Canola Response to Growing Season Climatic Conditions

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INTRODUCTION

Recently, canola growers have expressed concern over low yields of apparently highly productive crops. A survey of growers regarding their 1994 and 1995 crops requested information about situations where yields were below expectations and the grower either knew or did not know the cause. Where the cause was known, drought and insect damage were the most common causes, although stress at flowering, diseases, poor stands or early vigor were implicated in several cases. Where the cause was unknown, stand establishment, fertility, weed control, diseases, insects and rotation did not generally appear to be a problem. However they did indicate that in most cases affected crops were either poorly podded, had areas on the plant with missing pods and/or unusually high proportions of shrivelled and shrunken seeds. This response would suggest that yield reductions occurred during flowering and seed development. All of these symptoms are typical of canola responses to high temperature or moisture stress during flowering and seed development.

All grain crops have mechanisms to adjust their vegetative and reproductive growth in response to climatic conditions. These traits are desirable and have been selected to enable improved cultivars to adjust production in response to climate, rather than fail completely under stress. The degree of adjustment that is desirable depends on climatic variability where the crop is grown. In general, initial yield potential is at some theoretical maximum for the crop and declines as stress is encountered during the growing season. The objective of individual plants and the crop as a whole is to match crop productivity to environmental limitations. Typically yield adjustment involves the numbers of productive plants per unit area, the numbers of pods per plant, the numbers of seeds in each pod,and seed size. All can change in response to environmental stress, with their relative importance a reflection of the growth stage at which stress occurs.

DISCUSSION

Yield adjustment in canola begins at seeding and continues until seed filling is complete. Competition for soil water begins with imbibiiion, germination and emergence. Under moisture or temperature stress, germination and emergence decreases. For example, % emergence of canola declines as rates of seeding or row spacings increase due to greater competition (Table 1). However, canola retains a very large capacity to compensate for reduced plant densities if conditions improve or other factors (flea beetles, disease, hail) reduce plant stands (McGregor, 1987). Where initial plant densities are high, further reductions in plant number can occur as less vigorous plants fail to compete and die, while under low densities, later emerging plants may survive, grow substantially, and contribute to yield.

Table 1. Influence of competition induced by wider rows and increased seeding rates on emergence of canola (means for B. *napus* and B. *rapa* over 3 years each).

Seed rate (kg/ha)	Row spacing (cm)					
	11.5		23		46	
	%	plants/m*	%	plants/m*	%	plants/m*
2	**69**	**55**	**49**	**39**	**40**	**32**
4	51	81	41	66	39	62
8	43	136	39	124	28	90
12	47	224	33	157	24	134

Vegetative growth prior to flowering has a substantial effect on yield. The extent of this growth establishes the potential for pod and seed production. Where soil water and nutrients are abundant, the balance of root to shoot and leaf growth typically shifts in favor of shoot growth at the expense of roots. Where water is limiting, the opposite usually occurs. This is know as the functional relationship between root and shoot growth (Brouwer, 1983). This concept assumes that root and shoot growth compliment one another by adjusting their relative size to meet the basic requirements of the whole plant in response to climatic and soil conditions. It is an attempt by the crop to balance the energy expended on root development against that directed to other growth in support of seed production. With canola, roots accounted for 25% of plant dry matter when moisture stress occurred at stem elongation compared with 20% for unstressed plants (Richards and Thurling 1978).

During vegetative growth, the canola crop develops the structures, mainly leaves, that produce assimilates to support subsequent reproductive growth. Stress at this stage reduces leaf development which may restrict assimilate production (Clarke and Simpson 1978., Mendham and Scott, 1975.).

At or just prior to stem elongation (bolting), flower and branch initiation begins. The canola plant initiates many more inflorescences than it can support, then aborts back according to percieved carrying capacity. Similarly, flower production and seed production undergo substantial abortion depending on the carrying capacity established by vegetative growth and environmental stress imposed during flowering and seed set. Environmental stress can reduce the degree of branching (Ghosh and Chatterjee 1988), and if the second to fourth primary branches (from the top) are affected, total flower production can be reduced. Since these branches make a substantial contribution most to yield, seed production can be seriously reduced. Development of branches are not fixed until the end of flowering. Removal of some (eg. hail) can initiate replacement. Similarly, stress (hail, heat, drought) can abort pods and fertilized seed. Then, the only way the crop can respond to more favorable conditions is by producing larger seeds. A general trend for branching to be reduced with later planting has been observed for 5. *Juncea* (Ghosh and Chatterjee 1988)

