Indian Journal of Agronomy **49** (3) : 163—167 (September 2004)

Post-anthesis dry-matter accumulation and its partitioning in different wheat (*Triticum aestivum*) genotypes under varying growing environments

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Received : April 2003

ABSTRACT

An experiment was conducted in micro-plots during winter (*rabi*) seasons of 2000–2001 and 2001–2002 at Hisar on 5 wheat genotypes ('PBW 343', 'NIAW 34', 'UP 2338', 'HD 2428' and 'Raj 3765') subjected to different growing environments by sowing on normal date (25 and 20 November) or late (3 January and 24 December), to study post-anthesis dry-matter accumulation and its partitioning. The total dry matter as well as its partitioning into leaves, stems, roots, spikes and grains was reduced significantly at anthesis and maturity under late sowing compared with normal date of sowing. The reduction in dry-matter partitioning into leaves, stems and roots was 31.3, 12.0 and 21.9% at anthesis; while at physiological maturity it was into leaves, stems, roots, spikes and grains was 31.7, 34.3, 22.4, 31.3 and 38.5% respectively. Partitioning of dry matter at anthesis indicated the maximum contribution from stems (35.9%), followed by roots (34.6%), leaves (15.5%) and spikes (14.0%); whereas at physiological maturity, the spikes contributed the maximum (38.4%), followed by roots (25.9%), stems (25.5%) and leaves (10.4%) towards total dry matter. Among the genotypes, 'PBW 343' and 'NIAW 34' produced significantly higher total dry matter as well as spikes and grain weight at maturity under both normal and late sowing. A significantly positive association of grain weight with total dry matter, stem weight, root weight and spike weight under normal and late sowing indicated that higher biomass yield and its maximum partitioning into spikes improved the grain yield of wheat.

Key words : Anthesis, Dry matter partitioning, Genotypes, Grain yield, Physiological maturity, Reproductive phase, Sowing dates, Wheat

Plants have a remarkable capacity to co-ordinate the growth of organs so that there is generally a tight balance between the biomass invested in shoots and roots. It is unsatisfactory to describe the allocation of biomass only in terms of above-ground shoots and below-ground roots. Partitioning of total dry matter into leaves, stems, roots and reproductive organs give a better indication of different functions of leaves and stem (Poorter and Nagel, 2000). All plant are able to modify their basic partitioning pattern to a certain degree in response to specific environmental conditions. The allocation of biomass to different plant organs depends on species, ontogeny and environment. Brouwer (1962) proposed that biomass allocation of plants follow the model of a "functional equilibrium', according to which, the plants respond to a decrease in above-ground resources with increased allocation to shoots (leaves), whereas they respond to a decrease in below-ground resources with increased allocation to roots. The grain yield of cereals has been reported to increase with increase in allocation to the reproductive organs with little increase in biological yield (Donald and Hamblin, 1976). It would be, therefore, appropriate that the plants function in such a manner that maximum amount of dry matter goes to the spikes for increased weight of grain during post-anthesis period, leading to higher grain yield. The present study was conducted to determine the post-anthesis dry matter accumulation and its partitioning in different wheat genotypes under varying growing environments.

MATERIALS AND METHODS

Five bread wheat genotypes, viz 'PBW 343,' 'NIAW 34', 'UP 2338', 'HD 2428' and 'Raj 3765', were grown during winter (*rabi*) season of 2000–2001 and 2001–2002 in micro-plots (6 m long × 1 m wide × 1.5 m deep) filled with light-textured dunal sand at Agronomy Research Farm, CCS Haryana Agricultural University, Hisar. Four rows of each genotype with 20 seeds per row of 1m length at 20 cm row spacing were sown on 2 dates, viz. 25 and 20 November (normal), and 3 January and 24 December (late) during 2000-2001 and 2001-2002 respectively. The experiment was laid out in factorial randomized block de-

Table 1. Days taken to anthesis and maturity by different wheat genotypes under varying growing environments (pooled over 2 years)

Genotype	Anthesis		Physiological maturity	
	Normal sowing	Late sowing	Normal sowing	Late sowing
'PBW 343'	95(817)	84(789)	132(1,368)	109(1,282)
'NIAW 34'	94(797)	80(732)	129(1,311)	108(1,258)
'UP 2338'	98(843)	87(840)	134(1,395)	111(1,336)
'HD 2428'	96(827)	82(766)	129(1,309)	109(1,284)
'Raj 3765'	93(789)	79(707)	129(1,307)	106(1,227)
Mean	95(814)	82(767)	130(1,338)	108(1,277)

Values in parentheses are heat units (°C)

sign with 3 replications. The crop was fartilized with 150 kg N/ha in 3 splits i.e. one-third at sowing one-third at first irrigation and one-third at second irrigation through urea, besides 60 kg P_2O_5/ha and 25 kg Zn SO_4/ha as basal dose. Six irrigations in timely and 5 in late-sown wheat were applied.

