REPORT OF EUROPEAN CO-OPERATIVE STUDY OF FERTILITY IN HYBRID VARIETAL ASSOCIATIONS

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ABSTRACT

Hybrid variety associations (VA's) are a mixture of male sterile hybrid plants and fertile plants of one or more varieties. Concern over the reliability of VA's led to a co-operative study by Austria, France, Germany and the UK. Trials were conducted in 1996 and 1997 to assess yield, quality and agronomic performance. In addition, the UK examined components of yield of hybrids and pollinators separately for each VA under test. The performance of VA's trialled in proximity to and isolated from conventional varieties was compared. Examining the evidence from trials and field crops from different regions within Europe has allowed us to conclude that pollination may be sub-optimal when VA's are grown in isolation from fully fertile rape. Consequently, VA yield potential measured in trials containing conventional varieties could be overestimated and the testing procedures have been changed to limit this possibility.

KEYWORDS cytoplasmic male sterility, pods, pollen, trials

INTRODUCTION

The quest for hybrids of oilseed rape, with a yield advantage over conventional lines and able to achieve suitable quality standards, has proved difficult. In particular, the restorer gene for the widely used Ogura cytoplasmic male sterility system (Ogura, 1968), is associated with genes controlling glucosinolate content (Delourme, 1995). Consequently, most restored Ogura hybrids have an unacceptably high glucosinolate content. To overcome this problem the first hybrids to be submitted for official trials in the UK were hybrid varietal associations (VA's): seed mixtures, predominantly of male sterile hybrid lines with, typically, 20% of one or more fully fertile, 'line' varieties as the pollen source. In the field the hybrid component is easily identified at flowering, usually having reduced petal size and with vestigial anthers that produce no pollen.

The first VA to show real promise was the French-bred Synergy, first tested in France in 1993 and in the UK in 1994. In the first year of UK trials, its mean yield was 23% above the mean of controls with very high yields in all trials but since then its performance has been more marginal with some trial results at or below the control mean. From the out-set there has been concern that this system might be flawed by the reliance of the hybrid plants on cross pollination, in a crop traditionally considered mainly self pollinating. In France, additional trials at isolated locations have been used to assess pollination in the absence of conventional rape (CTPS, 1994). In the UK isolated trials were introduced for harvest 1995. The 1995 spring was unusually dry and cold across Europe with numerous reports of pod abortion and poor seed set. This was particularly so in southern areas of the UK. With heightened concerns over VA's, the 1995 Rapeseed Congress in Cambridge created an opportunity for workers already collaborating on the EU Concerted Action on Oilseeds, to design a 2-year joint examination of the reliability of VA's across Europe. This paper considers the key findings of the European trials network and examines in greater detail additional work in the UK.

MATERIALS AND METHODS

A network of hybrid varietal associations was established in Austria, France, Germany and the United Kingdom and grown using a standard protocol. The 4-replicate trials were isolated by a minimum of 400m from the nearest oilseed rape crop and surrounded by a VA border. The project ran for two years with 14 trials in year one and 15 in year two. VA's in the trials were those included in the various European National Lists and, in the UK, additional entries undergoing their second year of official trials. A total of 14 varietal associations were studied but because of withdrawal of some of these after the first year, only two, Synergy and Cocktail, were included in the whole 29 trial matrix. These were both bred in France by Serasem and Cargill Semences, respectively.

In addition to measurement of seed yield, a range of field characters was recorded, with emphasis on estimating the proportions of pollinator plants present at flowering—by inspection of 60 plants per plot. Seed samples were assessed for seed weight, oil content and glucosinolate content. Additional work in the United Kingdom examined yield components for both pollinator and sterile hybrid plants within each plot at isolated and non-isolated sites. Pollinator and hybrid plants were tagged at flowering to allow observation of:

- Fertile pods per plant (containing one or more seeds)
- Number of seeds per pod
- Aborted pod positions per plant
- Seed weight (g/1000)

RESULTS AND DISCUSSION

Data from the European Network

Table 1 summarises the key features the network's findings, looking at yield, pollinator survival and seed size of Cocktail and Synergy. The mean yield of 4.19 t/ha gives some reassurance that in many situations this type of hybrid system can produce high yields. However, Figure 1 demonstrates that considerable variation in yield was observed, with the lowest yield, 2.31 t/ha, in Austria in 1996 and a high of 5.75 t/ha, in the north of England, in the same year. Furthermore, comparison with yields at the nearest conventional trial location suggested that yields at isolated locations may have been sub-optimal. Comparisons of isolated *vs.* non-isolated trials are available for 25 of the locations. In 19 of the comparisons, Synergy in the isolated trials gave lower yields (4.3 t/ha) than in the nearest conventional trials (4.7 t/ha). These comparisons cannot be submitted as rigorous evidence of sub-optimal pollination, because of the differences in soil fertility, rainfall and microclimate between the paired locations. They do, however, add further weight to the general concern over reliability of varietal associations. This concern partly arose following a preliminary series of isolated trials in 1995 in which VA's produced low yields. This year was conspicuous for poor seed set and pod abortion and the mean yield of eight VA's at two locations was 3.4 t/ha (Kightley, 1996).

