

THE INTRODUCTION OF OILSEED RAPE HYBRIDS IN THE UNITED KINGDOM

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Introduction

Uptake of oilseed rape hybrids by farmers has been cautious, but estimates suggest that they achieved sales equivalent to 25% of the UK winter rape market, for the coming 1999 harvest. In spring rape they achieved, approximately, a one third market share in 1998 which is likely to increase in 1999. The first winter oilseed rape hybrid to enter official trials in the UK was sown in autumn, 1992 for harvest 1993. After a gradual start numbers of hybrids then rose rapidly and represented nearly 50% of the 71 new entries for the autumn 1998 sowings. Spring oilseed rape has shown a parallel development, where 8 out of 21 new entries for 1999 are hybrids.

The first hybrid to be added to the UK National List was the varietal association Cannon, in 1995. Its yields, in trials, were below those of the best conventional varieties and it was not considered for addition to the Recommended List of varieties. In 1996 another varietal association, Synergy, became the first hybrid to be Recommended, with yields significantly above those of conventional varieties. The first restored hybrids, Artus and Pronto, were Recommended in 1997. Since then, only one further winter hybrid has been Recommended, a varietal association, Gemini, in 1999, which incorporates Artus as its pollinator. Its seed yield is 5% higher than the best conventional variety, Escort and 12 % higher than the market leader, Apex.

The spring oilseed rape Recommended List is also dominated by hybrids, with the restored hybrid, Hyola 330, currently 6% higher yielding than the top conventional variety, Maskot.

In the EU, the proposals included in Agenda 2000, to standardise area payments across all arable crops have given new importance to increasing rape yields, if the crop is to remain competitive with cereal crops. Hybrids seem likely to be the best method of achieving this aim. This paper details the introduction of hybrids into the United Kingdom, with particular reference to performance, in trials, of the range of hybrid system so far encountered. The picture closely resembles that seen in the other oilseed rape growing countries of Europe. Hybrids have presented a number of challenges to the workers responsible for testing varieties.

Hybrid Systems

Several hybrid systems are represented in the range of hybrids commercially available at present and more still are working through the trials programme. From the grower's perspective, hybrids would, ideally, offer very high yields with satisfactory quality, disease resistance and agronomic characters, and be indistinguishable as field crops, from conventional varieties derived from pedigree selection. However the path to achieving this has proved long and hard.

To summarise briefly, the majority of the breeding activity has been directed towards the introduction of cytoplasmic male sterility (CMS) into the selected female lines. In the seed production field the female line produces no pollen and is thus dependent on pollination from adjacent strips of the selected male line. The seed produced by the female line is an F1 hybrid and can either continue the male-sterile trait of the maternal line or, if a male line bearing a 'restorer' gene in its nucleus is chosen, the hybrid seed will give rise to pollen producing fully fertile plants - restored hybrids.

Of a number of systems available, the Ogu-INRA cms system is currently the most widely used. Introduction of Ogura hybrids has been impeded by a close linkage between the restorer gene and the gene or genes controlling glucosinolate content in the seed. Many high yielding crosses have been unusable because of their high glucosinolate content. To avoid this problem, the first hybrids entered into official trials were, what have become known as, **varietal associations**, or "composite" hybrids: mixtures of male sterile hybrid seed and seed of a conventional variety needed as a pollen source. These were followed two years later by fully restored hybrids from two sources, one using a **self incompatibility system** (SI) and one using the **Lembke cytoplasmic male sterility system**. Pronto, from the Lembke programme has proved very popular in its first commercial season, taking an estimated 12 % of the market, and demand for the seed exceeding supply in autumn 1998. No SI hybrids have so far achieved commercial status.

The reliability of varietal associations has subsequently become the subject of some concern and investigation, with indications that they may be more sensitive to cold at flowering time than other types and subject to poor pollination if there are prolonged periods of rain during this period. Partly to overcome these concerns, and in the absence of large numbers of fully restored hybrids, further approaches have been introduced:

- **Complex hybrids** - varietal associations in which the pollinator is itself a restored hybrid are thought to have the additional vigour to compete more successfully in the sterile hybrid canopy. Gemini is an example of this type.
- **Three-way hybrids**, which are formed by two successive hybrid crosses. A number of strategies have been used here. In some the final hybrid is fully restored.

