



Modelling early growth under different sowing conditions: A tool to predict variations in intercrop early stages



Benoit Fayaud^a, Françoise Coste^a, Guénaëlle Corre-Hellou^a, Antoine Gardarin^b, Carolyne Dürr^{c,*}

^a LUNAM Université, Groupe ESA, SFR 4207 Quasav, UR LEVA, 55 rue Rabelais, 49007 Angers, France

^b INRA-AgroParisTech, UMR 211, BP 01, 78850 Thiverval-Grignon, France

^c INRA, UMR 1345, IRHS, 42 rue Georges Morel, 49071 Beaucozéz, France

ARTICLE INFO

Article history:

Received 25 February 2013

Received in revised form

11 September 2013

Accepted 18 September 2013

Keywords:

Crop model

Emergence

Exponential growth

Mineral nutrition

Sowing depth

ABSTRACT

Early growth is a critical phase of the crop cycle, which lasts from emergence to the beginning of competition between plants and is sensitive to sowing conditions and species characteristics. Providing tools to improve the management of this critical phase in intercrops is a challenge for agroecology as these cropping systems are the subject of renewed interest for their ability to maintain yields while requiring fewer inputs. The aim of the present study was to investigate variations in early growth under different sowing conditions in different species with contrasted seed and seedling characteristics (seed mass, hypogeal or epigeal emergence, and legume and non-legume species), especially species used as intercrops. Experiments were carried out in glasshouses using different sowing depths and levels of mineral nutrition, first for each species separately, then in mixed sowings. In the first set of experiments, biomass at emergence and relative growth rate after emergence were measured and then modelled as a function of seed mass, mineral nutrition, and time to emergence. Predictive equations were tested by comparing simulations with biomass measured in the second set of experiments, for two intercrops grown under varied sowing conditions. Finally, simulations were run to analyse variations in the early growth of two intercrops (durum wheat/pea or alfalfa) under a wider range of sowing conditions (seed mass, sowing depth, and with or without mineral nutrition). Biomass at emergence was positively correlated with seed mass, and in epigeal species, was also negatively impacted by time to emergence. Relative growth rate was highly stimulated by mineral nutrition whereas its response to time to emergence varied among species. The amount of seminal reserves at emergence (in hypogeal species) and the cotyledon specific mass (in epigeal species) were correlated with the establishment of the relative growth rate. When evaluated, the model was shown to satisfactorily predict the early growth of two intercrops. Used as a simulation tool, the model indicated that all the sowing techniques tested can have a major influence on total biomass and on the proportion of each component species when competition begins. This model can thus contribute to the management of sowing techniques for sole as well as combined crops whose effects are difficult to predict and are also difficult to analyse from field experiments alone because of the number of possible combinations and interactions.

© 2013 Elsevier B.V. All rights reserved.

1. Introduction

Crop establishment is a critical phase of the plant cycle and varies according to sowing conditions (Boiffin et al., 1992). Improving our knowledge on this phase is a challenge for agroecology to better manage increasingly complex and diversified cropping

systems aimed at decreasing amounts of inputs (Malézieux, 2012; Wezel et al., 2009). Providing tools to predict variations in early growth stages would help to drive the use of multi-species systems such as sown meadows, or legume-based intercrops (Malezieux et al., 2009).

In intercrops, i.e. the cultivation of two or more species in the same field during a significant period of their growth (Willey, 1979), there are differences in early growth between mixed species, and the marked variation in species composition usually observed during early growth stages (Naudin et al., 2010) can have consequences throughout the cycle (Andersen et al., 2007; Bellostas et al., 2003). Early growth, i.e. from emergence to the beginning of above-ground competition, is therefore assumed to play a critical role in the

* Corresponding author. Tel.: +33 2 41 22 58 99; fax: +33 2 41 22 57 55.

