VERNALIZATION AND PHOTOPERIOD REQUIREMENTS FOR THE ADAPTABILITY OF RAPESEED TO THE SOUTHEASTERN UNITED STATES

M.S.S. Rao, P. L. Raymer

University of Georgia, Georgia Experiment Station
1109 Experiment Street, Griffin, GA 30223-1797, USA

INTRODUCTION

Rapeseed is emerging as an economically viable alternative to wheat in many parts of the USA. The southeastern United States with its long mild winters and well distributed rainfall offers the potential for double cropping rapeseed with soybean or sorghum (Raymer et al. 1990.). In developing this new crop in the USA, most of the varieties currently being made available either for cultivation or for breeding purposes are of Canadian or European origin. The environments for which these varieties were bred are markedly different from those prevailing in the southeastern United States.

Time of flowering is an important factor determining seed yield of rapeseed and is therefore a major objective in many successful breeding programs (Thurling and Vijendra Das, 1977). Rapeseed being a temperate climate crop is known to require some degree of vernalization (Mendham et al. 1990) and long daylengths (Levy and Peterson, 1972) in order to flower. Myers et al. (1982) showed that both spring and winter lines of rapeseed required both vernalization and long photoperiods for flowering within 21 weeks. The importance of these two factors in determining the phenological pattern and adaptation of rapeseed to some Australian environments has been shown by Hodgson, (1978). It is therefore necessary to quantify the vernalization and photoperiod requirements of the rapeseed genotypes currently available in the USA for successfully adapting rapeseed to the diverse environments of the southeastern United States. This paper discusses briefly the responses to different durations of vernalization, and short and long photoperiods of 24 genotypes of Brassica napus and B. campestris studied in two separate experiments in the greenhouse and growth chambers.

MATERIALS AND METHODS

In Experiment I, the 24 genotypes (Table 1) were grown up to two true-leaf stage in a greenhouse before being transferred into a cold room where they were vernalized at 4/2° C day/night temperatures at 34-40 $\mu E/m^2/s$ light intensity provided by two VHO fluorescent tubes for 13 hours/day. The vernalization durations were 0, 3, 5 and 7 weeks and the schedules were so arranged that all the treatments were completed simultaneously. The unvernalized and vernalized seedlings were then transplanted into 4 inch diameter pots filled with a soilless medium, Metromix grade 350 (Pennington Seed Co., Madison, Georgia, USA). The plants were grown up to flowering or 30 weeks from date of sowing in the greenhouse at 18 to 24° C temperatures and natural daylength which varied from 13 h in August to about 10-11 h in January-February.

In Experiment II, the genotypes used and the methods of vernalization were identical to those in Experiment I, except that they were vernalized for only two durations of 6 and 12 weeks. A set each of 6 and 12 weeks vernalized seedlings were then transferred into two separate growth chambers and were subjected to 8- and 16-hour photoperiods, respectively. Both the chambers were maintained at 18.5/12° C day/night temperatures and light intensities of 280-290 $\mu E/m^2/s$.

All the treatments were replicated four times and were given soluble fertilizer at weekly intervals. Experiment I was arranged in a completely

randomized design within a vernalization treatment and Experiment II was arranged in split-plot design within a photoperiod treatment. In both experiments, the number of days to first flower and the number of nodes to first flower when at least two replicates had one flower open were recorded for each genotype.

RESULTS

In Experiment I, all the spring genotypes and only two winter genotypes responded to the given durations of vernalization as measured by number of leaf nodes to first flower or the number of days to first flower (Table 1). Four spring genotypes, AU 154, Delta, Horizon and Westar flowered early with or without vernalization, but the trend appeared to be facultative in three lines and intrinsic earliness in at least one line, Horizon. The number of leaf nodes and days to first flower declined progressively with increasing duration of vernalization. Genotypic response to the different durations of vernalization was highly significant. The trends in the number of nodes to first flower were generally confirmed by the trends in the number of days to first flower. When averaged across genotypes, the number of nodes to first flower did not differ significantly between 0 and 3 weeks of vernalization, while 5 and 7 weeks of vernalization did produce differences in node numbers. The number of days to first flower, however, differed significantly between 0 and 3 weeks and were not significantly different between 5 and 7 weeks of vernalization.

In Experiment II, both long and short photoperiods following 12 weeks of vernalization promoted flowering in all the spring and winter types (Table 2). Given only 6 weeks of vernalization, long photoperiods promoted flowering in all the spring genotypes while only 4 winter genotypes flowered. Spring genotypes flowered at all combinations of vernalization and photoperiods. Spring types flowered at a lower node under long photoperiods while the winter types did so at 12 weeks of vernalization irrespective of photoperiod. Both spring and winter types flowered earlier under long photoperiod than under short photoperiod.

