REVIEW OF PERFORMANCE AND SEED PRODUCTION OF HYBRID BRASSICAS

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ABSTRACT

Hybrid Brassica (*B. juncea, B. napus, B. rapa*) varieties frequently display high parent heterosis for seed yield but rarely display high parent heterosis for oil or protein content in the seed. The levels of high parent and/or commercial heterosis observed for seed yield in hybrid Brassica varieties are sufficient to ensure the large-scale switch to hybrids at some point in the future. Difficulties encountered in hybrid Brassica variety performance, especially for oil content and/or protein content, and seed production have delayed the widespread adoption of hybrid Brassica cultivars. Hybrid Brassica variety performance is steadily improving and seed production techniques are being refined to increase the efficiency of seed production. Hybrid Brassica cultivars will likely become the dominant form of cultivated Brassica variety in the future.

INTRODUCTION

Many reports have indicated that hybrid Brassica varieties display significant levels of high parent heterosis for seed yield. In hybrid Indian mustard (*B. juncea*), high parent heterosis for seed yield from Indian X Exotic crosses was reported to average 55%, with a range of 30 to 90 % by Pradhan *et al.* (1993), while high parent heterosis for seed yield from Canadian X Exotic crosses was reported to average 40% with a range of 20 to 70 % by G. Rakow (1995, pers. comm.). In hybrid summer oilseed rape, (*B. napus*) high parent heterosis for seed yield averaged 30%, with a range of 20 to 50%, (apparently due primarily to increased number of pods per plant), (Sernyk and Stefansson 1983, Grant and Beversdorf 1985 and Brandle and McVetty 1990). In hybrid winter oilseed rape, (*B. napus*) Takagi (1970) and Lefort-Buson and Dattee (1982) reported that high parent heterosis for seed yield averaged 50%, with a range of 20 to 80%. In hybrid summer turnip rape, (*B. rapa*) high parent heterosis for seed yield was reported to average 15%, with a range of 0 to 60% (Schuler *et al.* 1992, Falk *et al.* 1994). Limited information suggests that commercial heterosis for seed yield in hybrid Brassica varieties will be approximately half of the high parent heterosis.

In contrast, high parent heterosis for oil or protein content is rarely encountered in hybrid Brassica varieties in oilseed rape or turnip rape, especially when the hybrids are evaluated on a plot basis (Takagi 1970, Brandle and McVetty 1990, Schuler *et al.* 1992, Falk *et al.* 1994). The oil content reduction observed for *pol* CMS hybrids is a reflection of the biological cost of this CMS system (McVetty *et al.* 1990). Seed coat colour differences between parents and hybrids account for the negative mid-parent heterosis for oil content observed for turnip rape hybrids (Schuler *et al.* 1992, Falk *et al.* 1994). Limited high parent heterosis for oil or protein content will likely be observed for hybrid Indian mustard varieties as well.

HYBRID PERFORMANCE

Several papers at this Congress report that heterosis for seed yield occurs for Brassica hybrids. High parent heterosis for seed yield in Indian mustard is reported by Pental *et al.* (1995), Singh *et al.* (1995a) and Singh *et al.* (1995b). McGee and Brown (1995) report high parent heterosis for seed yield of -1% for the F1 and +9% for the F2 for summer oilseed rape crosses, respectively, and +10% for the F1 and -6% for the F2 for winter oilseed rape crosses, respectively. Fu and Yang (1995) report that high parent heterosis for seed yield in canola quality hybrid winter oilseed rape cultivars is less than 20% but that commercial heterosis levels are sufficient to ensure large scale conversion to hybrid winter oilseed rape cultivar production in China. Busch (1995), reports mid-parent heterosis for seed yield of 15 to 23% for winter rape cross hybrids. In hybrid summer turnip rape, Falk *et al.* (1995) report high parent heterosis for seed yield of approximately 12%, and report that this is largely due to increased number of pods per plant.

