INFLUENCE OF TEMPERATURE AND RADIATION ON COMPONENTS OF SEED YIELD IN CRAMBE (*CRAMBE ABYSSINICA* HOCHST.)

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ABSTRACT

Seed yield components in *Crambe abyssinica* L were related to developmental stages, radiation and temperature. Data were obtained from field experiments in 1991 and 1992. Two early and two late cultivars were grown at plant densities ranging from about 40 to 140 m^{-2}. Over the growing season ground cover and plant stages were recorded and at final harvest seed yield, average seed weight and seed number per area were assessed. From the weather data the cumulative intercepted radiation and the temperature sum was calculated for the developmental stages.

Low temperatures after emergence in 1991 retarded development of the plants relative to vegetative growth and well before first flowering full ground cover was attained with all cultivars and at all plant densities. These crops produced high numbers of seeds, irrespective of plant density, and no significant relationship was found between seed yield and seed number or seed weight. In 1992, however, temperature after emergence was high, first flowering occurred when the plants were small, before (early cultivars and low plant densities) or at the time (late cultivars and high densities) the canopies closed. Seed yields of these crops were positively related to number of seed per area and, to a lesser extent, to seed weight. For all cultivars the number of seeds in 1992 was positively related to plant density. In both years seed weight depended on cultivar, but was not affected by plant density nor by the number of seeds per area and per plant. The number of seeds per area of the late cultivars was very similar in both years, whereas seed numbers of the early cultivars in 1991 were much increased. For all cultivars seed weight in 1992 was higher, probably because of the higher radiation during seed filling. Seed weight of the late cultivars was on average 11 % higher compared to 27 % for the early cultivars. These results suggest more pronounced effects of temperature and radiation on yield components in early cultivars. It is concluded that vigorous crop growth until flowering in *Crambe* assures high seed numbers and a high yield potential to be formed. Radiation during flowering and seed filling determines to what extent that yield potential is exploited.

INTRODUCTION

Interest in crambe has increased significantly since work began on breeding and growing rapeseed cultivars with low erucic acid contents suitable for the edible oil market. Meanwhile, the traditional outlet for oils with a high erucic acid contents, for erucamides as slip agents in plastic films, has continued to expand. New applications have been developed and research is in progress to increase these further. This has renewed awareness of the potential of crops that yield the industrial oil. Crambe can also be grown for this purpose. Hence breeding work is currently in progress in various countries to enhance the erucic acid content of rapeseed and crambe oil and to reduce the content of toxic glucosinolates in the residual meal. The research on rapeseed is supported by massive genetic and crop physiological programmes focusing on the edible oil type. Crambe is interesting because of the higher erucic acid content of its oil: between 53 and 57 % for most genotypes (Mastebroek et al., 1994). In these Brassicae erucic acid is not found at the middle position of the tri-glycerate, and crambe therefore approaches the theoretical maximum erucic acid content.

The high and low erucic acid rape varieties can cross pollinate. Furthermore, the high erucic acid genotypes are dominant. Therefore these cultivars must not be grown together. However, the breeding of crambe is hampered by the limited genetic variability for important agronomic characters such as seed and oil yield and fatty acid composition (Lessman and Meier, 1972; Lessman, 1975; Mastebroek et al., 1994). To be able to breed for improved seed yield, the plant characters and environmental conditions that affect seed yield components must be know and the optimal growing conditions for genotypes must be defined. This would enable an ideotype to be defined for North West European conditions. For these reasons we studied seed yield components and their interaction with environmental conditions. In this paper we report on the results with two early and two late cultivars in field experiments at different plant densities in two contrasting years.

MATERIALS AND METHODS

In 1991 and 1992 two early and two late cultivars were grown at three plant densities (aiming at 40, 80 and 120 plants/m^2) in a light clay soil. The crops were well supplied with minerals and water and protected from diseases. They were sown on 9 April (1991) and 23 April (1992), emerged two weeks later and were harvested on 13 (1991) and 12 (1992) August. Over the growing season plant stages and ground cover were recorded and at final harvest seed yield, 1000-seed weight and seed number per area were assessed. For all the crops a logistic function was fitted through the ground cover data and used to calculate the fraction intercepted radiation over the growth cycle. From the weather data the means of the daily minimum and maximum air temperatures were derived, and also the daily incoming photosynthetic active radiation (PAR) receipts. The temperature sum and accumulated PAR were calculated for two distinct periods (from emergence to first flowering and from first flowering to beginning of seed ripening, the latter period being fixed at 40 days) .

