



PROJECT REPORT No. OS30

**WINTER OILSEED RAPE:
POLLINATION OF VARIETAL
ASSOCIATIONS**

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POLLINATION OF VARIETAL ASSOCIATIONS**

by

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SUMMARY

Variety trials have shown that varietal associations can produce high yields relative to conventional varieties. However, these high yields depend on the male sterile female F1 plants being pollinated by the other component of the association.

It has been suggested that, when varietal associations are grown in isolated farm fields at the generally recommended seed rates, their yields are sometimes not as high as in variety trials where they are sown at the conventional seed rates and benefit from the pollen produced by neighbouring conventional varieties.

This report outlines two years of experiments to assess yields when varietal associations are grown at reduced seed rates within a crop of a varietal association so that pollen supply is not enhanced by neighbouring conventional varieties.

In both years, the performance of the associations was poorer in the isolated trials than at the nearest conventional trial site. This trend is illustrated using the example of the one variety common to the whole series of dedicated experiments and to official trials during the period, Synergy. In the 1996 harvest, at the five isolated trials it yielded 4.44 t/ha, 9% less than the nearest conventional trials with which they were paired and 10% less than the national mean for conventional trials. All of the five paired trials showed a lower yield for the isolated trial. In 1997 the mean yield of the three isolated trials was 19% lower yielding than of the paired conventional trials.

This poorer performance was associated with a much larger thousand seed weight which in some varieties in some sites reached 8 g/1000 compared with more typical rapeseed sizes of 4.5-5.5 g/1000. This suggests that it was seed number which limited yield in these trials. In 1996, low seed number appeared to be caused by fewer seeds per pod, but in 1997 pod survival may also have had a small influence. Hence to a farmer, the main manifestation of yields limited by poor pollination is likely to be low yields combined with a large seed size not poor pod numbers.

Reducing the seed rate of hybrids to that commonly used in farm situations reduced the yield of Synergy in these trials by 5% in 1996 and 1% in 1997. However, this treatment was also included in a total of 41 trials over the two years when the reduction was 3% and 4% in 1996 and 1997 respectively.

WINTER OILSEED RAPE: POLLINATION OF VARIETAL ASSOCIATIONS

1.0 Introduction

In the United Kingdom the first commercial hybrids of winter oilseed rape were composites, known as 'varietal associations' (VAs). These consist of a seed mixture principally of cytoplasmic male-sterile lines and a smaller proportion of one or more, conventional, fully fertile, varieties. The latter component is needed to supply pollen to allow the hybrid plants to set seed. While oilseed rape out-crosses readily, the crop itself is considered to be predominantly self-pollinating. The reliability of pollination in varietal associations, dependent as they are on cross-pollination, has therefore been a source of concern, both in the United Kingdom and elsewhere in Europe.

Since the first entries in 1992, varietal associations have been included in the same comprehensive series of variety trials as conventional varieties. Some have shown yield potential well above that of conventional varieties. In October 1995, the varietal association Synergy, became the first to be added to the UK Recommended List. Its yield at the time was 7% above the highest yielding variety, Capitol.

From the outset there has been debate about the extent to which varietal associations might benefit from pollen drift from neighbouring fully fertile varieties when randomised within these routine trials. This has led to the further question of whether such hybrid types can be considered as reliable "on farm" performers. Various schemes to monitor performance of such hybrids in isolation from conventional rape have been considered.

Isolated trials could be expected to indicate whether yields are broadly acceptable to growers. However, without the presence of conventional control varieties, it is clearly very difficult to demonstrate accurately and scientifically their economic advantage over conventional varieties. By including conventional controls the point of the exercise would be lost, since this would re-introduce a source of pollen in excess of the level normally produced by a varietal association.

Further concerns arose in the 1994/95 season when varietal associations appeared to be seriously affected by frost in the southern half of the country at the onset of the flowering period. A high proportion of aborted and poorly filled pods were observed and yields of varietal associations in general were not above those of the better conventional varieties. The relative yield of Synergy in 1994/95 was 109% of controls compared with 122% in the 1993/94 season.

Reports from other European countries also indicated poor pod set in a number of regions, although in others, particularly the more southerly and western French rape growing areas, growers and trial authorities reported a high degree of satisfaction.

In an attempt to investigate the performance of varietal associations the current project was proposed and designed by workers contributing to the recent EU Concerted Action: "Adaptation of oilseed crops management to new Common Agricultural Policy" (AIR 3 - CT94 - 2231). In the UK, the project, run as a two year investigation, has been funded by the Home-Grown Cereals Authority. A preliminary report after the first year, "Winter oilseed rape composite hybrid pollination trials" was presented to the HGCA in November 1996.

2.0 Aims

The principal aim of the project has been to determine the reliability of performance of varietal associations in situations reflecting farm cropping with relatively low external pollen availability.

Specific objectives were to investigate:

1. Yield variation of varietal associations at locations isolated from the high pollen availability associated with conventional rape crops.
2. Survival of the pollinator components of associations through to flowering.
3. Yield components, including number of pods per plant, seeds per pod and seed size for hybrid and pollinator plants.

3.0 Materials and methods

3.1 Design of isolated trials of varietal associations

Trials, separated from any other winter oilseed rape by a minimum of 400m and surrounded by a crop of a varietal association were grown to the following specifications:

- Replicates: 4
- Statistical design: complete block
- Plot size: 40m² at harvest
- Seed rate: 60 seeds/m²

3.2 Varietal associations tested

1995/96: Synergy, Cocktail, Cannon, Accent, B013, CCW 09, PMP SH 5005
1996/97: Synergy, Cocktail, Colorado, Concorde, Evora, Freja, RNX 54, Life, Corrida, Everest

Note: Of the varieties used in Year 1, all but Synergy and Cocktail were withdrawn by breeders and were not available for trials in Year 2.

