Growth duration and above-ground dry-matter partitioning in oats

Pirjo Peltonen-Sainio

Peltonen-Sainio, P. 1994. **Growth duration and above-ground dry-matter partitioning in oats.** Agricultural Science in Finland 3: 195–198. (Department of Plant Production, P.O.Box 27, FIN-00014 University of Helsinki, Finland.)

Duration of vegetative, generative, and grain-filling phases contribute to dry-matter accumulation and partitioning. Fourteen oat (*Avena sativa* L.) cultivars and six breeding lines were evaluated at the Viikki Experimental Farm, University of Helsinki, in 1988–1990. The following observations were made: (1) a short vegetative period accumulated less dry-matter into vegetative plant organs and resulted in higher grain yield and harvest index (HI), (2) a long period for maximum floret initiation yielded more grains per panicle and high panicle weight and (3) a short grain-filling period yielded high rates of panicle and grain filling associated with high HI. Hence, oat breeding and crop management should aim at improving the synchronization of the growth phases as shown in this study.

Key words: *Avena sativa* L., development, grain yield, phytomass, harvest index

Introduction

A short growing season and the consequent demand for early maturing cultivars are the main factors limiting productivity of annual small grains grown in Finland. Long days enable cereals to rapidly reach and pass several developmental stages (DVS), especially at pre-anthesis (Peltonen-Sainio 1994). The growth period of cereals is divided into three phases: 1) the vegetative period from germination to double-ridge stage, 2) the generative period from initiation of double ridges to pollination and 3) the grain-filling period. The vegetative period of oats is completed by 140 dd °C (base temperature 5°C) and hence, generative growth begins already at the two-leaf stage, and grain filling starts at <500 dd °C in Finland (Peltonen-Sainio and Pekkala 1993). The duration of growth phases is likely to contribute to both source and sink capacities, i.e. expansion, persistence and assimilate production of green area, set and assimilate demands of florets and grains, and the reciprocal feed-back effects between sources and sinks. The HI indicates the success of the synchronization between sources and economic sinks. Hence, this study evaluated the contribution of duration of vegetative, generative and grain-filling phases to dry-matter accumulation and partitioning in oats.

Material and methods

The plant material included 14 oat cultivars (Esa, Jalostettu maatiainen, Hankkijan Vouti, Karhu, Kyrö, Osmo, Pellervo, Pol, Puhti, Ryhti, Sisu, Svea, Veli, Virma) and six breeding lines from the Hankkija Plant Breeding Institute. Field studies were conducted at the Viikki Experimental Farm, University of Helsinki (60°13' N), in 1988–1990. A completely randomized block design with four replications in 1988–1989 and three in 1990 was used. Plot size was 10 m^2, and 500 viable seeds m^{-2} were sown. Sowing date was 9 May in

1988 and 27 April in 1989 and 1990. Soil type was sandy clay, and 80 kg N ha^{-1} as NH_4NO_3 was applied at sowing (N:P:K; 18–5–10). Weeds were controlled with MCPA [(4-chloro-2-methylphenoxy)acetic acid] at a rate of 700 g ha^{-1} after the double-ridge stage, and bird cherry-oat aphids (*Rhopalosiphum padi* L.) twice in 1988 by alternating dimethoate and deltametrin at a rate of 400 g ha^{-1} and 15 g ha^{-1}, respectively.

Early double-ridge stage (DVS 3.4) (Peltonen-Sainio and Pekkala 1993), the developmental stage when floret abortion begins (DVS 14.9) and pollination (DVS 25.3) were recorded from 10 randomly sampled main shoots, and were considered to be reached when ≥60% of the plants were at that stage. Cumulated degree days (CDD, dd °C, base temperature 5°C) were calculated for: (1) the vegetative period (from sowing to DVS 3.4), (2) the period for production of maximum floret number (from DVS 3.4 to DVS 14.9), and (3) the generative phase (from DVS 3.4 to DVS 25.3).