RESULTS AND DISCUSSION

Crambe pods contain a single seed, which remains in the hull at harvest and is included in the seed yield. Our analysis of seed formation focused on the number of seeds per area and on average seed weight. The early cultivars VN 61 and VN 98 produced high seed numbers in 1991 and low numbers in 1992 (Table 1). However, the seed numbers produced by the late cultivars Bel Ann and Boransky were similar in these years. In 1991 seed number was not affected by plant density but in 1992 it was less at the lower plant densities in all cultivars. The reductions were most severe in the early cultivars.

Table 1. The seed number, 1000-seed weight and seed yield of four crambe cultivars at three plant densities in 1991 and 1992.

Year	1991				1992			
Plants/m^2	53	81	103	*average*	40	78	113	*average*
seed number/m^2.1000								
VN 61 (early)	57	56	57	*57*	40	45	48	*44*
VN 98 (early)	52	55	52	*53*	39	43	47	*43*
Bel Ann (late)	49	48	49	*49*	46	48	50	*48*
Boranski (late)	42	48	45	*45*	44	48	49	*47*
average	*50*	*52*	*51*		*42*	*46*	*49*	
1000-seed weight (g)								
VN 61 (early)	5.5	5.5	5.4	*5.4*	7.1	7.0	7.1	*7.1*
VN 98 (early)	6.5	6.3	6.5	*6.4*	7.8	7.7	7.7	*7.7*
Bel Ann (late)	6.9	7.0	7.0	*7.0*	7.7	7.8	7.9	*7.8*
Boranski (late)	7.0	6.6	6.8	*6.8*	7.5	7.4	7.6	*7.5*
average	*6.7*	*6.6*	*6.7*		*7.5*	*7.5*	*7.6*	
seed yield (t/ha)								
VN 61 (early)	3.1	3.1	3.1	*3.1*	2.9	3.2	3.4	*3.2*
VN 98 (early)	3.4	3.5	3.4	*3.4*	3.1	3.3	3.6	*3.3*
Bel Ann (late)	3.4	3.4	3.4	*3.4*	3.6	3.8	4.0	*3.8*
Boranski (late)	2.9	3.2	3.1	*3.1*	3.3	3.6	3.7	*3.5*
average	*3.2*	*3.3*	*3.3*		*3.2*	*3.5*	*3.7*	

The differences between years are attributable to the temperature in the period from emergence to flowering. Temperature in that period was low in 1991 and high in

1992 (Table 2). Low temperatures retard development but growth processes are generally less affected. Therefore in 1991 flowering was retarded, the crops grew vigorously until first flowering and produced high seed numbers, irrespective of plant density. The high temperatures after emergence in 1992 accelerated development and first flowering occurred early, at about the time of canopy closure (Table 2). Because the growth of the plant and the formation of branches and flower sites depends solely on radiation, the early flowering cultivars VN 61 and VN 98 and the low plant densities were most affected and produced low seed numbers (Table 1). The late cultivars and high plant densities were largely able to compensate for the limited plant size at first flowering.