3.3 Trial locations

Trials were conducted at the following locations by the organisations indicated:

Location	Site name
1995/96	
• Hardwick, Cambs. (NIAB)	Cambridge
• Cockle Park, Northumberland (NIAB)	Cockle Park
• North Ythsie, Grampian (SAC)	Aberdeen
• Banbury, Oxon. (CPB Twyford)	Banbury
• Rothwell, Lincs. (Nickerson Seeds)	Rothwell

1996/97

- | | |
|--------------------------------------|-------------|
| • Stowmarket, Suffolk (NIAB) | Morley |
| • Cockle Park, Northumberland (NIAB) | Cockle Park |
| • Westertown, Grampian (SAC) | Aberdeen |

A trial in Cambridgeshire failed to establish because of drought.

3.4 Plot recording

3.4.1 Plant populations

Populations were estimated by counting fixed row lengths in late autumn when establishment was complete. These lengths were marked and re-counted after the winter to assess any winter losses.

3.4.2 Pollinator survival and plant tagging

At flowering time, plants in each plot were assessed visually for the presence or absence of male sterility and a number of plants (60) were marked with coloured tags to indicate whether they were pollinators or hybrids. Proportions of pollinators in the plot counts were then compared with the proportions of seed of each of the components, (either 20% or 30% pollinator, as specified by the breeders). The survival rate of pollinators was calculated.

3.4.3 Plot yields and sampling

Plots were swathed as maturity approached and combined to assess fresh yield, once desiccation was complete. Sub-samples of seed were oven dried to estimate moisture content to allow yield, corrected to 9% moisture, to be presented.

At swathing, five tagged plants each of hybrid and pollinator were collected for detailed examination.

3.4.4 Plant recording

The sampled plants were assessed for a) aborted or seedless pod positions and b) number of pods containing one or more seeds.

The pods stripped from each set of five plants were sub-sampled to take 50 pods at random, to allow an estimate of seed numbers per pod to be made.

Seed was then sub-sampled to determine thousand seed weight.

3.4.5 Additional work at non-isolated trials in year 2 of the project

In 1996/97 all the assessments described above were carried out at the National List trial site nearest to each isolated location, for those varietal associations common to the two sets of trials. In addition, the conventional variety Falcon was similarly assessed, as was varietal association Synergy, sown at the higher seed rate of 120 seeds/m², in addition to its 60 seed/m² sowing.

Falcon was of particular interest since it is the pollinator of Synergy. Synergy has been grown in conventional trials at both seed rates for two years now in order to provide linkage between the breeders recommended seed rate (60/m²) and the standard seed rate for conventional varieties (120/m²).

4.0 Results and discussion

4.1 Environment and the performance of oilseed rape

For the last three growing seasons, the weather has been far from perfect for winter rape at flowering time over much of the south and east of the country. These seasons were marked by severe late frosts and spring droughts. Frosts often result in pod abortion and in rape it is common when examining affected plants to find zones of missing pod positions corresponding with frost periods. Normally the plants can compensate for such losses during later growth. However, the two dry springs are thought to have restricted uptake of nutrients from spring top dressings and limited the degree to which compensatory growth could occur. Some breeders have suggested that hybrids have a particularly high demand for sulphur at stem extension time to support their extra vegetative vigour. The combination of frost and nutrient stress it is suggested is potentially more severe for hybrids than for conventional varieties.

As already noted, rapid turnover of varietal associations in UK trials during the lifetime of the project, resulted in only Cocktail and Synergy being available for both years of the experiments. Accordingly, this report concentrates on these with full results for all varieties being presented in Appendix 1. Further detailed comparisons of variety performance between isolated and non-isolated sites are given in Appendix 2.

4.2 Yield

Seed yield, expressed as a mean of Synergy and Cocktail, ranged from 5.75 t/ha at Cockle Park in 1996, to 2.83 t/ha, in 1997 also at Cockle Park (Table 1). Although both Synergy and Cocktail were examined in each year of this project, only Synergy was included in routine National List and Recommended List trials in both years.

Table 1 Seed yield of Cocktail and Synergy in isolated trials

Harvest year	Site	Yield (t/ha at 9% moisture)		
		Varietal association		Mean
		Cocktail	Synergy	
1996	Aberdeen	4.39	4.20	4.30
	Banbury	3.68	3.69	3.69
	Cambridge	3.94	3.97	3.96
	Cockle Park	5.48	6.01	5.75
	Rothwell	4.29	4.32	4.31
	Mean	4.36	4.44	4.40
1997	Aberdeen	4.28	4.84	4.56
	Cockle Park	2.98	2.68	2.83
	Morley	4.36	3.82	4.09
	Mean	3.87	3.78	3.83
Two year mean		4.18	4.19	4.18

Table 1 shows that, although there were fluctuations in yield, the levels achieved in these experiments did not indicate major failure in the performance of varietal associations when grown in isolation from sources of abundant pollen. This is also apparent for the candidates tested in a single season (Tables 2 and 3).

Table 2 Seed yield of varietal association candidates: 1996

	Yield (t/ha at 9% moisture)						
	Synergy	Accent	Cannon	Cocktail	B 013	CCW 9	PMP SH 5005
Aberdeen	4.20	4.22	3.67	4.39	3.54	4.14	3.70
Banbury	3.69	3.48	3.29	3.68	3.19	3.52	3.52
Cambridge	3.97	4.51	4.57	3.94	4.55	4.62	4.41
Cockle Park	6.01	5.39	5.59	5.48	5.95	5.43	5.56
Rothwell	4.32	4.12	3.91	4.29	4.13	4.41	4.20
Mean	4.44	4.34	4.21	4.36	4.27	4.42	4.28

Table 3 Seed yield of varietal association candidates: 1997

	Yield (t/ha at 9% moisture)								
	Synergy	Colorado	Concorde	Corrida	Everest	Evora	Freja	Life	RNX 54
Aberdeen	4.84	4.46	3.87	3.91	4.63	4.34	3.87	4.21	4.62
Cockle Park	2.68	3.00	3.18	2.96	3.10	3.11	3.32	2.97	3.67
Morley	3.82	4.79	4.14	4.10	4.55	4.31	3.98	4.80	3.99
Mean	3.78	4.08	3.73	3.66	4.09	3.92	3.72	3.99	4.09

The results from the routine programme of variety trials are of interest because the varietal associations were grown in the presence of external pollen. Table 4 compares these results with those from the nearest isolated trial for the variety Synergy. In both series the quoted results are from plots sown at the rate of 60 seeds/m². Although results have been paired, it should be noted that different sites were involved.

