

A Review for Growth and Development Processes in Canola (*Brassica napus* L.)

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ABSTRACT

Rapeseed (*Brassica napus* L. and *Brassica campestris* L.) are the important oilseed crops throughout the world which rank third among the oilseed crops after soybean and oil palm in production of vegetable oils, while fifth in the production of oilseed proteins. Rapeseed is also important oilseed crops of Iran. This article reviews the most important biological and yield processes that determine the yield of winter canola (*Brassica napus* L.). Biological yield is the product of growth rate and duration of the growing period, both of which indicate the potential for improvement in yield. Most of these models are poor predictors of biomass and yield there is a lack of information about key physiological processes involved in establishment of the stand, the production of biomass and formation of yield, cessation of growth in winter. To analyze yield, it is necessary to understand the structure of the yield and the primary and secondary components, which determine grain yield.

Key words: Growth, Canola, Yield and Morphological Processes

Introduction

Rapeseed hybrids have been recently introduced as a possible means of increasing yield due to heterosis. Becker (1987) reported that heterosis varies from 4 to 63% over the average parental yield and is relatively large under unfavourable conditions, suggesting that hybrids show better yield stability than their parents (Leon 1991). Field experiments (Schuster *et al.*, 1999). Grosse *et al.* (1992b) found that heterosis occurred at all stages of development. Hybrids had 11% more above-ground biomass in autumn, 8% more biomass at flowering and 25% more dry matter after flowering compared to their parents, indicating that major processes involved in the formation of yield are more effective in hybrid varieties. Thus, physiological processes play a key role in variations in yield as well as in selection of highyielding material. A quantitative analysis of processes that determine yield is necessary if greater yields are to be obtained. In recent years considerable effort has been put into the development of models for rapeseed. However, none of these developed so far has performed satisfactorily in predictions concerning biomass and yield. This is because most important processes involved in growth and development have not been studied in depth. Therefore, this review presents information on the yield potential, the most important stages of yield formation, and the yield components of winter oilseed rape including indications of where the existing models would benefit from further work. A more quantitative description with useful data on the various processes which could be incorporated in models is given by Mendham and Salisbury (1995).

2. Yield Potential:

Yield potential of a crop is a theoretical assessment of the maximum yield that can be generated when high yielding biological material is grown in an optimum physicochemical environment. Yield is classified as biological yield (total biomass) and economic yield (the economically useful part of the plant). The relationship between the two, the harvest index, is the proportion of seed dry matter to above-ground biomass, i.e. economic yield / biological yield = harvest index (Fageria, 1992).

2.1. Harvest Index:

As reviewed by Austin *et al.* (1980) and Feil (1992), genetic increases in cereal grain yield in recent decades were largely due to a higher harvest index. The harvest index of modern cultivars of winter wheat showed a 45±50% increase, while that of winter oilseed rape increased by about 25±30% (Diepenbrock *et al.*, 1999). This comparison might be misleading; however, because of the energy content in seeds of oilseed rape is greater than that of wheat. A comparison of aboveground dry matter, harvest index, concentration of energy in kernels and straw, and the energy harvest index of winter oilseed rape and winter wheat is presented in Table 1. Above ground biomass of winter wheat at maximum was 194 (dt ha⁻¹) and that of winter rapeseed 182 (dt ha⁻¹) (Grosse *et al.*, 1992a), so far. Considering ongoing breeding progress (e.g., introduction of hybrids) and for the sake of simplicity, this model assumes that both species produce 200 dt ha⁻¹ of above ground biomass. The harvest index of wheat remains greater than that of rapeseed, even when the energy content is taken into

account. A further analysis of winter rapeseed and winter wheat revealed that, apart from incoming photosynthetically active radiation (PAR), cumulative absorption of PAR and radiation use efficiency (RUE), harvest index is a major parameter that limits yield.

Table 1: Yield and harvest index of winter oilseed rape compared with winter wheat

	Biomass (dt.ha ⁻¹)	Seed yield (dt.ha ⁻¹)	Harvest Index	Energy Content (MJ kg ⁻¹ DM)		Energy harvest index (MJ seed*100/MJ Biomass)
				Seed	Straw	
Winter wheat	200	100	50	18.4	18.4	50.4
Winter oilseed rape	200	50(60)	25(30)	27.6	18.3	33.5(39.3)

^aAccording to Greef *et al.* (1993).