In others the hybrid segregates into fertile and non fertile plants in a 50:50 ratio. Triangle and Comodor respectively are the first examples of these types to have been added to the National List for 1999 and will be considered for Recommendation for the 2000 harvest season.

- **Top crosses**, in which the male line is heterozygous for the restorer gene and high/low glucosinolate content. Here again the F1 segregates for fertility but the high proportion of fertile plants and the fact that all plants are hybrids is thought to offer very high reliability of pollination. The Novartis-bred variety, RNX 9703, is undergoing its second year of trials and has been selected as a Recommended List candidate, having shown very high yields in its first year.

- As a separate and technically novel approach, we have also seen restored hybrids which use genetic modification for herbicide tolerance (to gluphosinate ammonium) in seed production. First seen in spring rape entries, winter varieties have now entered trials. Herbicide tolerance, genetically linked with control over anther development is introduced, so that the self maintaining maternal line, which segregates for male sterility, can be sprayed with the herbicide, leaving only the male sterile plants in the seed production block, which then receive pollen from the surrounding male line. This system avoids many of the difficulties seen in the more conventional hybrid methodology and there are no adverse effects on oil or glucosinolate levels in the F1. The herbicide tolerance is transmitted to the F1 and there is a possibility of gaining further benefit in the form of cheaper and more effective weed control from these hybrids.

- The relative importance of these different types of hybrids is shown in the table below.

Table 1 Entries into official trials - winter oilseed rape

Type	1993	1994	1995	1996	1997	1998	1999
Total entries	46	47	48	60	62	63	71
Varietal associations	1	2	2	15	7	7	5
Restored hybrids	-	-	4	2	2	13	18
Three-way hybrids	-	-	-	-	3	1	8
GM hybrids						3	2
Top cross hybrids						1	-

In spring oilseed rape a further hybrid system has played a prominent rôle: The Polima cms system has produced successful hybrids from several breeding programmes. Restoration is not linked to high glucosinolate content but some

crosses can give rather low oil content. More importantly Polima male sterility shows some environmental instability and where it breaks down, selfing gives rise to non-hybrid seed. Seed production problems have limited the introduction of this type of hybrid in the UK but recently introduced Canadian-bred Polima types are currently gaining popularity. The table below classifies the entry of spring rape hybrids into official trials.

Table 2 Entries into official trials - spring oilseed rape

Type	1993	1994	1995	1996	1997	1998	1999
Total entries	28	19	30	20	27	25	21
Varietal associations	-	2	3	2	8	2	1
Restored hybrids	1	1	4	2	-	1	3
GM hybrids	-	-	2	2	1	2	4
Three-way hybrids	-	-	-	-	-	1	-

Variety testing of hybrids

The introduction of hybrids has necessitated a number of revisions to trial procedures. Three factors considered to have a direct effect on the validity of trials data are the requirement for cross pollination of male sterile hybrids, the seed rate difference between hybrids and conventional varieties and lastly the inter-plot competition effects between hybrids and conventional varieties.

Pollination of male sterile hybrids in varietal associations

From the outset, there has been concern amongst technical workers that varietal associations might be prone to poor pollination when grown as crops, solely dependent on the 20-30 % admixture of one or more pollinators. In variety trials, where VAs are interspersed with fully fertile varieties, they might be expected to benefit from much more plentiful pollen availability than when grown as a farm crop. In fact no instances of very poor yields in commercial crops have been reported to the NIAB, although in a small number of cases we received reports of extensive pod abortion during the early flowering period.