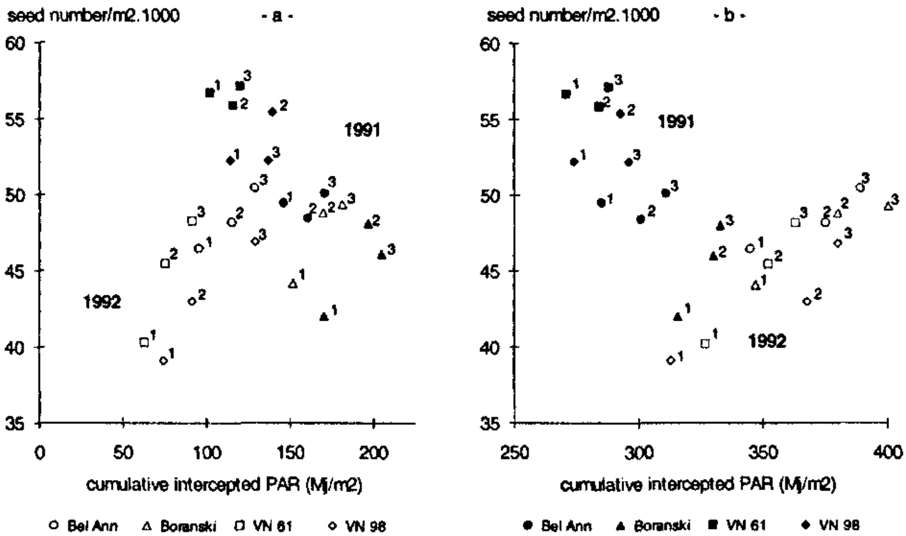

Figure 1. The seed number of four cultivars of crambe at three plant densities in 1991 and 1992 related to the cumulative intercepted photosynthetic active radiation (PAR) from:
a. emergence to first flowering
b. first flowering to beginning of seed ripening (40 days).
Numbers indicate plant densities; 1 = low, 2 = intermediate, 3 = high.
For the exact plant densities in 1991 and 1992 see Table 1.

Seed numbers in crambe seem to be determined by the growing conditions in the plant's vegetative and reproductive phases. Under favourable conditions biomass production is linearly related to the photosynthetic active radiation (PAR) intercepted by the canopy. The radiation intercepted over a given period is therefore a measure of crop growth. In Figure 1 the seed numbers of the various crops in 1991 and 1992 are plotted against intercepted PAR in the periods from emergence to first flowering (Fig. 1a) and from first flowering to the onset of seed ripening (Fig. 1b). In 1991 seed numbers were determined by cultivars only, and highest numbers were attained in the early types, which intercepted less radiation. With the small plants at flowering in 1992, seed numbers correlated positively with the intercepted radiation, giving the closer relationship with intercepted PAR in the phase from flowering to ripening (Fig. 1b). This suggests that seed numbers in 1992 were largely determined by crop growth after first flowering. From a series of six yearly crops Küchler (1963) concluded that low temperatures during early vegetative growth positively influenced seed number and attributed that positive effect to improved flower induction. Our results suggest that retarded development relative to vegetative growth is the explanation for the higher seed numbers at low temperatures.

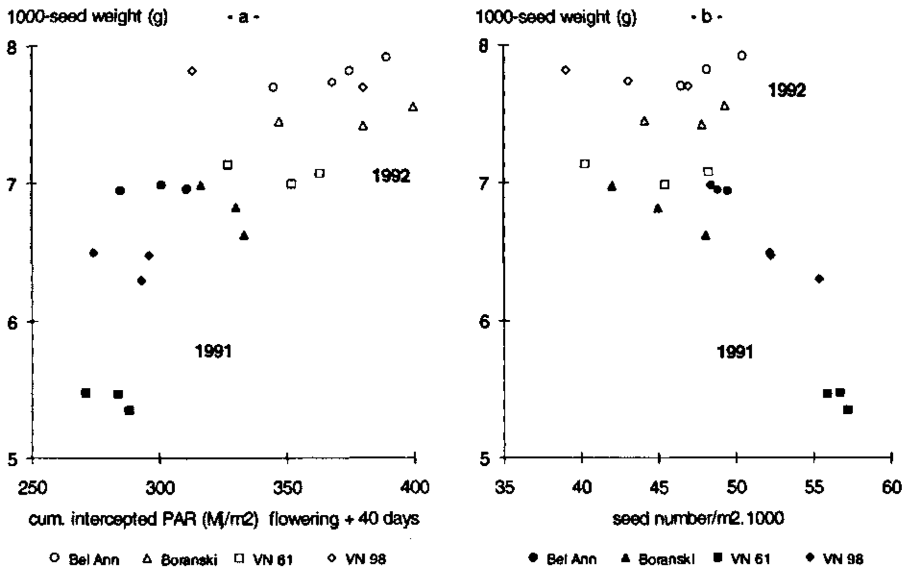

Figure 2. The 1000-seed weight of four cultivars of crambe at three plant densities in 1991 and 1992 related to: a. the cumulative intercepted PAR from first flowering to beginning of seed ripening (40 days) b. the seed number per area.

Average seed weight was not affected by plant density (Table 1). The genotypic differences in seed weight were fairly consistent in the two years; however, seed weight was much greater in 1992, especially in the two early cultivars. The increased seed weight of all cultivars in 1992 is probably attributable to the high radiation in that year: during the period from first flowering to beginning of ripening the daily radiation receipts were on average 23 % more than in 1991 (Table 2). In both winter and summer rape it has been demonstrated that from first flowering onwards, the assimilation activity shifts from the leaves to the stems and then to the pods (Rood et al., 1984; Chapman et al., 1984). If this also reflects the pattern of assimilate production in crambe, then it explains the higher seed weight in 1992.

