Physiological factors contributing to yield enhancement in winter apetalous oilseed rape (*Brassica napus*)

Eric J. Evans *[1], Jamie M. Gemmill [1], Peter Werner [2] and Elizabeth Williams [2]

[1] School of Agriculture, Food and Rural Development, The University of Newcastle,
Newcastle upon Tyne, NE1 7RU, UK. E-mail: e.j.evans@ncl.ac.uk
[2] CPB Twyford Ltd, Church Street, Thriplow, Nr Royston, Herts SG8 7RE, UK
E-mail: peter.werner@cpb-twyford.co.uk

ABSTRACT

It is widely recognised that the floral canopy of oilseed rape is highly inefficient due to the reflection and absorption of solar radiation by the non-photosynthetic yellow petals resulting in poor pod retention and seed production in the lower reaches of the canopy. Many authors have suggested that developing varieties exhibiting apetalous flowers could improve the yield potential of the crop by improving light penetration during flowering. To date however, attempts at evaluating the apetalous trait have been unable to give a true representation of the character due to the use of plants with non-isogenic backgrounds. To accurately determine the merit of the apetalous flower morphology, a series of near-isogenic lines (NILs) were assessed together with a parental variety (Nickel) as control. PAR reflection and absorption was greatly reduced in the apetalous lines. This resulted in delayed leaf senescence and improvement in dry matter production post flowering. Seed yield was significantly improved due to increased pod survival. Seed number per pod and seed weight were not significantly influenced.

Key words: *Brassica napus*, apetalous, yield and yield components,

INTRODUCTION

The yield potential of winter oilseed rape in the UK has been calculated to be in excess of 7.5 t ha at 9% moisture (Daniels *et al*, 1986), yet the average commercial yields have remained between 2.5 and 3.5 t ha. Genetic improvements in disease control, and the introduction of hybrid varieties have not had a significant impact on seed yields. Failure to achieve this potential has been considered to be largely due to the inefficiency of crops to provide sufficient assimilates during critical periods of plant development.

Seed yield is the product of pod density, seeds per pod and mean seed weight. During its development the crop develops three quite distinct canopies, a vegetative canopy, a floral canopy and a pod canopy. Growth before floral initiation influences pod density and is characterised by an overproduction of potential pod sites, with a significant reduction in the number surviving to harvest. The floral canopy is highly inefficient due to the reflection and absorption of solar radiation by the non-photosynthetic yellow petals limiting seed yield through pod abortion and reducing seed set. Once established, the pod canopy is highly efficient as a source of assimilates for the developing seed (Allen *et al*, 1971). Even under optimal agronomic conditions assimilate supply to the developing reproductive organs is therefore a major limiting factor on the yield of conventional rapeseed varieties (Mendham and Scott, 1975; Evans, 1984; Habekotté, 1993).

In an attempt to improve the efficiency of assimilate production post flowering, attention has been given to the development of apetalous genotypes (Buzza, 1983; Rao *et al* 1991; Fray *et al*, 1996 and Jiang and Becker, 2001). Until recently, detailed physiological comparisons of fully petalled and apetalous genotypes have not been possible due to the differing genetic background of the two forms. This paper reports on the physiological evaluation of a series of apetalous and fully petalled near-isogenic lines.

MATERIALS AND METHODS

The apetalous variant N-O-112, from the University of Göttingen, was used throughout the study as the source of the apetalous character. This was initially crossed at the John Innes Centre to produce the parent line JIC 14 (Fray, 1995). Following a series of backcross and selfing generations two sets of near-isogenic lines were derived from an F_1 individual (JIC 14 x Nickel). Two apetalous lines (AP1 and AP2) together with their fully petalled comparisons (FP1 and FP2) and the parent variety Nickel were grown in a randomised complete block experiment consisting of four replicates during the 2001/2 growing season.

From the start of flowering through to the pod development stage, incident, reflected and transmitted photosynthetically active radiation (PAR) was measured at frequent intervals using a Sunfleck Ceptometer (Delta-T Instruments). Dry matter production and green area index was measured on four occasions. Leaf senescence was also investigated by measuring leaf chlorophyll content (SPAD 502, Minolta). Prior to final harvest, seed yield and yield components were measured from an area of 1 m^2.

RESULTS

Incident PAR reflected and absorbed by the flowering canopy was significantly reduced from the middle to the end of flowering in the two apetalous lines (Table 1).

Table 1. The proportion of incident PAR reflected and absorbed by the floral canopy

Incident PAR reflected and absorbed (%)	Start of flowering (GS 4,1)	Middle of flowering (GS 4,5)	End of flowering (GS 4,9)	Pod development (GS 5,8)
AP 1	9.8	70.1	78.2	82.4
FP 1	11.0	83.5	83.1	82.7
AP 2	10.1	70.4	78.9	80.7
FP 2	10.1	88.9	85.0	85.0
Nickel	11.6	86.8	83.3	84.4
S.E (12 df)	0.98	1.46	1.45	1.41
Sig	NS	***	*	NS

Chlorophyll content of the sixth and ninth leaves from the top of the canopy are presented for the mid flowering and early pod development stage in Table 2. The absence of a dense petal canopy enabled a greater proportion of PAR to penetrate into the leaf canopy in both the apetalous lines, which resulted in a delay in leaf senescence.