Table 4 Synergy in isolated and non-isolated trials

Harvest year	Site	Yield t/ha at 9% moisture	
		Isolated	Non Isolated
1996	Aberdeen	4.20	5.41
	Banbury	3.69	4.52
	Cambridge	3.97	3.46
	Cockle Park	6.01	6.22
	Rothwell	4.32	4.97
	Mean	4.44	4.92
1997	Aberdeen	4.84	5.33
	Cockle Park	2.68	4.71
	Morley	3.82	3.84
	Mean	3.78	4.63
	Two year mean	4.19	4.81

The comparisons above are, however, of limited value. Several miles invariably separated the isolated hybrid sites from the conventional trials and the associated variability in soil fertility and moisture availability rule out any direct, scientific comparison between individual pairs of trials. However, there is a trend for Synergy to produce higher yields when grown in the presence of conventional, fully fertile varieties, than at the isolated sites.

4.3 Pollinator survival

In varietal associations, survival of sufficient pollinator plants within the predominantly male-sterile hybrid crop is clearly fundamental to the success of the crop. The pollinator plants were markedly shorter and less branched than the hybrid, being clearly less competitive.

Too high a proportion of pollinator will reduce yield by diluting the population of the higher yielding hybrid. Breeders therefore need to pay detailed attention to selecting pollinators and choosing an appropriate ratio for the commercial seed mixture. Pollinators must be chosen to provide a good “nick” with the hybrid both in terms of flowering date and overall height and vigour to compete adequately in the rapidly developing spring canopy. Breeders have addressed this in a number of ways: by the inclusion of a single pollinator, by the inclusion of two pollinators to spread the pollination period and by including restored hybrids as the pollinator to improve pollinator vigour. The proportions of pollinators investigated so far have been either 20% or 30%. Pollinator proportions in the growing plots are listed in Table 5.

Table 5 Percentage pollinator at flowering in isolated trials

Harvest year	Site	Percentage pollinator		
		Cocktail	Synergy	Mean
1996	Aberdeen	25	19	22
	Banbury	9	11	10
	Cambridge	12	12	12
	Cockle Park	24	18	21
	Rothwell	18	20	19
	Mean	17	16	17
1997	Aberdeen	10	24	17
	Cockle Park	26	25	26
	Morley	14	16	15
	Mean	17	22	19
	Two year mean	17	18	18

In general, it was observed that the proportion of pollinators was close to or just below that predicted by the nominal seed mixture but site-to-site and genotype variation was considerable. Winter losses and inter-plant competition are likely to have contributed to instances where pollinator proportion differed from the target. There were cases where the pollinator was below 10% of the population (Table 6 and Appendix 1b) but there were no clear indications of effects on yield.

4.4 Number of fertile pods per plant

The number of pods per plant for each varietal association was reasonably consistent across sites but very variable between sites (Table 6). It was also apparent that plant population did not always explain differences in pod number.

Table 6 Fertile pods

Harvest year	Site	Cocktail			Synergy		
		Plants <i>m</i> ²	Pods per plant		Plants <i>m</i> ²	Pods per plant	
			hybrid	pollinator		hybrid	pollinator
1996	Banbury	62.8	369	112	59.0	332	181
	Cambridge	34.8	379	89	28.0	549	207
	Cockle Park	40.5	430	156	43.0	473	200
	Rothwell	66.0	305	162	63.0	310	115
	Mean	51.0	371	130	48.3	416	176
1997	Aberdeen	25.0	446	319	24.8	515	258
	Cockle Park	28.0	168	106	23.5	192	113
	Morley	24.0	397	277	25.0	440	205
	Mean	25.7	337	234	24.4	382	192
	Two year mean	40.2	356	174	38.0	402	183

Plant analysis from the non-isolated trials allows us to examine pollinator competitive ability further. Table 7 indicates the effect of sowing density on pod numbers at three locations in 1997 with the male sterile hybrid plants of Synergy being compared with those of its pollinator, Falcon, at two seed rates. Data are included for Falcon grown as a pure variety.

Table 7 Pods per plant at non-isolated sites 1997

Site	Synergy				Falcon as a pure variety
	Male sterile hybrid component		Falcon pollinator component		
	60 seeds/ <i>m</i> ²	120 seeds/ <i>m</i> ²	60 seeds/ <i>m</i> ²	120 seeds/ <i>m</i> ²	120 seeds/ <i>m</i> ²
Aberdeen	548	459	262	229	284
Cockle Park	366	202	156	103	193
Morley	284	178	124	89	130
Mean	399	280	181	140	202

Hybrid plants showed marked heterosis for pod number. A consistent pattern for Falcon was observed at all three sites. The highest pod numbers were recorded in pure stands of the variety. A significant reduction in pod numbers occurred when grown in competition with the hybrid at high populations. This evidence should be taken to support the breeder's recommendation for the lower seed rate in order to safeguard the effectiveness of the pollinator. However, even at low population, in competition with the hybrid, with theoretically twice the growing space for each plant, Falcon still failed to produce the fertile pods recorded for pure stands of the same variety sown at high density.

4.5 Proportion of fertile pods

Over the two-year period the hybrids produced a slightly lower proportion of fertile pods than the pollinators, with the mean of Synergy and Cocktail giving 66.3% fertile pods for

the hybrids and 70.7 % fertile for the pollinators (Table 8). However, in this context all pods containing one or more seeds were classified as fertile.