During the 1995 season there were cold spring conditions across Europe and these seemed responsible for significant levels of poor pod set in varietal associations in some regions, particularly in parts of France. A research project into the reliability of performance, in this type of hybrid, was set up between the UK₁, France₂, Germany₃ and Austria₄. Trials, of VAs only, were grown at 15 locations in 1996 and 1997 in order to observe variety performance in isolation from the high pollen availability associated with conventional rape. The full report of this work is in preparation but perhaps the most important observation has been that, at the

majority of sites, variety yields were lower than at the closest trial sites where the VAs were incorporated with conventional varieties. Such comparisons are, scientifically, difficult to justify because of the differences in soil and weather characteristics between pairs of sites. However, in the UK, where yields at *all* the isolated trials were lower than at the nearest mixed trial, it has been concluded that the evidence suggests that conventional variety trials may have been overestimating normal yield potential of varietal associations.

Additional work, as part of this project, and conducted in the UK only, looked at yield components at the individual plant level. Kightley (1998) compared tagged plants of the male sterile hybrid and the pollinators at both isolated sites and in conventional trials. Data for the two VAs common to the whole trial series, Synergy and Cocktail are presented in Table 3.

Table 3 Varietal association pollination experiments - Mean data for 1996 and 1997

	Cocktail		Synergy		Mean	
Seed yield - t/ha	4.18		4.19		4.18	
Plants/m ²	38		40		39	
Pollinator %	17		18		18	
	Hybrid	Pollinator	Hybrid	Pollinator	Hybrid	Pollinator
Pods/plant	356	174	402	183	379	178
Fertile pods (%)	66	69	67	72	66	71
Seeds/pod	14	19	14	21	14	20
Seed weight (g/1000)	5.8	4.5	6.3	4.2	5.25	4.35

It was found that the survival of the two components through to flowering was very similar, with a small reduction in the proportion of pollinator. At isolated sites the proportion of fertile pods (containing one or more seeds) to aborted pod positions was again similar for the two components. However, the pollinator plants were shorter than the hybrids, branched less and produced fewer pods than the hybrids. This was thought to be a direct effect of inter-plant competition. The pods of the hybrids contained fewer but larger seeds than those of the pollinator.

1 NIAB, Cambridge; 2 CETIOM, Paris; 3 Lehr- und Versuchsanstalt für Landwirtschaft, Futterkamp; 4 Bundesamt und Forschungszentrum für Landwirtschaft, Vienna

It was concluded that pollination of the male sterile hybrid plants was poorer than in the pollinator plants themselves but that their prolonged flowering allowed the plants to produce more pods and their increased seed size would tend to

compensate for this. This work complemented studies carried out by CETIOM (1994) in France.

Partly as a consequence of this work, the variety testing protocols in the UK for National List and Recommended List have been modified. Varietal associations are now grown within separate sub-blocks, randomised within conventional trials. The sub blocks are buffered with a minimum of three 2-metre plots sown on either side. It is hoped that this will minimise the cross pollination effect of neighbouring, fully fertile varieties, while maintaining satisfactory linkage with their performance and the VAs.

Sowing rate

In the United Kingdom seed rates for oilseed rape have traditionally been higher than in the other principal rape growing areas of Europe. Rates up to 7 kg/ha have been common, equivalent to 120 seeds/m², aiming at establishing 80 plants/m². This compares with France where rates of 3-4 kg are used and Germany where 2 kg/ha is quite common. The high seed

rates used by many British growers reflect the difficult autumn seed bed conditions and high pest pressure frequently encountered.

For hybrids, seed companies in the UK are recommending a seed rate of 60-70 seeds/m², targeting a population of 40 plants/m². This change has an economic and a technical basis. For conventional varieties, sown at 7 kg/ha seed costs of £42 are typical, while hybrid seed, sown at 3.5 kg/ha will cost £54-£60/ ha. Doubling the hybrid seed cost by sowing at the higher rate would not be acceptable to farmers. From a practical view point, breeders believe that, because of their superior vigour and their more branching habit, hybrids can perform better at lower populations. Additionally, in the case of VAs, low populations are important to avoid smothering the less vigorous pollinator plants. Again, because of the very vigorous nature of hybrids, they believe that the lower population is required to improve their lodging resistance.