During flowering, yield adjustment occurs as a function of the number of flowers produced and fertilized. Under stress, the numbers of branches that produce flowers may be reduced and the numbers of flowers on each branch decline. Further, flowers that are open during stress may fail to fertilize(Tayo and Morgan, 1975). At mean daily temperatures above **22^0** C, plants are sterile (Morrison et al. 1992). This occurs frequently during periods of heat stress. Normally, fertility of flowers that open later are unaffected if stress has been alleviated. Areas on the raceme with no pod development is evidence of this type of response. Under severe stress, increased numbers of unopened buds can be lost. This typically signals the end of flowering. Where severe stress has occurred early in flowering and the crop stops flowering, it may resume if very favorable conditions return. This is particularly true for the mustards and Brassica. ***mpa,*** but occurs less frequently with Brassica napus and **is evidenced** by increased branching.

Environmental stress towards the end of flowering or just after flowering affects the number of seeds that develop in each pod.Substantial stress is evident as shorter pods or lack of expansion of pods around missing seeds. The number of seeds that develop in each pod can be influenced by availability of assimilates at the time when seed expansion begins. Lack of assimilates at this point, reduces the number of seeds that begin development even though fertilization may have occurred.

During early seed development, the seed coat develops before the embryo, leading to the ‘balloon stage”, when the seeds are full size, but are filled with a watery endosperm. At this stage, they are quite susceptible to losses (Mendham and Scott, 1975), with assimilates being redirected to those that remain. The strategy of the crop at this stage is to accept a reduction in seed number to ensure that those remaining will develop fully. When this response occurs early in seed expansion, it may be evidenced by segments of pods that do not expand normally with little or no sign of seed remnants inside the pod. When it occurs late, the pod expands normally because the seed expanded normally and then senesced. Inside the pod, is the shrivelled seed coat with little or no evidence of having started the seed filling process. Canola crops undergoing this type of stress may appear to have normal looking pods with normal length and girth, but when harvested yield little seed, much of it shrivelled.

Once seed expansion is complete, seeds are more resistant to loss under stress, but losses can occur if stress is sufficiently severe. When this occurrs, the plant attempts to remobilize assimilates from available sources (eg. stems and pods) and redirect them preferentially to the seeds that continue filling. Pod development shows no outward signs of stress, but affected seeds may be visibly shrivelled within the pod. A typical response, even if shrivelling is not evident, is for seed size to be reduced, due to reduced production and mobilization of assimilates required for seed filling. Where stress is severe enough, a large portion of seeds will likely have wrinkled seed coats.

Limited research on the Canadian Prairies indicates that the bolting to seed filling stage is critical for canola yield determination. Precipitation and moisture conditions during this period are both important factors. Yield declines rather sharply as temperatures rise or water deficits increase.

It is important to note that the stress causing these responses can be internal to the plant whereby the plant is unable to take up soil water available to it or to generate the assimilates necessary for seed filling. The stress can also be external where soil water is limiting or temperatures excessive for optimal crop development.

In long term fertilizer response studies in Northeastern Saskatchewan, (Nuttal et al. 1992) canola ***B.napus*** yield has been shown to decrease by 430 kg/ha with a three degree rise in maximum daily temperature during July and August (2.6 bu/ac per ^{o}C rise in temp). For each mm of July - August precipitation received, yield increased by 5.9 kg/ha (approx 2.7 bu/ac/in).

A similar attempt to relate yield to growing season temperatures and precipitation at Scott, Sask. indicated that yield on summerfallow is closely related with temperatures during flowering and early seed development, while precipitation from early seed development through seed filling is essential to achieving full yield potential. For example, for each degree rise in mean daily temperature, yield of B. *napus* declines by 188 kg/ha (3.3 bu/ac), and B. rapa declines 217 kg/ha (3.9 bu/ac). For each mm increase in precipitation, B *napus* yield increases by 5.90 kg/ha (2.7 bu/ac/in) while B. *rapa* increases by 3.33 kg/ha (1.5 bu/ac/in). There also was a weak negative relationship between available water prior to bolting and yield. It may be a reflection of reduced root development where the crop was not stressed early. This relationship would require furthur assesment prior to inclusion in the following equations to describe canola yield responses to temperature and precipitation.