Table 8 Flower positions producing fertile pods

Harvest year	Site	Fertile pods as % of flowers					
		Cocktail		Synergy		Mean	
		<i>hybrid</i>	<i>pollinator</i>	<i>hybrid</i>	<i>pollinator</i>	<i>hybrid</i>	<i>pollinator</i>
1996	Banbury	59	64	61	58	60	61
	Cambridge	52	61	53	65	53	63
	Cockle Park	76	68	77	76	77	72
	Rothwell	67	70	62	64	65	67
	Mean	64	66	63	66	63	66
1997	Aberdeen	79	85	85	79	82	82
	Cockle Park	78	84	82	88	80	86
	Morley	48	53	49	75	49	64
	Mean	68	74	72	81	70	77
	Two year mean	66	69	67	72	66	71

It had been speculated that the proportion of unfilled or aborted pods on the hybrids would be considerably greater than on the pollinators because of the dependence on cross-pollination.

Comparing sites, the proportion of fertile pods was seen to be greater at the northern sites (Aberdeen and Cockle Park) than at the southern sites. This is explained by the weather pattern, mentioned above, with the northern sites free of the late frost and drought effects described for the south and east.

4.6 Seeds per pod

Hybrid plants of Cocktail and Synergy produced 70% of the seeds per pod of the pollinator plants (Table 9). At Aberdeen in 1997 conditions for pollination appear to have been very good and seed numbers per pod were similar in hybrid and pollinator. Seed numbers per pod were very low at Cambridge in 1996 and Morley in 1997

Table 9 Seeds per pod

Harvest year	Site	Number of seeds per pod					
		Cocktail		Synergy		Mean	
		<i>hybrid</i>	<i>pollinator</i>	<i>hybrid</i>	<i>pollinator</i>	<i>hybrid</i>	<i>pollinator</i>
1996	Banbury	14	19	15	18	15	19
	Cambridge	9	14	9	22	9	18
	Cockle Park	15	22	16	23	16	23
	Rothwell	13	20	13	22	13	21
	Mean	13	19	13	21	13	20
1997	Aberdeen	20	20	20	22	20	21
	Cockle Park	15	19	15	22	15	21
	Morley	9	16	9	16	9	16
	Mean	15	18	15	20	15	19
	Two year mean	14	19	14	21	14	20

4.7 Seed weight

Thousand grain weight for separate hybrid and pollinator components was recorded in 1997. Seed of the hybrid plants (Table 10) tends to be larger than that of the pollinator plants and this trend is also seen in all the hybrids tested in this project (Appendix 1f). In 1997 the mean thousand seed weight of Cocktail and Synergy was 6.05g/1000 seeds for the male sterile hybrid plants and 4.35g/1000 seeds for the pollinators. Seed of the hybrid component showed more variation in size than that of the pollinator. In general, the relationship of seed size with seed numbers per pod is inverse and instances of low seed numbers are associated with large seeds (Morley, 1997 where the pollinator is unaffected) and high seed numbers with small seed, (Cockle Park 1996). This implies that hybrids have a large capacity for compensatory growth at seed development time.

Table 10 Thousand seed weight

Harvest year	Site	Thousand seed weight (g)					
		Cocktail		Synergy		Mean	
		<i>varietal association</i>		<i>varietal association</i>		<i>varietal association</i>	
1996	Banbury	5.30		5.39		5.34	
	Cambridge	6.48		6.90		6.70	
	Cockle Park	5.04		4.99		5.02	
	Rothwell	6.02		6.32		6.17	
	Mean	5.71		5.90		5.80	
1997		<i>hybrid</i>	<i>pollinator</i>	<i>hybrid</i>	<i>pollinator</i>	<i>hybrid</i>	<i>pollinator</i>
	Aberdeen	5.20	4.60	6.10	4.60	5.56	4.60
	Cockle Park	5.00	4.00	5.20	3.80	5.10	3.90
	Morley	7.20	4.90	7.60	4.20	7.40	4.55
	Mean	5.80	4.50	6.30	4.20	5.25	4.35

5.0 Conclusions

Performance of varietal association hybrids grown in isolation from fully fertile, conventional, oilseed rape has been broadly comparable with commercial rape crops. However, yields of the hybrids at the isolated varietal association hybrid-only sites have been, by an average of 15.1%, below those of the nearest conventional trial sites when sown at the same seed rate but with high levels of pollen available. This trend to lower yields from varietal associations grown in isolation, occurred in seven of the eight paired comparisons and was also identified in a series of trials conducted in N Europe in 1996.

The non-isolated series of recommended list trials included Synergy at two seed rates: 60 seeds/m², and 120 seeds/m². The 41 trials in 1996 and 1997 indicate a 3% advantage gained by growing the hybrid at the higher rate (Table 11).

This work has shown that pollinators are less vigorous than the hybrid plants and in the trials have shown survival rates down to 8% when sown as 20% or more of the combined population. The non isolated trials showed that the growth of Falcon in a mixed stand, was restricted during the flowering phase, resulting in small plants with little branching and fewer pods and seeds (Appendix 2a,b,c). Consequently there is a danger that increasing the seedrate to 120 seeds/m² could lead to the smothering of the pollinators before they flower to the extent that pollen supplies are inadequate.

Table 11 Effect of seed rate on yield: Synergy

Year	Yield (t/ha at 9% moisture)	
	60 seeds/m ²	120 seeds/m ²
1996	4.95	5.08
1997	4.45	4.62
Mean	4.70	4.85

At some sites (Cambridge 1996, Morley 1997) there were relatively high numbers of seeds in the pollinators and the hybrids produced a few large seeds per pod. This is a strong indication of seed set being limiting for the hybrid component which was probably caused by lack of pollen.

Ironically, it seems probable that poor pollination may actually increase the number of pods as the plant continues to flower in an attempt to increase the number of seeds set. The male-sterile hybrid plants have substantial capacity for compensatory growth. Either by prolonged flowering to produce more numerous pods or allowing development of larger seeds than are typical of conventional, non-hybrid plants. The degree to which compensatory growth is achieved will be dependent on environmental factors, including rainfall and nutrient availability.