Table 2. Chlorophyll content (SPAD units) of leaf 6 and 9 at two stages of growth

	Middle of flowering (GS 4,6)		Early pod development (GS 5,1)	
	Leaf 6	Leaf 9	Leaf 6	Leaf 9
AP 1	64.6	56.8	57.3	42.3
FP 1	62.0	52.0	52.3	27.1
AP 2	64.6	55.0	56.5	39.3
FP 2	63.2	52.1	49.8	28.8
Nickel	64.9	52.9	52.6	25.0
S.E (12 df)	0.55	0.68	0.53	1.02
Sig	*	***	***	***

At harvest the apetalous lines performed significantly better than their near-isogenic comparisons with the exception of seed size (Table 3). Pod survival was greatly enhanced in the apetalolus lines as a result of reduced pod abortion. Seed number per pod was not significantly different between the lines, whilst seed weight was significantly lower in both the fully petalled and apetalous lines compared to Nickel. The harvest index was not significantly influenced.

Table 3. Seed yield and yield components at final harvest

	AP 1	FP 1	AP 2	FP 2	Nickel	S.E (12df)	Sig
Aborted pod no. m^{-2}	3512	4654	3795	4417	4843	149.8	***
Fertile pod no. m^{-2}	7523	6801	7781	6878	7447	119.8	***
Pod survival (%)	68.2	59.4	67.4	60.9	60.6	0.62	***
Seed no. pod^{-1}	13.7	13.0	14.1	13.4	13.3	0.40	NS
TSW (g)	5.01	5.15	4.86	4.98	5.59	0.082	***
Seed yield (g m^{-2})	513.7	456.4	532.4	456.8	552.5	15.61	**
Harvest Index	0.28	0.26	0.30	0.27	0.28	0.008	NS
Total DM (g m^{-2})	1847	1753	1777	1688	1984	28.9	***

DISCUSSION

Seed yield was significantly improved in the apetalous compared to the fully petalled near-isogenic lines. This improvement was achieved through a greater proportion of the incident PAR penetrating to the green leaf canopy from mid flowering onwards. This resulted in delayed senescence, as measured by chlorophyll content.

Dry matter production was significantly higher in the apetalous lines as flowering progressed. This increase in assimilate supply resulted in reduced pod abortion, especially in the lower regions of the pod canopy (Gemmill *et al*, 2003). Seed growth, measured as seed number per pod and seed weight was not significantly altered by the removal of petals.

Introduction of the apetalous character into high yielding winter oilseed rape varieties provides plant breeders with an opportunity to increase pod survival through improved assimilate supplies during the latter stages of flowering.

REFERENCES

Allen, E. J., Morgan, D. G., and Ridgman 1971: A physiological analysis of the growth of oilseed rape. *Journal of Agricultural Science*, **77**, 339-341

Daniels, R. W., Scarisbrick, D. H., and Smith, L. J. (1986). Oilseed rape physiology. *In* "Oilseed Rape" (R. W. Daniels and D. H. Scarisbrick, eds.), pp. 83-126. Collins, London.

Buzza, G. (1983). The inheritance of an apetalous character in canola (*Brassica napus)*. *Cruciferae Newsletter* **8**, 11-12.

Evans, E. J. (1984). Pre-anthesis growth and its influence on seed yield in winter oilseed rape. *Aspects of Applied Biology. Agronomy, physiology, plant breeding and crop protection of oilseed rape* **6**, 81-90.

Fray, M. J. (1995). The genetic and physiological assessment of apetalous flowers and erectophile pods in oilseed rape (*Brassisca napus* L.). Ph.D., University of Newcastle upon Tyne.

Fray, M. J., Evans, E. J., Lydiate, D. J., and Arthur, A. E. (1996). Physiological assessment of apetalous flowers and erectophile pods in oilseed rape (*Brassica napus* L.). *Journal of Agricultural Science* **127**, 193-200.

Gemmill, J. M., Evans, E. J., Werner, C. P., Williams, E. (2003). Influence of the apetalous character on the distribution of pods and seeds in near-isogenic lines of winter oilseed rape (*Brassica napus*). *Proceedings of the 11th International Rapeseed Congress, Copenhagen*.

Habekotté, B. (1993). Quantitative analysis of pod formation, seed set and seed filling in winter oilseed rape (*Brassica napus* L.). *Field Crops Research* **35**, 21-33

Jiang, L., and Becker, H. C. (2001). Environmental effects on expression of apetalous flowers in oilseed rape. *Journal of Applied Botany* **75**, 75-79.

Mendham, N. J., and Scott, R. K. (1975). The limiting effect of plant size at inflorescence initiation on subsequent growth and yield of oilseed rape (*Brassica napus*). *Journal of Agricultural Science* **84**, 487-502.

Rao, M. S. S., Mendham, N. J., and Buzza, G. (1991). Effect of the apetalous character on radiation distribution in the crop canopy, yield and its components in oilseed rape (*Brassica napus*). *Journal of Agricultural Science* **117**, 189-196.