DISCUSSION

In general, 5 weeks of vernalization at 4/2°C day/night temperatures appeared to be adequate for fulfilling the vernalization requirements of spring genotypes of Brassica napus, all of which flowered under short daylengths of 10-11 h in January-February. Four genotypes, (one Brassica campestris and three early flowering B. napus) appeared to require no vernalization, with one genotype, Horizon also showing intrinsic earliness. For most spring types, given short daylengths, there appears to be an optimum duration of vernalization beyond which both the number of nodes to first flower and the number of days to first flower may be delayed. Spring line, 353/86 responded to 7 weeks of vernalization only indicating that some spring genotypes may be obligate for vernalization if the daylengths are not long enough. The progressive decline in the number of nodes and days to first flower with increasing duration of vernalization was similar to that reported by Mendham et al. (1990) and Thurling and Vijendra Das, (1977). In both experiments, the number of days to first flower appeared to be a more consistent indicator of a genotype's response to vernalization and photoperiods. The number of nodes to first flower appears to be more a genotypic character and hence less sensitive to vernalization or photoperiod effects relative to the number of days to first flower. Levy and Peterson (1972) reported similar observations for wheat.

The range of durations of vernalization applied in this experiment proved inadequate under the given daylengths for most of the winter types

which were bred for over-wintering during the long cold winters, make rapid growth during spring and flower in late spring and summer under long daylengths, Mendham et al (1990). Only two early flowering winter varieties, expected to flower late in March-April (daylengths around 14 h) under field conditions in the southeastern United States flowered at 7 weeks of vernalization indicating photoperiod insensitivity.

Longer duration of vernalization decreased the dependence on photoperiod of most of the winter genotypes and is indicative of the relative importance of vernalization for the winter types. Long photoperiod appeared to be of greater importance for most of the spring types when leaf node number was considered indicative of a response. The trend however, was different when the number of days to first flower was considered as indicative of a response, in that they were similar for a vernalization duration irrespective of short or long photoperiod (Table 2).

The marked differences observed between the spring and the winter types in the present experiment were similar to the results of a study comparing European, Japanese and Canadian cultivars (Thurling and Vijendra Das, 1977).

The present study indicated that sufficient variation in vernalization and photoperiod requirements exists among the large genetic material currently available in the USA. The interaction between the duration of vernalization and photoperiod indicates the possibility of breeding genotypes to suit the temperature and daylength regimes prevalent in different regions of the southeastern United States. The genotype x temperature x photoperiod interactions merit further study for designing effective breeding strategies for the southeastern United States. Given the wide genotypic variation among the Brassica spp., it should not be difficult to select and breed rapeseed for a better adaptation to local environments.

REFERENCES

HODGSON, A.S. 1978. Rapeseed adaptation in Northern New South Wales. I. Phenological responses to vernalization, temperature and photoperiod by annual and biennial cultivars of Brassica campestris L., Brassica napus L. and wheat cv. Timgalen. Aust. J. Agric. Res. 29:693-710.

LEVY, J. and PETERSON, M. L. 1972. Response of spring wheats to vernalization and photoperiod. Crop Sci. 12:487-490.

MENDHAM, N. J., RUSSELL, J. and JAROSZ, N. K. 1990. Response to sowing time of three contrasting Australian cultivars of oilseed rape (Brassica napus). J. Agric. Sci., Camb. 114:275-283.

MYERS, L. F., CHRISTIAN, K. R. and KIRCHNER, R. J. 1982. Flowering response of 48 lines of oilseed rape (Brassica spp.) to vernalization and daylength. Aust. J. Agric. Res. 33:927-936.

THURLING, N. and VIJENDRA DAS, L. D. 1977. Variation in the pre-anthesis development of spring rape (Brassica napus L.). Aust. J. Agric. Res. 28:597-607.

RAYMER, P. L., BULLOCK, D. G. and THOMAS, D. L. 1990. Potential of winter and spring rapeseed cultivars for oilseed production in the southeastern United States. In: Advances in New Crops. Simon, J. E. and Janick, J. (eds). Timber Dioscorides Press, Portland, Oregon. pp. 223-224.

Table 1. The effects of different durations of vernalization on the number of leaf nodes (LN) and days to first flower (DFF).