Plotting pod numbers per hybrid plant against percentage survival shows that conditions in the trials have varied and that both varieties responded very similarly. For two sites (Cockle Park 1996 and Aberdeen 1997), both Cocktail and Synergy produce high pod numbers with a high percentage of the flowers producing pods. This suggests a relatively good pollination which is confirmed by high number of seeds per pod and the medium size

of those seeds. At one site (Cockle Part 1997), there was a high percentage conversion of flowers to pods but very few pods were set. The seeds were small and the yields low. This implies that some other factor curtailed the growth of the plants and pollination was not implicated.

However, at two sites (Cambridge 1996, Morley 1997), a large number of pods were set from a low percentage conversion of flowers. This implies that the plant produced a very large number of flowers in response to pollination difficulties which is confirmed by the low seeds per pod and the large seed achieved.

There is now strong evidence that varietal associations perform less well when grown in isolation than when grown in conventional trials. As a result of the first year's trials in this project, the recommended list variety testing protocol has been modified to provide isolation for varietal associations from conventional rape varieties while maintaining reasonable proximity to the main trials. The National List trials will also adopt this procedure for sowings in autumn 1998.

APPENDIX 1a Seed yield - t/ha (corrected to 9% moisture)

VARIETY	1995/96					Mean	1996/97			Mean	2 - year overall mean
	1	2	3	4	5		1	2	3		
Synergy	3.97	6.01	4.20	3.69	4.32	4.44	3.82	2.68	4.84	3.78	4.19
Cannon	4.57	5.59	3.67	3.29	3.91	4.21	*	*	*	*	*
Accent	4.51	5.39	4.22	3.48	4.12	4.34	*	*	*	*	*
Cocktail	3.94	5.48	4.39	3.68	4.29	4.36	4.36	2.98	4.28	3.87	4.18
B 013	4.55	5.95	3.54	3.19	4.13	4.27	*	*	*	*	*
CCW 9	4.62	5.43	4.14	3.52	4.41	4.42	*	*	*	*	*
PMP SH 5005	4.41	5.56	3.70	3.52	4.20	4.28	*	*	*	*	*
Colorado	*	*	*	*	*	*	4.79	3.00	4.46	4.08	*
Concorde	*	*	*	*	*	*	4.14	3.18	3.87	3.73	*
Evora	*	*	*	*	*	*	4.31	3.11	4.34	3.92	*
Freja	*	*	*	*	*	*	3.98	3.32	3.87	3.72	*
RNX 54	*	*	*	*	*	*	3.99	3.67	4.62	4.09	*
Life	*	*	*	*	*	*	4.80	2.97	4.21	3.99	*
Corrida	*	*	*	*	*	*	4.10	2.96	3.91	3.66	*
Everest	*	*	*	*	*	*	4.55	3.10	4.63	4.09	*
Mean of Synergy and Cocktail	3.96	5.75	4.30	3.69	4.31	4.40	4.09	2.83	4.56	3.83	4.18
LSD (PAIRS)	0.467	0.511	0.336	0.395	0.829	0.346	0.309	0.39	0.306	0.659	
S.E.	0.1559	0.172	0.1129	0.133	0.2765	0.1186	0.1064	0.1344	0.105	0.2007	
C.V.	7.1	6.1	5.7	7.6	13.2	6.1	5.0	8.7	4.9	8.9	

Sites - 1996: 1. Cambridge, 2. Cockle Park, 3. Aberdeen, 4. Banbury 5, Rothwell
 1997: 1. Morley 2. Cockle Park 3. Aberdeen

APPENDIX 1b Pollinator at flowering - percentage of the varietal association

VARIETY	1995/96					Mean	1996/97			Mean	2 - year overall mean
	1	2	3	4	5		1	2	3		
Synergy	12	18	19	11	20	16	16	25	24	22	18
Cannon	25	27	29	22	26	26	*	*	*	*	*
Accent	21	37	32	21	28	28	*	*	*	*	*
Cocktail	12	24	25	9	18	17	14	26	10	17	17
B 013	16	33	8	23	23	21	*	*	*	*	*
CCW 9	21	30	17	13	21	21	*	*	*	*	*
PMP SH 5005	15	30	11	8	21	17	*	*	*	*	*
Colorado	*	*	*	*	*	*	23	30	18	24	*
Concorde	*	*	*	*	*	*	21	24	15	20	*
Evora	*	*	*	*	*	*	19	28	12	20	*
Freja	*	*	*	*	*	*	10	16	9	12	*
RNX 54	*	*	*	*	*	*	29	29	*	29	*
Life	*	*	*	*	*	*	22	25	18	22	*
Corrida	*	*	*	*	*	*	26	26	21	24	*
Everest	*	*	*	*	*	*	22	25	20	22	*
Mean of Synergy and Cocktail	11.6	20.6	21.9	9.7	19.3	16.6	15.0	25.5	17.0	19.2	17.6

Sites - 1996: 1. Cambridge, 2. Cockle Park, 3. Aberdeen, 4. Banbury, 5. Rothwell
 1997: 1. Morley, 2. Cockle Park, 3. Aberdeen

APPENDIX 1c Fertile pods per plant (pods containing one or more seeds)