To more effectively use the heterosis observed in hybrid Brassica varieties, assignment of Brassica genotypes, whether existing cultivars, derived lines or newly created genotypes, to appropriate heterosis groups is essential. This can be done using traditional crossing techniques to generate information on combining ability as well as heterosis group assignments (e.g. Brandle and McVetty 1989). More modern approaches using direct DNA assessment of genetic differences correlated with heterosis for seed yield and/or seed yield related traits can also be used.

Several of the papers presented in this conference look at the relationship of genetic distance to heterotic response for seed yield and/or seed related traits in the progeny of Brassica crosses as a means of identifying heterotic patterns for a wide range of Brassica genotypes. Knaak and Ecke (1995) used RFLP analyses of the genetic diversity for 64 winter oilseed rape cultivars and report a correlation of 0.72^{*} between the mid-parent heterosis for yield of the hybrids and the genetic distances separating their parent lines. Knaak and Ecke (1995) also reported that cluster analyses of the RFLP data indicated that there were seven genetically divergent groups present within these 64 winter oilseed rape cultivars. Becker and Engqvist (1995) report on the use of RAPD data to identify high parent heterosis for leaf dry matter production in hybrids produced from resynthesized winter oilseed rape parents, finding a correlation of 0.55^{**} for mid-parent heterosis for leaf dry matter production at six weeks and genetic distance between parents. The authors conclude that RAPD estimated genetic distance can be used to predict heterosis for leaf dry matter production. Becker and Engqvist (1995) report that they are currently studying the genetic distance - heterosis for seed yield relationship in this material.

Significant high parent and/or commercial heterosis for seed yield alone is probably sufficient to justify the development of hybrid Brassica cultivars. The successful development of hybrid Brassica cultivars requires much more than just high parent and/or commercial heterosis for seed yield, however. In addition, fully functional pollination control systems and efficient hybrid seed production techniques are required to ensure the success of hybrid Brassica cultivars in world agriculture.

POLLINATION CONTROL SYSTEMS

There are several pollination control systems being developed and/or used for hybrid seed production in Brassica cultivar production including SI systems, CMS systems, GMS systems (all of these pollination control systems reviewed by Downey and Robbelen 1989), and gametocides (Guan and Wan 1987). In addition, a pollen killer approach to pollination control (now called nuclear male sterility or NMS), in Brassica has been developed by Mariani *et al.* (1990, 1992). Pental *et al.* (1995) report on the development of the *tour* CMS system in oilseed rape and Indian mustard, and further report that efficient transformation systems have been worked out in Indian mustard. This latter development will permit the development of an NMS system such as developed by Mariani *et al.* (1990, 1992) in Indian mustard. Several pollination control systems are currently being used to produce hybrid summer and winter rape cultivars throughout the world currently. These include genetic male sterility, self incompatibility, nuclear male sterility, and cytoplasmic male sterility, using the *ogu* CMS system, both with and without male fertility restoration in the hybrid and the *pol* CMS system. The development of pollination control systems has been thoroughly reviewed by several speakers at this Congress.

HYBRID SEED PRODUCTION TECHNIQUES

A wide range of hybrid seed production techniques are being developed and used throughout the world currently. These include both block or strip methods of hybrid seed production (Renard and Mesquida 1983) and mixed methods of hybrid/synthetic seed production (Frauen 1987).

Block method hybrid winter rape seed production in France, using the *ogu* CMS system components used a 14 A-line : 2 R-line row ratio and naturally occurring insect pollinators to achieve commercially acceptable hybrid seed yields and hybridities (Renard and Mesquida 1983).