In fact, data from Recommended list trials, where Synergy has been grown at both seed rates for three years now, suggests that reducing the seed rate from 7 to 3.5 kg/ha depresses yield by 3-4 %.

In the early years of hybrid testing, in the UK, all hybrids were sown at 120 seeds/m² in official trials, to allow direct comparison with conventional varieties. This has now changed, in recognition of the commercial reality, and all hybrids are now sown at 70 seeds/m².

Inter-plot competition

Breeders of conventional varieties have been concerned that some of these may be penalised, through inter-plot competition, when grown next to very vigorous hybrids. Again calling on the results of the European hybrid project previously mentioned, there is some evidence to support this, at the individual plant level. Table 4 lists the mean number of pods/plant for the variety Falcon when grown as a) the pollinator in Synergy sown at 60 seeds/m², b) the pollinator in Synergy sown at 120 seeds/m² and c) a pure stand sown at 120 seeds/m². Data is expressed as the mean of three trial locations and 20 plants per location.

The clear implication of the higher number of pods per plant for Falcon, when grown as a pure stand, is that its yield may be suppressed when grown in competition with hybrid plants.

Table 4 Pods per plant - the effect of competition on conventional cultivar, *Falcon*, compared with cms hybrid

Synergy - 60 seeds/m ²		Synergy - 120 seeds/m ²		Pure stand of
CMS hybrid	Falcon	CMS hybrid	Falcon	Falcon - 120 seeds/m ²
399	181	280	140	202

NIAB are conducting an investigation into plot interference effects seen in trials since 1994. This will complement the work of Talbot *et al.* (1995) which identified lodging, stem stiffness and disease as the most important contributory characters, with height a comparatively insignificant component of interference. This work preceded the entry of hybrids into trials and the results of the new study are awaited with interest.

As an interim measure, trial designs have been altered so that, apart from the varietal associations which are blocked separately, all other varieties and hybrid types are randomised using a restricted neighbour design, based on height. It is thought that this and the wide inter-plot gaps normally used (60cm) will minimise any interference effect resulting from hybrid vigour

Performance of hybrids

The performance of winter and spring oilseed rape hybrids is indicated by tables 5 and 6. The 4- and 5-year mean yield figures respectively and the individual year means for NIAB Recommended varieties are listed, expressed relative to the mean yield of control varieties. As a comparison of performance stability, between types, the range in relative yield, for each cultivar, is included for 1996-98, the period which offers the most complete matrix for both crops.

NIAB have recently started to describe varieties in terms of their 'economic performance', relative to the mean of controls. This is the seed yield adjusted by the value of the oil content of the seed. (An oil premium is paid at the rate of 1.5 % of the contract price for the crop for every 1 % increase in oil content over 40 %). Using this adjustment, top yielding hybrid Gemini, having rather low oil content, is brought down to the same economic performance as Pronto, both on 106, 2 % ahead of new variety, Escort and 9 % ahead of market leader Apex.

Nationally, the UK crop has been estimated at 3.0 t/ha over the last 5 years. For winter rape this is a low estimate, as the UK figures include the lower yielding spring rape crop and an average yield of 3.5 tonnes for winter rape is probably realistic. At this yield level, using a typical crop price of £150/t, a 1 % yield increase is worth £5.30/ha. Gemini and Pronto therefore offer an advantage of £10.60/ha over Escort. More significantly, they offer an advantage of £47.70/ha over market leader, Apex. As a crude estimate of what hybrids have to offer in the UK, replacing the Apex area, of perhaps 200,000 ha, with these top yielding hybrids, might be expected to increase the value of the national crop by £9.5m.

Inspection of the 'range' column of both tables suggests that hybrids are no more or less variable in their performance than conventional varieties. As a general observation, the more disappointing trial yields have come from sites which have experienced very dry spring conditions, where mobilisation of fertiliser top dressings has been restricted. The key to success with both varietal associations and restored hybrids seems to be in avoiding nutrient stress during the stem extension period.