VARIETY		1995/96					Mean	1996/97			Mean	2 - year overall mean
		1	2	4	5	1		2	3			
Synergy	H	549	473	332	310	416	440	192	515	382	402	
	P	207	200	181	115	176	205	113	258	192	183	
Cannon	H	469	372	324	283	362	*	*	*	*	*	
	P	263	109	90	107	142	*	*	*	*	*	
Accent	H	347	313	267	297	306	*	*	*	*	*	
	P	89	130	175	151	136	*	*	*	*	*	
Cocktail	H	379	430	369	305	371	397	168	446	337	356	
	P	89	156	112	162	130	277	106	319	234	174	
B 013	H	439	471	328	435	418	*	*	*	*	*	
	P	90	158	131	115	124	*	*	*	*	*	
CCW 9	H	502	381	220	290	348	*	*	*	*	*	
	P	184	189	94	127	149	*	*	*	*	*	
PMP SH 5005	H	549	356	337	342	396	*	*	*	*	*	
	P	140	160	78	115	123	*	*	*	*	*	
Colorado	H	*	*	*	*	*	440	197	373	337	*	
	P	*	*	*	*	*	205	130	219	185	*	
Concorde	H	*	*	*	*	*	466	239	501	402	*	
	P	*	*	*	*	*	211	88	183	161	*	
Evora	H	*	*	*	*	*	439	258	378	358	*	
	P	*	*	*	*	*	125	127	270	174	*	
Freja	H	*	*	*	*	*	583	169	500	417	*	
	P	*	*	*	*	*	176	198	230	201	*	
RNX 54	H	*	*	*	*	*	472	180	201	326	*	
	P	*	*	*	*	*	286	104	*	195	*	
Life	H	*	*	*	*	*	473	211	574	419	*	
	P	*	*	*	*	*	286	68	190	181	*	
Corrida	H	*	*	*	*	*	411	247	360	336	*	
	P	*	*	*	*	*	230	75	236	180	*	
Everest	H	*	*	*	*	*	468	251	456	392	*	
	P	*	*	*	*	*	262	106	252	207	*	
Mean of Synergy and Cocktail	H	464	452	351	308	363	419	180	481	360	379	
	P	260	257	247	214	244	259	213	286	253	248	

Sites - 1996: 1, Cambridge; 2, Cockle Park; 4, Banbury; 5, Rothwell
 1997: 1, Morley; 2, Cockle Park; 3, Aberdeen

H = hybrid plants
 P = pollinator plants

APPENDIX 1d Flower positions producing fertile pods (%)

VARIETY		1995/96					Mean	1996/97			Mean	2 - year overall mean
		1	2	4	5	1		2	3			
Synergy	H	53	77	61	62	63	49	82	85	72	67	
	P	65	76	58	64	66	75	88	79	81	72	
Cannon	H	64	79	60	69	68	*	*	*	*	*	
	P	61	73	63	58	64	*	*	*	*	*	
Accent	H	49	77	58	63	62	*	*	*	*	*	
	P	68	80	65	65	70	*	*	*	*	*	
Cocktail	H	52	76	59	67	64	48	78	79	68	66	
	P	61	68	64	70	66	53	84	85	74	69	
B 013	H	53	80	65	67	66	*	*	*	*	*	
	P	39	76	73	62	63	*	*	*	*	*	
CCW 9	H	56	68	52	66	61	*	*	*	*	*	
	P	58	76	63	56	63	*	*	*	*	*	
PMP SH 5005	H	55	81	55	69	65	*	*	*	*	*	
	P	54	79	60	64	64	*	*	*	*	*	
Colorado	H	*	*	*	*	*	56	81	80	72	*	
	P	*	*	*	*	*	57	81	85	74	*	
Concorde	H	*	*	*	*	*	50	76	78	68	*	
	P	*	*	*	*	*	42	88	84	71	*	
Evora	H	*	*	*	*	*	56	71	80	69	*	
	P	*	*	*	*	*	36	79	83	66	*	
Freija	H	*	*	*	*	*	51	79	71	67	*	
	P	*	*	*	*	*	58	81	80	73	*	
RNX 54	H	*	*	*	*	*	48	73	*	61	*	
	P	*	*	*	*	*	54	75	*	65	*	
Life	H	*	*	*	*	*	53	81	75	70	*	
	P	*	*	*	*	*	73	86	88	82	*	
Corrida	H	*	*	*	*	*	54	83	85	74	*	
	P	*	*	*	*	*	66	84	87	79	*	
Everest	H	*	*	*	*	*	54	85	80	73	*	
	P	*	*	*	*	*	68	89	78	78	*	
Mean of Synergy and Cocktail	H	53	77	60	65	63	49	80	82	70	66	
	P	63	72	61	67	66	64	86	82	77	71	

Sites - 1996: 1. Cambridge, 2. Cockle Park, 4. Banbury, 5. Rothwell
1997: 1. Morley, 2. Cockle Park, 3. Aberdeen

H = hybrid plants
P = pollinator plants

APPENDIX 1e Seeds per pod in the hybrid and pollinator components

VARIETY		1995/96					Mean	1996/97			Mean	2 - year overall mean
		1	2	4	5			1	2	3		
Synergy	H	9	16	15	13	13	9	15	20	15	14	
	P	22	23	18	22	21	16	22	22	20	21	
Cannon	H	15	17	14	12	15	*	*	*	*	*	
	P	18	24	18	20	20	*	*	*	*	*	
Accent	H	12	17	15	12	14	*	*	*	*	*	
	P	18	19	20	20	19	*	*	*	*	*	
Cocktail	H	9	15	14	13	13	9	15	20	15	14	
	P	14	22	19	20	19	6	19	20	15	17	
B 013	H	8	13	13	11	11	*	*	*	*	*	
	P	20	21	17	25	21	*	*	*	*	*	
CCW 9	H	10	17	13	10	13	*	*	*	*	*	
	P	16	20	25	17	20	*	*	*	*	*	
PMP SH 5005	H	9	12	13	12	12	*	*	*	*	*	
	P	22	21	18	16	19	12	17	19	16	16	
Colorado	H	*	*	*	*	*	12	17	19	16	*	
	P	*	*	*	*	*	16	18	21	18	18	
Concorde	H	*	*	*	*	*	10	19	21	17	*	
	P	*	*	*	*	*	17	20	18	18	*	
Evora	H	*	*	*	*	*	11	16	20	16	*	
	P	*	*	*	*	*	18	19	17	18	*	
Freja	H	*	*	*	*	*	9	14	16	13	*	
	P	*	*	*	*	*	19	20	21	20	*	
RNX 54	H	*	*	*	*	*	12	14	*	13	*	
	P	*	*	*	*	*	14	17	*	16	*	
Life	H	*	*	*	*	*	11	16	20	16	*	
	P	*	*	*	*	*	18	16	20	18	*	
Corrida	H	*	*	*	*	*	10	13	24	16	*	
	P	*	*	*	*	*	15	18	22	18	*	
Everest	H	*	*	*	*	*	10	20	21	17	*	
	P	*	*	*	*	*	15	19	19	18	*	
Mean of Synergy and Cocktail	H	9	16	15	13	13	9	15	20	15	14	
	P	18	23	19	21	20	11	21	21	18	19	

