59.8a(4)	74.0b(10)	79.8ab(11)	85.0b(18)	89.4a(7)	
	— Natural			66.7a(10)	80.5b(16)	88.5b(18)	89.6a(5)	
Sunfola	— Nil	31.5(2)	22.6a(10)	15.5a(8)	31.8a(9)	30.0a(8)	35.2a(3)	34.8a(4)
68-3	— Self			33.2a(5)	40.4a(8)	41.1a(15)	27.8a(14)	29.1a(7)
	— Cross		77.0b(3)	71.5b(4)	82.5b(2)	77.6b(14)	76.8b(10)	80.5b(14)
	— Natural			86.4c(5)	82.8b(5)	84.4c(17)	82.8b(11)	84.0b(10)

Figure 1. Effect of head area on percentage seed set in three varieties of sunflower; (a) Hysun 30, (b) Dekalb (500), and (c) Sunfola 68-3.







DISCUSSION

Factors affecting head size. The reason Sunfola had the biggest heads was no doubt due to this variety's lower plant establishment, as mentioned previously. The nil pollination treatment caused a significant reduction in head size for all varieties. The only factor that can be surmised to have caused this reduction is the physical shock of the tying down process involved in this treatment. The stressed plant would receive less light, which could be manifested as a smaller head. Other methods of obtaining a suitable nil pollination treatment, without tying down, have been tried but not yet analysed (Forrester, unpublished data).

Effect of head size on percentage seed set. There has been no previous work to show that percentage seed set is dependent on head size. This can be of critical importance when comparing seed sets of different hybrids as significant differences in seed set may be simply due to differing head sizes and not due to any real genetic differences at all. The head size classes proposed in this paper serve as a guideline for future screening work. Most modern hybrids have a small patch of unset seeds in the middle of the head. It is thought that this is due to the plant directing its food and water resources to the already set outer seeds in preference to the later flowering centre florets. This still seems to be the case in fully irrigated, adequately nourished and seemingly unstressed crops. This central patch of unset seeds would decrease in importance as head size (and hence seed number) increases. Hence, in these hybrids, the bigger the head the better the seed set. However, in Sunfola, the older open pollinated variety, percentage seed set is independent of head size. This is because Sunfola has the ability to set seed right to the centre of the head. This character is one that modern hybrids could well emulate.

Effect of pollination treatment on percentage seed set. Both Hysun and DeKalb proved to be fully self fertile but could not fully pollinate themselves in the absence of insects. The distinction between self pollination and self fertility has not often been appreciated but George and Shein (1980) tested 5 hybrids using a technique similar to that of Forrester *et al.*, (1980). George and Shein (1980) found 2 hybrids that were almost self fertile and with a reasonable ability to self

pollinate. However the other 3 hybrids had significantly lower self fertility and a poor self pollinating ability. The first 2 hybrids were similar to the two hybrids tested in this trial in that their self fertility was good and their self pollination reasonable. The small differences between the self and natural pollination treatments in George and Shein's (1980) best varieties may be due to a slightly different self pollination technique. Nevertheless, their work shows that self fertility can be a limiting factor in some hybrids. The results of this current trial would suggest that self pollination and not self fertility is the limiting factor to good seed set in the absence of pollinators. However, there is a large range of available hybrids with different genetic backgrounds and it is very hard to extrapolate across this range from work on just two hybrids. Therefore, it is suggested that screening for better seed set in hybrid sunflowers should be for a better self pollinating ability and better self fertility.

Fine muslin bags were used to exclude pollinators in this trial. The use of parchment or paper bags in this type of work is not recommended, as seed sets can be adversely affected by the use of inadequately ventilated bags during hot weather (Free, 1970). An interesting result was reported by Landridge (1974). He recorded a nil pollination seed set of 5% for Hysun 30 under bags (presumably paper) when flowering occurred over a particularly hot period (35 — 40°C). This was much lower than expected especially when the same treatment in cage trials gave a 63% seed set.

The performance of Sunfola in this trial was as expected for an open pollinated variety except for the small number of heads (3/46) which had the ability to pollinate and fertilize themselves. This means that the potential exists to develop a self pollinating and self fertile open pollinated variety, if the need ever arises.

Suggested preliminary guidelines for a standard seed set screening technique are:—

1) Choose sowing rate so that large heads (300 — 400 cm^2) are obtained (equivalent of 19.5 — 22.5 cms (7.7 —8.9") diameter). The bigger head size class is chosen as a marginal self pollinating ability may only manifest itself in larger heads e.g. DeKalb 500.
2) Trial should be fully irrigated. Moisture stress can cause a significant drop in percentage seed set (Forrester *et al.* loc. cit.).
3) Use well ventilated bags e.g. muslin, to isolate insect pollinators.
4) Compare nil pollination and natural pollination treatments in the same head size range. (Include self pollination treatment, if it is desired to know whether self pollination or self fertility or a combination of both, is the limiting factor).
5) Record temperature during flowering period.

The preceeding guidelines outline a method to screen seed sets. These seed set figures alone are of little value as increase in seed size can compensate to a certain extent for low seed set. Hence, the important question is: how low can seed set go before compensation is no longer effective and yield begins to fall? This and the equally important question of the effect of pollination treatment on oil content/quality, will be examined in later papers.

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EFFECT OF ISOLATION BAGS ON SEEDSET IN SUNFLOWER.

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ABSTRACT

Altered seedset under isolation bags could bias estimates of autogamy and self-compatibility. To study this effect, a split plot design was used where main plots were two F_1 hybrids and two inbred male fertile lines. Sub-plots were natural open-pollination (OP) and artificial open-pollination (AOP). The AOP treatment was performed daily on Delnet isolated heads by hand pollinating with foreign pollen. Mean seedset across inbreds for the OP (64%) and AOP (49%) treatments was significantly different but the mean seedset across hybrids was not. Thus genotypes were differentially affected by bagging. The reduced AOP seedset for one inbred was greater than observed in previous studies and suggests either a genotype x environment interaction for bag effect or severe floral injury during pollination. These results indicate that all studies of self-compatibility and autogamy should include an estimate of the effect of the isolating device on each genotype in each environment.

INTRODUCTION

Reliable estimates of autogamy and self-compatibility can only be obtained from isolated heads. Autogamous seedset under different types of isolation bags has differed significantly in previous studies (Hamilton, 1921; Putt, 1941; Kalton, 1951; Gundaev, 1971; and Robinson, 1980). If an isolation device affects genotypes differently, estimates for each genotype must be standardized for valid comparisons. Comparisons between biased estimates of autogamy and self-compatibility at different environments cannot be accurately interpreted.

The objective of this study was to estimate the effect of isolation bags on seedset. This was attempted in a previous study (George *et al.*, 1980) but accurate estimates were precluded by inadequate pollination.