2.2. Growth and Development:

Rapeseed growth models attempt to elucidate breeding goals or to contribute to crop management or systems that support decision making. However, models of rapeseed that can accurately predict biomass or yield have not yet been developed (Gabrielle *et al.*, 1999). Most of the recently published rapeseed models (Table 2) were developed by adapting, with some modifications, complex crop-soil system models, created originally for other crops (Table 2). Therefore, the principal parameters and algorithms are comparable to corresponding basic models for rapeseed. In all models, potential growth is estimated from the product of absorbed photosynthetically active radiation (PAR_a) and canopy RUE. In CER 98 and LIR 97, canopy light absorption coefficient and RUE change during plant development. In DAR 95, the RUE term is substituted by a function approximating the saturation type dependence of RUE on leaf area index (LAI) and PAR_a. Partitioning of biomass to various plant organs and, in particular, to the seeds is generally expressed by a biomass partitioning coefficient (BPC), which varies roughly with developmental stages, to reflect most of the processes that determine yield. Details on the physiology of seed filling are incorporated into LIR 97 (accumulation and redistribution of carbohydrates, maximum potential growth rate per individual seed, seed density) and CER 98 (partitioning of pod photosynthesis among pod walls and seeds, allometric relationships between pod walls and seeds, yield components as a function of radiation intercepted). N uptake from the soil, stress factors and growth constraints are only included in the models EPR 95, DAR 95 and CER 98. The simple model LIR 97 does not include modules for mineral nutrition and water regime, and is, therefore, valid only for optimum growth conditions. Furthermore, LIR 97 does not simulate the autumn and winter development phases and DAR 95 does not account for the loss of leaves by senescence or the partitioning of dry matter between pods and vegetative parts after Flowering. CER 98 was tested only for fully irrigated crops. Physiological modules of model HUR 97 are similar to those of CER 98. For these reasons, it is necessary to describe the development of yield and the structure of yield in order to extend the database for model development and to compare and to verify the hypotheses of various models. In general, the fitted curve representing dry matter accumulation is sigmoid in shape. The pattern of dry matter accumulation as affected by three important agronomic determinants: pre-crop, type of N fertiliser and N supply, is illustrated in Fig. 2. Although the curve based on growth data does not describe the special events that occur during the formation of yield, it reveals that N supply followed by the type of N fertiliser and the previous crop all have a strong effect on yield. The important role played by plant-available N in the growth of autumn-sown rapeseed is well established (Rathke, 2000).

Table 2: Recently Published Rapeseed Crop Models

Basic model	Symbol	Author
EPIC (Williams <i>et al.</i> , 1989)	EPR 95	Kiniry <i>et al.</i> (1995)
DAISY (Hansen <i>et al.</i> , 1991)	DAR 95	Petersen <i>et al.</i> (1995)
LINTUL (Spitters, 1990)	LIR 97	Habekottel <i>et al.</i> (1997a,b)
See Husson <i>et al.</i> (1997)	HUR 97	Husson <i>et al.</i> (1997)
CERES-N maize (Jones and Kiniry, 1986), NCSOIL (Molina <i>et al.</i> , 1983), HUR 97 (Husson <i>et al.</i> , 1997)	CER 98	Gabrielle <i>et al.</i> (1998)

2.3. Number of Pods per Plant:

The seed yield of individual plants is closely related to the number of pods per plant. During the course of development, this trait is ultimately determined by reduction in the number of branches, buds, Flowers, and young pods by source capacity, the supply of nutrients and water and hormonal factors (de Bouille *et al.*, 1989) rather than by the potential numbers of Flowers and pods. Single plants may have at least 20±25

primary branches, many of which do not set pods due to intra-plant competition. Accordingly, Geisler and Henning (1981a) reported that at nine plants per m² (very weak, or no, competition) only 43% of the potential branches were fertile. External factors such as arrangement of the stand, sowing date and N-fertilisation also play a crucial role in control of pod number. It was repeatedly demonstrated that the number of pods per plant is negatively correlated with the number of plants per unit area (Sierts *et al.*, 1987). Since the number of branches is directly linked to the geometry of the stand, increasing plant density from 9 to 50 plants (normal) per square metre resulted in a dramatic decrease in the number of fertile branches to 28% of the potential number of fertile branches (Geisler and Henning, 1981a). Furthermore, increased competition not only reduces branching, but also the number of pods on all branches. The terminal raceme is least affected, indicating that its relative contribution to the total number of pods per plant or area increases when the density of the stand is increased.

3. Plant Density:

Plant density has the greatest effect on seed yield and the yield components of individual plants. Variations in seeding rate and seedling emergence control patterns of distribution of plants per unit area, thus establishing the boundaries of intra-specific competition within the canopy. As reported by Huehn (1998), inaccurate sowing machines as well as abiotic and biotic effects lead to a nonregular distribution of plants in the canopy. Based on three data sets for drilled seeds, different accuracies of the longitudinal distribution within rows were quantitatively measured using the coefficient of variation in the distance between plants within rows. Yield decreased with increased variability in the distance between plants in the row. Competition reduces plant density during crop growth. At the end of the growing season, therefore pod bearing plants are just a proportion of those in the same area at emergence (Boiffin *et al.*, 1981). Results reported Sierts *et al.* (1987) demonstrate that when plants are evenly distributed there are fewer losses as a result of environmental stress. In consequence, yield is most stable when plants are evenly distributed.

4. Conclusions:

Duration of growth, rate of production and harvest index are crucial for enhancing biomass and seed yield. During the growth cycle, establishment of the stand, use of radiation and availability of assimilates for pod set and seed filling are decisive factors in yield.

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