Sites - 1996: 1, Cambridge; 2, Cockle Park; 4, Banbury; 5, Rothwell
 1997: 1, Morley; 2, Cockle Park; 3, Aberdeen

H = hybrid plants
 P = pollinator plants

APPENDIX 1f Thousand seed weight (g/1000)

VARIETY		1996/96					Mean	1996/97			Mean	2 - year overall mean
		1	2	4	5	1		2	3			
Synergy	H	6.90	4.99	5.39	6.32	5.90	7.60	5.20	6.10	6.30	6.07	
	P						4.20	3.80	4.60	4.20		
Cannon	H	5.46	4.70	5.46	5.46	5.27	*	*	*	*	4.20	
	P											
Accent	H	5.43	4.95	5.00	6.17	5.39	*	*	*	*	*	
	P											
Cocktail	H	6.48	5.04	5.30	6.02	5.71	7.20	5.00	5.20	5.80	5.75	
	P						4.90	4.00	4.60	4.50		
B 013	H	6.54	4.77	4.85	6.97	5.78	*	*	*	*	*	
	P											
CCW 9	H	5.67	4.63	5.44	6.42	5.54	*	*	*	*	*	
	P											
PMP SH 5005	H	6.41	4.75	5.39	6.75	5.83	*	*	*	*	*	
	P											
Colorado	H	*	*	*	*	*	6.90	5.60	6.00	6.17	*	
	P						5.50	4.40	5.40	5.10		
Concorde	H	*	*	*	*	*	7.10	5.40	5.90	6.13	*	
	P						4.90	4.70	5.30	4.97		
Evora	H	*	*	*	*	*	8.20	6.40	7.60	7.40	*	
	P						4.10	4.60	5.90	4.87		
Freja	H	*	*	*	*	*	8.20	6.00	6.00	6.73	*	
	P						4.10	4.10	4.40	4.20		
RNX 54	H	*	*	*	*	*	8.20	6.20	*	7.20	*	
	P						5.20	4.00	*	4.60		
Life	H	*	*	*	*	*	7.20	5.10	5.40	5.90	*	
	P						5.10	3.90	5.40	4.80		
Corrida	H	*	*	*	*	*	7.60	5.30	6.00	6.30	*	
	P						4.80	4.50	5.40	4.90		
Everest	H	*	*	*	*	*	7.60	5.30	5.50	6.13	*	
	P						4.10	4.30	4.20	4.20		
Mean of Synergy and Cocktail	H	6.70	5.02	5.34	6.17	5.80	7.40	5.10	5.56	5.25	5.91	
	P						4.55	3.90	4.60	4.35		

Sites - 1996: 1. Cambridge, 2. Cockle Park, 4. Banbury, 5. Rothwell
 1997: 1. Morley, 2. Cockle Park, 3. Aberdeen

H = hybrid plants
 P = pollinator plants

COMPARISONS OF YIELD COMPONENTS AT ISOLATED AND NON-ISOLATED TRIAL SITES:

APPENDIX 2a Morley

WR7EE12T/MORLEY - NON-ISOLATED TRIAL

VARIETY	HYBRID						POLLINATOR						
	YIELD (T/HA)	ABORTED PODS	FERTILE PODS	POD % SURVIVAL	PLANT HEIGHTS (CM)	SEEDS PER POD	TSW (g)	ABORTED PODS	FERTILE PODS	POD % SURVIVAL	PLANT HEIGHTS (CM)	SEEDS PER POD	TSW (g)
FALCON	4.53	*	*	*	*	*	*	50	130	72	75	23	4.4
SYNERGY (60)	4.70	87	284	77	100	18	4.4	60	124	67	76	21	3.8
SYNERGY (120)	4.93	61	178	74	88	19	4.0	38	89	70	63	18	3.8
FREJA	4.07	63	192	75	86	20	4.6	36	73	67	40	21	3.8
CONCORDE	4.82	48	145	75	70	22	4.5	37	89	71	65	19	4.1
COLORADO	4.88	60	179	75	82	18	4.7	39	97	71	73	19	4.2
EVORA	4.44	74	184	71	78	18	4.6	28	78	74	107	19	4.2
MEAN	4.62	66	194	75	84	19	4.5	40	92	70	71	20	4.0

WR7EE32T/MORLEY - ISOLATED TRIAL

VARIETY	HYBRID						POLLINATOR						
	YIELD (T/HA)	ABORTED PODS	FERTILE PODS	POD % SURVIVAL	PLANT HEIGHTS (CM)	SEEDS PER POD	TSW (g)	ABORTED PODS	FERTILE PODS	POD % SURVIVAL	PLANT HEIGHTS (CM)	SEEDS PER POD	TSW (g)
SYNERGY	3.82	449	440	49	128	9	7.6	69	205	75	82	16	4.2
FREJA	3.98	553	583	51	137	9	8.2	127	176	58	77	19	4.1
CONCORDE	4.14	379	385	50	126	10	7.7	173	126	42	84	17	4.9
COLORADO	4.79	369	466	56	116	12	6.9	157	211	57	96	16	5.5
EVORA	4.31	338	439	56	128	11	8.2	226	125	36	87	18	4.5
CORRIDA	4.10	354	411	54	115	10	7.6	120	230	66	93	15	4.8
EVEREST	4.55	406	468	54	123	10	7.6	123	262	68	80	15	4.1
RNX54	3.99	510	472	48	127	12	8.2	240	286	54	92	14	5.2
COCKTAIL	4.36	430	397	48	132	9	7.2	248	277	53	90	16	4.9
CGW10 (LIFE)	4.80	423	473	53	131	11	7.2	86	231	73	98	18	5.1
MEAN	4.28	421	453	52	126	10	7.6	157	213	58	88	16	4.7