The following traits were recorded: (1) grain yield (g m^{-2} at 15% moisture), (2) number of days from sowing to heading, (3) length of grain-filling period (d), (4) phytomass (g $plant^{-1}$), (5) vegetative phytomass (g $plant^{-1}$), (6) panicle weight (g), (7) number of grains $panicle^{-1}$, (8) average grain weight (mg), (9) harvest index (HI, %), (10) average vegetative growth rate (VGR, mg $plant^{-1}$ d^{-1}), (11) average phytomass growth rate (PGR, mg $plant^{-1}$ d^{-1}); (12) average panicle-filling rate (PFR, mg $panicle^{-1}$ d^{-1}), and (13) average grain-filling rate (GFR, mg $grain^{-1}$ d^{-1}). Traits (4)–(13) were measured from 40 mature, randomly sampled plants. Linear regressions and second-degree polynomials between duration of growth period and morpho-physiological traits were calculated for different genotypes over years.

Results and discussion

The longer the growth period before heading, the higher was the grain yield, which resulted from increased weight of total phytomass and panicle (Table 1) associated with higher PGR. However, more dry-matter accumulated into above-ground vegetative plant organs in cultivars that were characterized by longer vegetative period (Fig. 1). Correlation between the length of the vegetative period and VGR ($r=0.52^{*}$) supported this finding.

Table 1. Relationship between duration of pre-heading and grain-filling phases and morpho-physiological traits of oats in 1988–1990.

Trait	Days to heading		Length of grain filling	
	$r^{probability}$	b_i	$r^{probability}$	b_i
Grain yield	0.47^{*}	12.3	-0.32^{ns}	-8.66
Phytomass	0.60^{**}	0.08	0.04^{ns}	0.01
Vegetative phytomass	0.42^{ns}	0.03	0.25^{ns}	0.02
Panicle weight	0.67^{***}	0.05	-0.20^{ns}	-0.02
No of grains	0.43^{ns}	0.99	-0.34^{ns}	-0.82
Grain weight	0.20^{ns}	0.25	0.28^{ns}	0.37
HI	0.14^{ns}	0.23	-0.57^{**}	-0.98
VGR	-0.04^{ns}	-0.00	0.38^{ns}	0.02
PGR	0.56^{**}	0.80	-0.06^{ns}	-0.09
PFR	0.72^{***}	1.78	-0.64^{**}	-1.66
GFR	0.50^{*}	0.02	-0.46^{*}	-0.02

r correlation coefficient

b_i regression coefficient

***P≤0.001, **P≤0.01, *P≤0.05, ns non-significant

HI=harvest index, VGR=vegetative growth rate, PGR=phytomass growth rate, PFR=panicle-filling rate, GFR=grain-filling rate

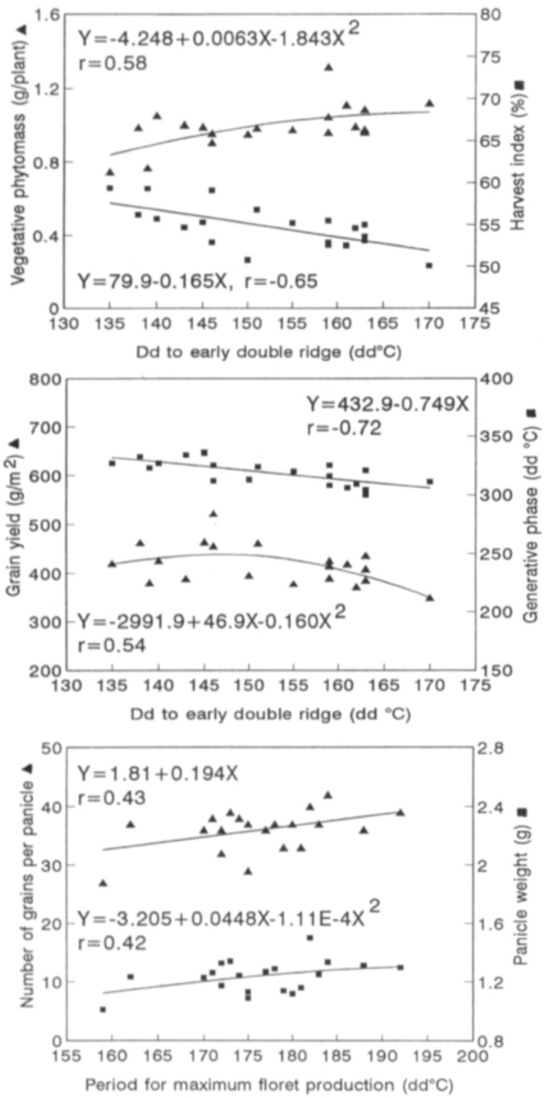

Fig. 1. Relationship between duration of growth phases and accumulation of dry-matter in 1988–1990.