In Fig. 2a seed weight is related to the intercepted radiation in the period from first flowering to first ripening. From Fig. 2a no clear relationship can be derived between seed weight and the PAR intercepted by the crops and this figure illustrates that seed weight is mainly determined by cultivars and year.

Table 2. Weather and crop data, means of cultivars and plant densities.

Parameter	Year	
	1991	1992
daily average photosynthetic active radiation (KJ/m^2.d)		
emergence to first flowering	7.0	9.8
first flowering + 40 days	8.2	10.1
daily average temperature (°C)		
emergence to first flowering	10.4	16.6
first flowering + 40 days	17.9	16.9
number of days		
emergence to first flowering	64	34
emergence to 80 % ground cover	51	28

In 1992, with small plants at flowering stage, light interception in Fig. 2a is greater at the higher plant densities in each cultivar. However, seed weight is similar. This agrees with the above suggestion that it is assimilation by the pods, and therefore radiation at pod level, that determines seed weight, not radiation intercepted by stems and leaves. Weiss (1983) stated that seed size in crambe varies considerably and is mainly affected by the number of seeds per plant, but our results refute this. In both years and in all cultivars, seed numbers per plant at the three plant densities were very different but 1000-seed weight was not affected (Table 1). When seed weight is plotted against seed numbers (Fig. 2b) there seems to be a negative relation for all cultivars and densities in 1991, but that relationship is determined by the reduced seed weight of a single cultivar.

The highest seed yields in 1991 were attained from an early cultivar which had high seed numbers and a moderate seed weight. Similar yields were obtained from a late cultivar which had moderate seed numbers and a high seed weight. In 1992 the highest yields were obtained with the same late cultivar, which had both high seed numbers and high weight. The seed yields of all cultivars at all densities in 1992 were linearly related to seed numbers (R = 0.87). In 1992 no such a relationship was found because the seed weight of the early cultivar VN 61 was most affected by the low radiation in that year (Fig. 3a). In 1992 a weak linear relationship was found between seed yield and seed weight, but no such relationship was found in 1991 (Fig. 3b).

CONCLUSION

The early cultivars exhibited more pronounced effects of plant density, temperature and radiation on yield components than the late cultivars. Seed numbers were affected by the growing conditions in both the pre-flowering and the post-flowering stages.

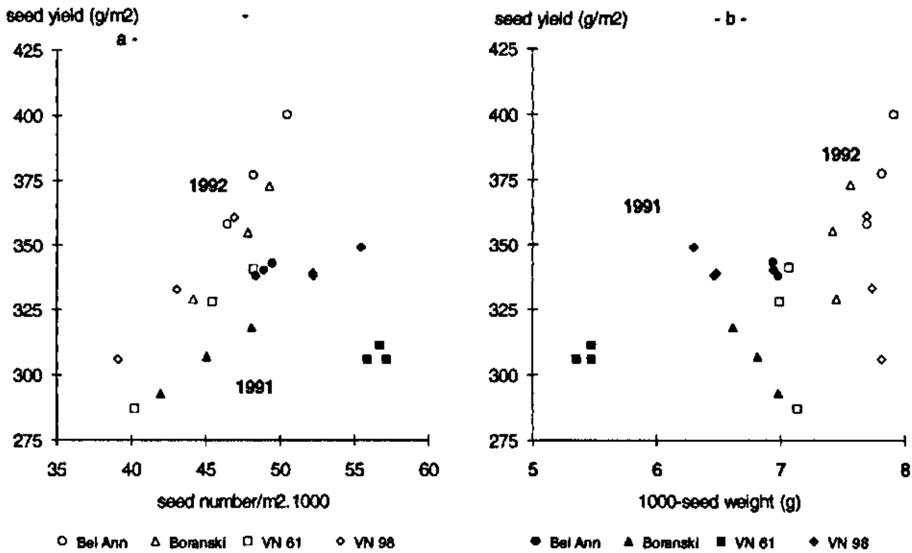

Figure 3. The seed yield of four cultivars of crambe at three plant densities in 1991 and 1992 related to: a. the seed number per area b. the 1000-seed weight.

Seed weight is probably mainly determined by the radiation intercepted by the pods. This suggests that vigorous growth until flowering assures high seed numbers and therefore a high potential yield. Radiation receipts during the phase from flowering to ripening determine to what extent that potential is exploited.

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