E-mail addresses: benoit.fayaud@hotmail.fr (B. Fayaud),

f.coste@groupe-esa.com (F. Coste), g.hellou@groupe-esa.com (G. Corre-Hellou),

antoine.gardarin@grignon.inra.fr (A. Gardarin), carolyne.durr@angers.inra.fr

(C. Dürr).

establishment of the future relationships between component species in competition for resources. These interactions begin early, e.g. three weeks after emergence in greenhouse conditions (Benincasa et al., 2012). However, knowledge is lacking on the key factors involved in the early growth of different species.

Until plants start competing, growth is exponential and can be described by the following equation (Blackman, 1919; Boiffin et al., 1992):

$$DM_{TT} = DM_0 \times \exp^{(RGR \times TT)} \quad (1)$$

where TT is thermal time from emergence ($^{\circ}\text{Cd}$), DM_{TT} is above-ground dry matter at TT (mg), DM_0 is above-ground dry matter at emergence (mg), and RGR is relative growth rate ($\text{mg mg}^{-1} \text{ } ^{\circ}\text{Cd}^{-1}$).

Several authors reported a positive correlation between seed mass and DM_0 both within (Black, 1956, 1957; Dürr and Boiffin, 1995; Tamet et al., 1996) and among species (Gross, 1984). In epigeal species (i.e. photosynthetic cotyledons), DM_0 can be reduced by a long pre-emergence phase due to the higher depletion of cotyledon reserves (Black, 1956; Dürr and Boiffin, 1995; Tamet et al., 1996). The time to emergence varies with seedbed conditions and seedling elongation (Addae and Pearson, 1992; Charles et al., 1991). A supply of nutrients can hasten emergence (Durrant and Mash, 1989), meaning that cotyledon reserves are less depleted at emergence and thus could lead to higher DM_0 .

Previous studies on sugarbeet (*Beta vulgaris* L.), cabbage (*Brassica oleracea* L.), carrot (*Daucus carota* L.) and sainfoin (*Onobrychis viciaefolia* Scop.) showed a negative impact of the duration of the pre-emergence phase on RGR which may be related to the decrease in cotyledon specific mass observed in dicotyledonous epigeal species (Cooper and Franssen, 1974; Dürr and Boiffin, 1995; El Amrani et al., 1994; Shanmuganathan and Benjamin, 1992; Tamet et al., 1996). Studies on maize (*Zea mays* L.) and pea (*Pisum sativum* L.), two hypogeal species, revealed the negative impact of partial removal of seminal reserves on subsequent growth (Bourdu and Gregory, 1983; Cooper and MacDonald, 1970; Hanley et al., 2004). Even if variations in mineral nutrition and especially in nitrogen (N) availability have not been described in detail during the very early stages, such variations could also influence RGR and different species may respond in different ways. The influence of seed composition on the ability of seedlings to survive or be vigorous has often been reported but not demonstrated. N absorption begins just after germination in sugar beet and at the appearance of the first leaf in wheat (Dürr and Mary, 1998) changing the N concentration of the future photosynthetic organs during pre-emergence growth, and potentially increasing their photosynthetic capacity at emergence (Hikosaka, 2010; Weih et al., 2011).

The aim of the present work was to determine and prioritize the effects of the main factors which influence DM_0 and RGR in

order to better predict their consequences for early growth of different cultivated species used in legume-based intercrops. The species studied included a range of seed and species characteristics: seed mass, epigeal or hypogeal emergence and legume and non-legume species. We investigated early growth in these species with different levels of mineral nutrition and time to emergence. Predictive equations were then built for DM_0 and RGR . The species studied can be used in legume-based intercrops; and these equations were tested as predictive tools of early growth in such associations, by comparing simulated and observed values for total biomass and proportions of species just before competition starts for light in two different intercrops. Finally, the equations were used to simulate early growth in legume-based intercrops under different sowing conditions, showing that sowing practices (sowing depth, mineral nutrition and seed mass depending on species and cultivar) can have a major influence on the relative biomass produced by each species just before plants begin to compete.