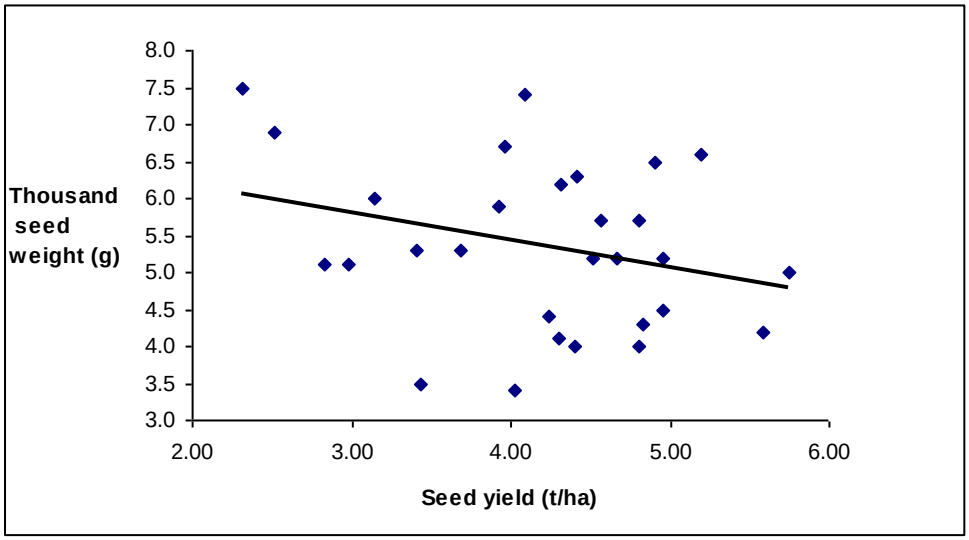
Table 1 Yield, pollinator proportion at flowering and seed weight: mean data

	Seed yield (t/ha)			Pollinators (%)			Seed weight (g/1000)		
	1996	1997	Mean	1996	1997	Mean	1996	1997	Mean
Cocktail	4.42	3.97	4.19	16	17	17	5.6	5.2	5.4
Synergy	4.37	4.01	4.18	18	23	20	5.5	5.1	5.3
Mean	4.40	3.99	4.19	17	20	19	5.5	5.1	5.3

One concern with the varietal association concept has been the survival of line variety pollinators in association with hybrid plants likely to have higher vegetative vigour. As indicated by Table 1, plant

counts revealed pollinator levels at or just below their nominal proportion in the seed mixture (20% in both cases). At two sites, pollinator numbers of about 10% were recorded. One of these was the low yielding Austrian trial and the other was a UK trial at which the mean yield of 3.69 t/ha was recorded, a comparatively low figure for the season. Clearly pollinator survival remains an area of concern with varietal associations and we return to this subject when considering the UK studies.

Figure 1 Relationship between seed yield and thousand seed weight. Mean data for Cocktail and Synergy 1996/1997



Oilseed rape is renowned for its ability to compensate for poor establishment and one of the mechanisms for this is by increasing seed size. Large (heavy) seeds are usually associated with either poor populations or poor pollination. However, the relationship between seed size and yield is by no means clear since, though high yields are often associated with high numbers of small seeds, small seed can also occur in situations of low yield due to drought or disease. The trend line fitted to the chart in Figure 1 is not significant. The scatter was, however, consistent with the principle of high thousand seed weights indicating sub-optimal pollination at the two lowest yielding sites and but a good degree of compensation at others.

Data from the UK series

The following section summarises the detailed investigations of the reproductive behaviour of varietal associations conducted in the UK by Kightley (1998).

Yield As indicated in the previous section there is a trend for yield at the isolated sites to fall below those at non-isolated sites. This was consistently the case in the UK series, (Table 2). Synergy at non-isolated sites showed a yield advantage of 0.77 t/ha. Nationally, based, on the 4-year Recommended List data matrix, the yield of Synergy is estimated at 4.48 t/ha, now only equal to the highest yielding conventional variety, Escort.