		Duration of Vernalization (weeks)							
		0		3		5		7	
Genotype	Sp	LN	DFF	LN	DFF	LN	DFF	LN	DFF
Spring type									
353-86	n	NF	NF	26	178	20	157	11	109
AU 154	n	21	115	12	96	11	82	10	100
BLN 292	n	NF	NF	NF	NF	15	129	*	*
BLN 340	n	NF	NF	19	124	14	85	12	94
A112	n	NF	NF	17	118	15	90	13	85
Delta	n	21	116	19	130	13	131	12	103
Global	n	NF	NF	NF	NF	13	80	14	97
Horizon	c	14	68	10	86	10	73	10	79
Marnoo	n	NF	NF	23	133	12	77	13	81
Rebel	n	NF	NF	NF	NF	13	80	12	92
Topas	n	NF	NF	33	184	13	97	10	97
Westar	n	19	120	13	98	10	73	08	80
Mean		**19**	**105**	**17.3**	**127**	**13.6**	**96**	**11.7**	**92**
Winter Type									
2455 A-89	c	NF	NF	NF	NF	NF	NF	NF	NF
Bienvenu	n	NF	NF	NF	NF	NF	NF	14	113
Cascade	n	NF	NF	NF	NF	NF	NF	NF	NF
Ceres	n	NF	NF	NF	NF	NF	NF	NF	NF
Crystal	n	NF	NF	NF	NF	NF	NF	NF	NF
Diadem	n	NF	NF	NF	NF	NF	NF	NF	NF
Dwarf Essex	n	NF	NF	NF	NF	NF	NF	NF	NF
Glacier	n	NF	NF	NF	NF	NF	NF	NF	NF
Jupiter	n	NF	NF	NF	NF	NF	NF	16	125
Lindora	n	NF	NF	NF	NF	NF	NF	NF	NF
Touchdown	n	NF	NF	NF	NF	NF	NF	NF	NF
Windfield	n	NF	NF	NF	NF	NF	NF	NF	NF
Mean								**15**	**119**
LSD^{+} (0.05)		1.22	2.94						

Sp = species; n = Brassica napus; c = B. campestris; NF = not flowered; * no plants; $^{+}$ between vernalization duration.

Table 2. Mean numbers of leaf nodes (LN) and days to first flower (DFF).

		Photoperiod/vernalization							
		Short				Long			
		6 weeks		12 weeks		6 weeks		12 weeks	
Genotype	Sp	LN	DFF	LN	DFF	LN	DFF	LN	DFF
Spring type									
353-86	n	14	172	14	135	13	97	13	122
AU 154	n	15	140	13	124	13	90	12	118
BLN 292	n	17	155	17	122	16	97	17	124
BLN 340	n	17	144	14	127	14	111	15	123
A112	n	17	144	17	124	16	97	16	120
Delta	n	13	149	18	125	15	92	16	118
Global	n	18	163	17	119	13	107	16	120
Horizon	c	13	145	13	126	15	86	15	115
Marnoo	n	19	176	16	138	18	91	17	121
Rebel	n	16	158	16	126	18	94	16	122
Topas	n	16	149	17	123	15	94	14	118
Westar	n	13	136	14	126	13	94	12	122
Mean		**15.7**	**153**	**15.5**	**126**	**14.9**	**96**	**14.9**	**120**
Winter Type									
2455 A-89	c	26	175	19	146	23	99	20	123
Bienvenu	n	15	175	14	150	15	103	16	124
Cascade	n	17	173	16	135	15	97	14	122
Ceres	n	NF	NF	15	158	20	111	15	125
Crystal	n	NF	NF	17	163	20	103	17	126
Diadem	n	NF	NF	14	171	20	111	17	131
Dwarf Essex	n	NF	NF	18	189	20	120	16	129
Glacier	n	NF	NF	16	156	21	112	17	132
Jupiter	n	NF	*	17	144	*	*	18	127
Lindora	n	NF	NF	17	159	23	107	18	130
Touchdown	n	NF	NF	16	160	23	112	17	137
Windfield	n	16	171	15	144	16	102	15	127
Mean		**18.5**	**174**	**16.2**	**156**	**19.6**	**107**	**16.7**	**128**
LSD_1 (0.05)		0.45	1.06						
LSD_2		2.46	9.49	1.63	4.09	2.45	2.12	2.19	1.98

Sp = species; n = Brassica napus; c = B. campestris; NF = not flowered; * no plants; LSD_1 = between photoperiods within a vernalization treatment; LSD_2 = between cultivars within photoperiod and vernalization.