Yield(kg/ha); B. ***napus* =** 4323 + 5.90 **Precip - 187.7 Temp.**

R^2 = **0.76** Std error = 221

B. ***rapa* = 4836 + 3.33 Precip - 216.7 Temp.**

R^2 = **0.72** Std error = **200**

Where; Precip = June 21 to Aug 20 precip Temp = June 15 to Aug 15 mean daily temp.

Which is very similar to that reported by Nuttal et al 1992.

Yield (kg/ha) B. *Napus* = *4290* + *5.90* Precip. - 148 Temp **(R^2=0.32;** S.E.=590)

Where; Precip = July -Aug 31 Precip Temp = July l-Aug 31 mean maximum temp.

Seeding typically occurs one to two weeks earlier at Scott than Melfort, and may explain why the critical period occurs earlier. Mean daily temperature was only slightly more closely related to yield than mean maximum temperature.

5. rapa appeared to be more sensitive to high temperatures, while 5. napus was more sensitive to precipitation. Observations made in Western Australia (Richards and Thurling 1978) also suggested that B. *napus* **was** more sensitive to drought than B. rapa. This may explain the popularity of B. *rapa* in the NW prairies where growing seasons are cooler and drier than on the eastern prairies were B. *napus* is generally more frequently grown.

Disappointing yield of canola during the early 1990's in some areas of the traditional growing area were typified by crops that appeared, before harvest to be quite productive. Plant stands were adequate, podding and pod development appeared to be supportive of higher than average yields, yet grain yield was well below normal. Given these observations, it appears that the problem arose during seed filling. This would suggest that water was limiting and / or the crop suffered damage from abnormally high temperatures. A preliminary evaluation of temperatures during the 1994 and 1995 (Table 2) growing seasons did not reveal any highly abnormal events. Although there were periods of hot weather during both years. Temperatures from mid June to mid August were near or below normal and precipitation was generally above normal, except in crop districts 78 and 9A in the northwest. These events undoubtedly did result in yield losses, but are unlikely to be the full explaination for losses of the magnitude reported.

While temperatures do not vary greatly over short distances, precipitation frequently does. However, even when yield estimates were based on 50% of normal precipitation during June 21 to August 20 and 1995 temperatures, yields would not have been drastically reduced below normal (Table 3). This is because of the mitigating effect of lower than normal temperatures.

Table 2. Temperature (June 16-Aug 16 mean daily) and precipitation (June 21-Aug 20) conditions for several Crop Districts in the traditional canola growing area of Sask.

	Temperature °C		Precipitation (mm)	
Crop dist no.	1996	Long term	1996	Long term
5A	17.8	17.7	101	79
5B	17.2	16.6	177	87
6A	17.5	17.8	98	68
6B	16.9	18.0	91	62
7B	16.4	17.2	75	72
6A	17.3	17.4	190	96
8B	17.1	17.1	124	94
9A	16.9	17.3	82	94
9B	16.6	16.8	103	113

Table 3. Estimated 1996 yield as % of estimated normal yield for several Crop Districts in the traditional canola growing area of Sask. based on climatic variables related to yield

Crop dist.	1995 Est. *B napus* yield (% normal)		Est. *B rapa* Yield (% normal)	
no.	1995 precip	50% normal	1995 precip	50% normal
5A	108	83	105	88 5B
	128	79	115	82
6A	117	90	111	96
6B	119	98	123	112
7B	109	95	114	103
8A	136	84	124	90
8B	114	83	110	89
9A	106	88	103	91
9B	99	84	101	91

B.napus yield = 4323 + 5.90 Precip June 21 to Aug 201 - 187 mean daily temp June 18 to Aug 15
B.rapa **yield** = 4836 + 3.33 Precip June 21 to Aug 20 - 217 mean daily temp June 16 to Aug 15

Overall, one thing appears obvious; these yield reductions were not solely a result of the typical climatic responses of canola as we understand them. Understanding the nature and causes of such yield losses will be a critical step in developing improved strategies for canola management.

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