Table 2 Seed yield - t/ha (corrected to 9% moisture) for Cocktail and Synergy at eight UK isolated trial sites compared with Synergy yields at non-isolated sites

	Trial sites 1996[a]						Trial sites 1997[b]				Mean 96/97
Variety	Camb.	Cock.	Aber.	Banb.	Roth.	Mean	Stow.	Cock.	Aber.	Mean	
isolated											
Cocktail	3.94	5.48	4.39	3.68	4.29	4.36	4.36	2.98	4.28	3.87	4.18
Synergy	3.97	6.01	4.20	3.69	4.32	4.44	3.82	2.68	4.84	3.78	4.19
Mean	**3.96**	**5.75**	**4.30**	**3.69**	**4.31**	**4.40**	**4.09**	**2.83**	**4.56**	**3.83**	**4.18**
non-isolated											
Synergy[c]	4.71	6.22	5.41	4.52	4.97	4.79	3.83	4.70	5.30	4.61	4.96

[a] 1996 sites: Cambridge, Cockle Park (Northumberland), Aberdeen (Scotland), Banbury (Oxfordshire), Rothwell (Lincolnshire).
[b] 1997 sites: Stowmarket (Suffolk), Cockle Park, Aberdeen.
[c] Synergy yields at the nearest non-isolated trial site.

Components of yield Table 3 summarises yield components for the hybrid and pollinator, measured in the UK series, as a mean of the values of Synergy and Cocktail. The data are broadly comparable to those published by CETIOM (1994) in France. The discrepancy in pod numbers between the hybrid and pollinator components merely served to quantify clear visual differences between the two types of plants. The hybrid plants were invariably taller and more extensively branching in habit. This was taken to be a strong indication that there is a strong competition effect within varietal associations, limiting the growth and the effectiveness of the pollinator.

Table 3 Yield components: mean of Cocktail and Synergy in UK trials[a]

Component	Pods/plant		Seeds/pod		Seed size (g/100)	
	1996	1997	1996	1997	1996	1997
Hybrid	394	360	13	14	5.8[b]	5.25
Pollinator	153	213	20	19	-	4.35

[a] Mean population of VA mixture: 40 plants/m^2.
[b] Estimated seed weight from whole plot harvest samples containing hybrid and pollinator seed.

Further evidence of this came from the non-isolated sites in 1997. During this period Synergy was being grown at two seed rates: 70 and 120 seeds/m^2. This was because the traditional seed rate for oilseed rape in the UK has been 120 seeds, while for agronomic and seed cost reasons hybrids seed rates have been recommended at 70 seeds/m^2. Plant tagging and plant recovery was carried out at both seed rates and also on the variety, Falcon, chosen not just as an example of a conventional variety, but because it is the pollinator in the Synergy association. Thus data was available for Falcon grown as a pure stand at 120 seeds/m^2, as a pollinator in an association sown at 120 seeds and at 70 seeds/m^2, (Table 4). The data suggests that development of the pollinator plants is indeed suppressed when grown within a varietal association and, even when not in competition with hybrid plants, pod production is less prolific than the hybrid.

Over the two year period the hybrid plants produced 30% fewer seeds/pod than the pollinator. However in 1997, when this deficit was only 21%, the data show that there was an apparent seed weight compensation of 26%. This assumption may be too simplistic, however. An alternative interpretation of the seed weight difference between hybrid and pollinator may equally be an extension of the competition effect between the two components. Thus the smaller seed weight of the pollinator seed might be attributable to reduced access to light, water and nutrients.

Table 4 Pod numbers per plant at non-isolated sites: comparison of hybrid and pollinator plants. Mean data for 3 locations on 1997

Synergy				Falcon (pure)
Male sterile hybrid		Falcon pollinator		
70 seeds/m^2	120 seeds/m^2	70 seeds/m^2	120 seeds/m^2	120 seeds/m^2
399	280	181	140	202

To blame lack of pollen as the principal source of yield variation would be misleading. There is circumstantial evidence from recent seasons that weather and nutrient stress can have a direct bearing on hybrid performance. Frost, drought and nutrient stress all appear to have an influence on hybrids during the period of rapid spring growth. Certain symptoms, particularly low seed numbers, which have been attributed to poor pollination are very similar to those associated with sulphur deficiency for example. It is beyond the scope of this paper to explore plant stress more fully.

CONCLUSIONS

Cross pollination appears a yield limiting factor in VA's and it is suggested that a principal cause of this is the relative lack of vigour of conventional varieties in such mixtures. This is clearly illustrated when comparing pod numbers per plant of the two components. Reduced seed numbers in hybrid pods indicates sub-optimal pollination and there may be compensation from increased seed size. The consistent pattern of lower yield at locations isolated from fully fertile rape suggests that full compensation for poor pollination does not occur however.

It has been suggested that VA yields have been overestimated to a degree in the UK Recommended List. Trial layouts have now been changed to give limited segregation to varietal association and minimise the effect of pollen drift from fully fertile varieties. The introduction of a new generation of varietal associations, using restored hybrids as pollinators should improve reliability of pollination.

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ACKNOWLEDGEMENTS

NIAB acknowledge funding from the Home Grown Cereals Authority. We also thank the following organisations for co-operation: CETIOM, France, Lehr- und Versuchsanstalt für Landwirtschaft, Futterkamp, Germany and Bundesampt und Forschungszentrum für Landwirtschaft, Austria.