COMPARISONS OF YIELD COMPONENTS AT ISOLATED AND NON-ISOLATED TRIAL SITES:

APPENDIX 2b Cockle Park

WR7N10T COCKLE PARK - NON-ISOLATED TRIAL

VARIETY	HYBRID					POLLINATOR							
	YIELD (T/HA)	ABORTED PODS	FERTILE PODS	POD % SURVIVAL	PLANT HEIGHTS (CM)	SEEDS PER POD	TSW (g)	ABORTED PODS	FERTILE PODS	POD % SURVIVAL	PLANT HEIGHTS (CM)	SEEDS PER POD	TSW (g)
FALCON	4.16	*	*	*	*			53	193	78	71	22	4.6
SYNERGY (60)	3.83	163	366	69	79	13	4.4	71	156	69	62	19	3.9
SYNERGY (120)	4.84	87	202	70	90	13	4.4	48	103	68	68	20	3.8
FREJA	4.81	49	90	65	34	12	4.6	34	47	58	32	15	3.5
CONCORDE	4.45	65	94	59	67	12	5.6	33	52	61	109	15	3.4
COLORADO	4.16	53	147	74	77	16	6.0	36	77	68	61	19	5.2
EVORA	4.44	68	116	63	64	14	5.8	52	100	66	69	17	3.4
MEAN	4.38	81	169	67	69	13	5.1	46	89	65	67	18	3.9

WR7N31T COCKLE PARK - ISOLATED TRIAL

VARIETY	HYBRID					POLLINATOR							
	YIELD (T/HA)	ABORTED PODS	FERTILE PODS	POD % SURVIVAL	PLANT HEIGHTS (CM)	SEEDS PER POD	TSW (g)	ABORTED PODS	FERTILE PODS	POD % SURVIVAL	PLANT HEIGHTS (CM)	SEEDS PER POD	TSW (g)
SYNERGY	2.68	41	192	82	114	15	5.2	16	113	88	86	22	3.8
FREJA	3.32	46	169	79	117	14	6.0	47	198	81	107	20	4.1
CONCORDE	3.18	77	239	76	115	19	5.4	12	88	88	77	20	4.7
COLORADO	3.00	47	197	81	116	17	5.6	31	130	81	87	18	4.4
EVORA	3.11	106	258	71	112	16	6.4	34	127	79	86	19	4.6
CORRIDA	2.96	50	247	83	124	13	5.3	14	75	84	73	18	4.5
EVEREST	3.10	46	251	85	106	20	5.3	13	106	89	79	19	4.3
RNX54	3.67	68	180	73	102	14	6.2	35	104	75	86	17	4.0
COCKTAIL	2.98	47	168	78	118	15	5.0	20	106	84	89	19	4.0
CGW10 (LIFE)	2.97	49	211	81	104	16	5.1	11	68	86	54	16	3.9
MEAN	3.10	58	211	79	113	16	5.6	23	112	83	82	19	4.2

COMPARISONS OF YIELD COMPONENTS AT ISOLATED AND NON-ISOLATED TRIAL SITES:

APPENDIX 2c Aberdeen

WRTNS2T FORDOWN - NON-ISOLATED TRIAL

HYBRID										POLLINATOR				
VARIETY	YIELD (T/HA)	ABORTED PODS	FERTILE PODS	POD % SURVIVAL	PLANT HEIGHTS (CM)	SEEDS PER POD	TSW (g)	ABORTED PODS	FERTILE PODS	POD % SURVIVAL	PLANT HEIGHTS (CM)	SEEDS PER POD	TSW (g)	
FALCON	5.54	*	*	*	*			27	284	91	99	22	4.9	
SYNERGY (60)	5.30	55	548	91	130	20	5.0	30	262	90	103	15	4.7	
SYNERGY (120)	5.44	59	459	89	117	16	5.4	44	229	84	93	16	4.8	
FREJA	5.46	89	364	80	115	16	5.4	52	236	82	98	21	5.1	
CONCORDE	5.59	62	382	86	110	21	5.5	58	342	86	107	19	5.4	
COLORADO	5.25	80	437	85	116	18	5.5	23	166	88	85	20	5.8	
EVORA	5.51	141	444	76	121	22	5.7	87	336	79	107	20	5.0	
MEAN	5.44	81	439	84	118	19	5.4	49	262	85	99	19	5.1	

WRTNS31T WESTERTOWN - ISOLATED TRIAL

HYBRID										POLLINATOR				
VARIETY	YIELD (T/HA)	ABORTED PODS	FERTILE PODS	POD % SURVIVAL	PLANT HEIGHTS (CM)	SEEDS PER POD	TSW (g)	ABORTED PODS	FERTILE PODS	POD % SURVIVAL	PLANT HEIGHTS (CM)	SEEDS PER POD	TSW (g)	
SYNERGY	4.84	88	515	85	137	20	6.1	70	258	79	124	22	4.6	
FREJA	3.87	208	500	71	158	16	6.0	57	230	80	109	21	4.4	
CONCORDE	3.87	139	501	78	160	21	5.7	36	183	84	122	18	5.3	
COLORADO	4.46	96	373	80	140	19	6.0	38	219	85	118	21	4.8	
EVORA	4.34	96	378	80	143	20	7.6	56	270	83	115	17	5.9	
CORRIDA	3.91	115	350	85	137	24	6.0	35	236	87	125	22	5.4	
EVEREST	4.63	112	456	80	138	21	5.5	71	252	78	118	19	4.2	
COCKTAIL	4.28	121	446	79	161	20	5.2	55	319	85	134	20	4.6	
CCW10 (LIFE)	4.21	195	574	75	146	20	5.4	27	190	88	117	20	5.4	
MEAN	4.27	130	455	79	147	20	5.9	49	240	83	120	20	5.0	