Block method hybrid summer rape seed production in Canada, using the *pol* CMS system has been under development for several years. Initial attempts to produce hybrid summer oilseed rape seed were unsuccessful (Pinnisch and McVetty 1990), primarily because the male sterility of the *pol* CMS A-line used was insufficient. Consequent improvements in male sterility have resulted in *pol* CMS A-lines with male sterility indexes (MSI) (Burns *et al.* 1991) of 1.0 or less being developed (Pinnisch and McVetty 1992). There is a balance between MSI and hybrid seed yield obtained on the *pol* CMS A-lines, however. Pinnisch and McVetty (1992) reported that hybrid seed yield declines by 352 kg ha^{-1} for each unit decline in MSI while hybridity decreased by 6.0% for each unit increase in MSI. Pinnisch and McVetty (1992) noted that seed yields on *pol* CMS A-lines with very low MSI were unacceptably low (i.e. 55 kg ha^{-1} for MSI of 0.1). The compromise solution that is currently being used for *pol* CMS system hybrid summer rape seed production in western Canada utilizes a 3 A-line : 3 R-line row ratio and introduced high insect vector populations (McVetty *et al.* 1995). Using the 3 A-line : 3 R-line row ratio system with *pol* CMS A-lines with MSI of approximately 1.0, hybrid seed yields average 500 kg ha^{-1} and hybridities average 90%, commercially acceptable values.

Block method seed production, using the *ogu* CMS system materials which possess the apetalous trait in the A-line, has been studied in Tasmania (Hogarth *et al.* 1995). Hybrid seed production was studied on row ratios of 1 A-line : 1 R-line, 2 A-lines : 1 R-line and 4 A-lines : 1 R-line row ratios using the above materials and honey bees as the pollen vector. Seed yield on all *ogu* CMS A-line rows was nearly equal regardless of row ratio, and the average hybrid seed yield in this study was 1175 kg ha^{-1}. These hybrid seed yields are reported to be comparable to those seen for conventional hybrid seed production (presumably for *pol* CMS system hybrids).

Research and development of a CMS-based mixed method seed production system is ongoing in Canada. The mixed method system uses 90% A-line and 10% R-line interplanted in the seed production field and bulk harvested. Seed yields average 1000 kg ha^{-1} and hybridities average approximately 80%, but with a wide range. The seed lots for varieties produced using a mixed method of seed production contain hybrid seed, A-line seed and R-line seed and are classified in Canada as "Advanced Generation Synthetics" rather than as hybrids, (L. Duke 1995, pers. comm.).

The hybrid summer rape cultivars currently grown in Canada likely possess high parent heterosis for seed yield in the 20 to 40% range. In contrast, the same hybrids display commercial heterosis for seed yield in the 10 to 20% range. Rapid increases in seed yield for both conventional and hybrid summer rape cultivars is occurring in Canada currently. It is difficult to predict, in this very competitive environment for new cultivar development, when or if commercial heterosis for the hybrid summer rape cultivars will exceed the current 10 to 20%.

CONCLUSIONS

High parent and/or commercial heterosis for seed yield in hybrid Brassicas is frequently encountered. In many cases this increase in yield is due to an increase in the number of pods per plant while all other yield components display compensating interactions. High parent heterosis for oil or protein content is rarely observed. The eventual commercial success of hybrid Brassica cultivars will likely rely upon commercial heterosis for seed yield coupled with minimal decreases in oil content and protein content.

Adequate pollination control systems to permit efficient production of commercial quantities of hybrid Brassica seed will also be required. This challenge is being met on many fronts through the development and assessment of numerous pollination control systems based on SI, GMS, CMS, NMS, and male gametocides. A fully functional system of pollination control has yet to be clearly identified. Further pollination control system development and refinement can be anticipated, resulting eventually in one or more fully functional pollination control systems for use in hybrid Brassica cultivar seed production.

Regardless of the pollination system chosen, methods of hybrid seed production to permit the efficient production of hybrid seed must be developed . Progress has been made on this front, with hybrid seed of several registered hybrid Brassica cultivars being produced in Asia, Europe and Canada at the present time. The refinement of currently available pollination control systems, the development of new and better pollination control systems, and the development of more efficient hybrid seed production techniques should ameliorate the present difficulties with hybrid Brassica cultivar seed production.

Hybrid Brassica cultivars will likely become the dominant form of cultivated Brassica variety in the future - but there are still too many challenges to resolve at the present time to permit us to predict when this will occur.

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