The fact that growers have been slow to make the change into hybrids is partly due to concerns about the reliability of the varietal association system and in part the very attractive agronomic characteristics of conventional variety, Apex, which has very good resistance to lodging and remains stiff stemmed at maturity. Straw characteristics are crucial factors when high seed rates are used and Apex has gained enormous popularity because of these characters. It might be anticipated that as low seed rate hybrid testing becomes standard growers will be increasingly attracted to hybrids because of the stem strength that they will demonstrate, in addition to their yield.

In the case of spring rape, the majority of hybrids have shown very good early vigour, which is thought to aid crop establishment, and very early maturity, which is particularly important in the north of the country where most spring rape is grown.

Table 5 Yields of winter oilseed rape varieties - 1995-98

Variety	Type	1995	1996	1997	1998	4-year mean	Range 1996-98
Gemini	CVA	-	-	107	108	109	(1)
Pronto	RH	110	105	107	107	107	2
Comodor	3-H	-	-	108	102	106	(6)
Synergy	VA	103	107	103	105	105	4
Artus	RH	110	106	102	102	105	4
Escort		-	-	104	103	105	(1)
Panther	RH	-	107	104	104	105	3
Madrigal		-	103	104	103	104	1
Licrown		104	99	98	97	99	2
Boston		-	100	100	97	99	3
Lipton		103	98	97	98	99	1
Meteor		103	98	99	95	99	4
Lightning		100	97	97	100	98	3
Herald		103	100	97	94	98	6
Contact		100	97	99	97	98	2
Capitol		100	95	100	96	98	5
Apex		95	96	98	101	97	5
Alpine		97	97	97	95	97	2
Gazelle		97	96	94	96	96	2
Commanche		90	94	-	88	92	(6)
Mean of controls (t/ha)		4.42	4.64	4.42	3.56	4.27	

() = incomplete matrix

VA = varietal association; CVA = complex varietal association; RH = restored hybrid; 3-H = three-way hybrid

Conclusion

In the UK new conventional varieties of oilseed rape are continuing so show significant yield improvements but hybrids are maintaining a small but economic advantage over them. There has been a relatively slow up-take of hybrids by farmers, principally because of worries about the reliability of the first hybrids to be commercialised, which were varietal associations of

Table 6 Spring oilseed rape yields - 1994-98

Variety	Type	1994	1995	1996	1997	1998	5-year mean	Range 1996-98
Hyola 330	RH	-	-	112	108	103	108	9
Superol	RH	107	105	107	109	106	107	3
Hyola 401	RH	-	108	109	111	101	107	10
Concept	VA	-	102	108	110	103	106	7
Colstar	VA	-	-	107	101	107	105	6
Hyola 420	RH	-	109	103	103	101	104	2
Triolo	VA	110	99	108	102	103	104	6
Hyola 38	RH	-	107	110	101	95	103	15
Maskot		97	103	101	103	103	102	2
Liaison		108	101	95	100	104	101	9
Canyon		-	106	101	97	98	101	3
Aries		101	105	99	95	99	100	4
Archimedes	GMRH	-	-	106	99	96	100	10
Rebel		102	100	99	98	98	99	1
Marinka		103	97	101	98	92	99	9
Licosmos		98	97	100	93	104	99	11
Star		101	99	100	98	95	99	5
Sprinter		-	90	93	100	105	97	7
Solar		100	101	96	93	-	97	(3)
Acrobat		98	95	98	97	96	97	2
Mean of controls (t/ha)		2.67	2.37	2.90	2.31	2.78	2.60	

() = incomplete matrix /

VA = varietal association; CVA = complex varietal association; RH = restored hybrid; 3-H = three-way hybrid; GMRH = genetically modified restored hybrid predominantly male-sterile hybrid plants.

With hybrids from several breeding systems now offering better reliability, and an adaptation to growing lower seed rates and the agronomic advantages that these offer, farmers are likely to move rapidly to replace conventional varieties as the dominant breeding type. This will be important in maintaining the economic viability, in competition with cereals, as the new subsidy schemes of Agenda 2000 are put into place.

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