Production of high vegetative phytomass resulted in smaller grain yield and HI, which indicated reduced ability to allocate photoassimilates into harvestable yield. This can be attributed to the negative correlation between length of vegetative period and generative phase. Each 10 dd °C increase in duration of vegetative period resulted in a 7–8 dd °C shorter generative phase and 1.5–2% units lower HI. Moreover, the less CDD from initiation of double ridges (DVS 3.4) to beginning of floret abortion (DVS 14.9), the less grains per panicle were produced, which possibly resulted from reduced floret set. Slafer and Miralles (1993) showed that a decreased floret set was associated with a decreased grain number in wheat. Hence, a shorter period for production of maximum floret number resulted in a lower panicle weight.

The results from this study indicated that cultivars that have a short grain-filling period had high rates of panicle and grain filling, which resulted in increased HI (Table 1) but had no effect on grain yield. An increase of one day in the grain-filling period reduced PFR by 1.7 mg panicle^{-1} d^{-1}, GFR by 0.02 mg grain^{-1} d^{-1}, and HI by 1% unit. Therefore, oat cultivars in which the relative length of the growth phases is synchronized as (1) short period for vegetative growth, (2) relatively long period for appearance of maximum floret number and (3) moderate duration of grain filling are likely to be advantageous in the growing conditions prevailing in Finland and should therefore be aimed at by breeding and crop management.

References

Peltonen-Sainio, P. 1994. Response to daylength in oats: Pre-anthesis development and set of spikelets and florets. Journal of Agronomy and Crop Science 172: 104–112.

– & Pekkala, T. 1993. Numeric codes for developmental stages of oat apex in the growing conditions of Southern Finland. Agricultural Science in Finland 2: 329–336.

Slafer, G.A. & Miralles, D.J. 1993. Fruiting efficiency in three bread wheat (*Triticum aestivum*) cultivars released at different eras. Number of grains per spike and grain weight. Journal of Agronomy and Crop Science 170: 251–260.

Manuscript received January 1994

SELOSTUS

Kauran kehitysjaksojen kesto ja biomassan tuotanto

PIRJO PELTONEN-SAINIO

Helsingin yliopisto

Aikaisuus on kevätviljojen sadontuottoa eniten rajoittava tekijä Suomen lyhyessä kasvukaudessa. Viljojen kehittyminen ja kasvu voidaan jakaa useisiin jaksoihin, joiden kestot vaikuttavat kuiva-aineen tuotantoon ja jakaantumiseen eri kasvinosien kesken. Viikin koetilalla tutkittiin vuosina 1988–1990 20 kauralajikkeen ja -linjan kehitysjaksojen pituutta ja arvioitiin niiden merkitystä sadontuoton, erityisesti kuiva-aineen jakaantumisen kannalta. Tutkitut kehitysjaksot olivat: (1) kaksoiskehävaihetta edeltävä vegetatiivinen jakso, jolloin lehti- ja sivuversoaiheet erilaistuvat, (2) jakso kaksoiskehien muodostumisesta ensimmäisten kukkien kuolemiseen ja (3) jyväntäyttymisjakso.

Tulokset osoittivat, että lajikkeet, joiden vegetatiivinen jakso oli lyhyt, tuottivat vähän lehti- ja korsimassaa, jolloin satoindeksi ja jyväsato olivat suuria. Lajikkeet, joiden kehitysjakso kaksoiskehien muodostumisesta ensimmäisten kukkien kuolemiseen oli pitkä, tuottivat runsaasti jyviä ja suuren röyhysadon. Jyväntäyttymisjakson pituudella ei ollut yhtä suurta merkitystä. Tosin kuiva-ainetta kertyi jyviin ja röyhyihin huomattavasti nopeammin lajikkeilla, joiden täyttymisjakso oli lyhyt, joten ne olivat satoindeksiltään parhaita.

Näiden tulosten valossa on tärkeää, että niin kasvinjalostuksella kuin viljelyteknisin toimenpitein pyritään entistä paremmin sovittamaan yhteen (1) lyhyt vegetatiivinen jakso, (2) pitkä kukkien muodostumisjakso ja (3) lyhyehkö jyväntäyttymisjakso.