2. Materials and methods

2.1. Experiment 1. Factors influencing DM_0 and RGR

The species studied (Table 1) were two monocotyledons, durum wheat (*Triticum turgidum* L. subsp. *durum* (Desf.) Husn., large seeds) and tall fescue (*Festuca arundinacea* Schreb., small seeds); two legumes: pea (large seeds) and black medic (*Medicago lupulina* L., small seeds); and two non-legume dicotyledons: sunflower (*Helianthus annuus* L., large seeds) and carrot (small seeds). Two cultivars of durum wheat and pea with different seed masses were studied. Concerning the pea cultivar 'Hardy', two ranges of seed mass in the same seed lot were studied. Each seed was weighed individually and seed N content was determined on a subsample of 200 seeds using the Dumas method (IDAC, Nantes, France).

Experiments were conducted in 2010–2011 in pots in a glasshouse (mean daily temperature 22.8 ± 1.5 $^{\circ}\text{C}$; except for carrot which was subject to high temperatures after emergence, 26.5 ± 1.9 $^{\circ}\text{C}$, leading to some heat stress), in Angers ($47^{\circ}5' \text{N}$, $0^{\circ}6' \text{W}$, France). Pots ($d=20$ cm, $h=15$ cm) were filled with 5 kg white sand (mean particle size: 200 μm , SIFRACO quality NE34, Paris, France). Three sowing depths were chosen to obtain significant differences in times to emergence (Table 1). The experiments were carried out using two levels of mineral nutrition, one low (C1) and one high (C4). The nutritive solution formulated for young seedlings (Saglio and Pradet, 1980) in treatment C4 contained: 2.8 mmol L^{-1} KNO_3 , 2.6 mmol L^{-1} $\text{Ca}(\text{NO}_3)_2$, 1.0 mmol L^{-1} KH_2PO_4 , 0.10 mmol L^{-1} K_2HPO_4 , 0.64 mmol L^{-1} MgSO_4 , 3 mmol L^{-1} NH_4NO_3 , 200 $\mu\text{mol L}^{-1}$ NaCl and the following micronutrients: 24 $\mu\text{mol L}^{-1}$ H_3BO_3 , 11 $\mu\text{mol L}^{-1}$ MnSO_4 , 4 $\mu\text{mol L}^{-1}$ ZnSO_4 ,

Table 1
Species and treatments used in Experiment 1.

Name	Class	Genotype	Seed dry mass (SD, mg)	Emergence	% Seed N	Tb (SD, $^{\circ}\text{C}$)	Shallow depth (cm)	Medium depth (cm)	Deep depth (cm)
Tall fescue	Monocot	Tomahawk	2.4 (0.2)	Hypogeal	2.1	2.7 ± 0.9	0.5	3	6
Durum wheat	Monocot	Dakter	57.4 (4.2)	Hypogeal	2.5	1.4 ± 0.2	1.5	4	7
		LA1823	56.9 (3.7)			1.4 ± 0.2	1.5 ^b	–	–
		Hardy	222.7 (13.4)			3.8 ± 0.2	2	4	7
Pea	Dicot	Hardy (SS)	173.5 (8.4)	Hypogeal	3.0	3.8 ± 0.2	–	4 ^c	–
		Champagne	115.0 (7.5)			2.8 ± 0.9	–	4 ^c	–
		Virgo Pajberg	1.2 ^a (0.2)			6.0	2.8 ± 1.4	0.5	2
Black medic	Dicot	Virgo Pajberg	1.2 ^a (0.2)	Epigeal	6.0	2.8 ± 1.4	0.5	2	3.5
Carrot	Dicot	Nantaise améliorée	0.7 ^a (0.1)	Epigeal	3.7	4.4 ± 0.9	0.5	2.5	4.5
Sunflower	Dicot	NK Countri	45.8 ^a (4.3)	Epigeal	4.0	4 ^d	2 ^b	4 ^b	7 ^b

SD: standard deviation. Tb: base temperature.

^a For epigeal species, seed mass is without seed coat.

^b Only in treatment C1 (low level of mineral nutrition).

^c Only in treatment C4 (high level of mineral nutrition).

^d Taken from Villalobos and Ritchie (1992).

Download English Version:

<https://daneshyari.com/en/article/4509021>

Download Persian Version:

<https://daneshyari.com/article/4509021>

[Daneshyari.com](https://daneshyari.com)