A sample of 5 uniform plants was taken after washing the roots with gentle pressure of water jet from 2 central rows to each replication for recording the dry weight of leaves, stems, roots and other reproductive plant parts (spikes/grains) at 2 growth stages, i.e. anthesis and physiological maturity. Different plant parts were first dried under sun and thereafter in oven at 70°C to a constant weight before taking dry weight. The grain weight was recorded at physiological maturity.

RESULTS AND DISCUSSION

Total dry-matter accumulation and its partitioning into different plant parts, viz. stems, leaves, roots, spikes and grain, was reduced significantly at both anthesis and physiological maturity under late sowing than normal sowing (Tables 2, 3). However, a reverse trend was observed in spike weight at anthesis, which increased significantly because of faster phenological development. The increased spike weight in late sowing was because of higher temperature (3-7°C) during late vegetative and reproductive phase, which caused early phenological development and reduced the crop duration and total biomass. The per cent reduction in dry matter accumulation to stems, leaves and roots due to late sowing was 31.3, 12.0 and 21.9, respectively at anthesis. On the other hand, the per cent reduction in dry-matter accumulation to stems, leaves, roots, spikes and grains was 31.7, 34.3, 22.4, 31.3, and 38.5, respectively, at physiological maturity. The greater reduction in total dry matter and its partitioning into different plant under delayed sowing was due to sudden drop in temperature during early vegetative phase and sharp rise in temperature at maturity. The increased temperature during the reproductive phase under delayed sowing was due to early completion of the required thermal unit for anthesis and maturity. Comparatively lesser heat units consumed by the late-sown crop were due to supra-optimal thermal regime (>35°C) in the month of April, which hastened the maturity (Table 1) Consequently, the crop growth period was shortened by 20-23 days, depending on genotypes. Dhiman *et al.* (1985) also reported reduction in dry matter production of wheat under late-sown conditions. Similar variations in allocation of biomass to different plant parts due to differences in ontogeny and environment were observed by Poorter and Nagel (2000).

Total dry matter accumulation and its partitioning into different plant parts varied significantly among the wheat genotypes at physiological maturity, but at anthesis all genotypes were at par for total dry matter accumulation (Tables 2 and 3). At anthesis, the genotypes 'Raj 3765' accumulated maximum dry matter in stems and spikes whereas 'PBW 343' accumulated maximum dry matter in roots. Maximum leaf dry weight was accumulated in 'HD 2428'. At physiological maturity, the genotypes 'PBW 343' and 'NIAW 34' accumulated highest total dry matter along with maximum partitioning into stems, roots, spikes and grains compared to other genotypes. The highest grain yield in 'PBW 343' and 'NIAW 34' was possible due to their efficient photosynthetic system, which produced the highest biomass. This strong source (leaves and stem) may also help to produce higher grain yield due to their larger capacity to mobilize more pre-anthesis assimilates to grain (Pannu *et al.,* 1996). Dry weight of leaves was maximum in 'HD 2428' followed by 'NIAW 34', and minimum in 'Raj 3765'. However, the per cent dry matter accumulation in stem, leaves, roots, spikes and grains differed marginally among the genotypes at physiological maturity when 2 sowing dates were compared. Nagel *et al.* (1994) also observed modest differences in the partitioning of biomass to different plant parts under stress conditions.

Irrespective of environments and genotypes, the stem contributed maximum towards total dry matter, followed by roots, leaves and spikes at anthesis (Table 2). At this stage, the stems, roots, spikes and leaves shared 35.9, 34.6,

Table 2. Dry matter partitioning (g/plant) at anthesis in different wheat genotypes (pooled over 2 years)

Genotype	Stem weight			Leaf weight			Root weight			Spike weight*			Total dry weight		
	Normal sowing	Late sowing	Mean	Normal sowing	Late sowing	Mean	Normal sowing	Late sowing	Mean	Normal sowing	Late sowing	Mean	Normal sowing	Late sowing	Mean
'PBW 343'	5.59 (30.9)	5.57 (37.7)	5.58 (34.3)	2.84 (15.7)	1.93 (13.0)	2.38 (14.4)	8.18 (45.2)	5.19 (35.1)	6.68 (40.2)	1.49 (8.21)	2.10 (14.2)	1.79 (11.2)	18.1	14.8	16.4
'NIAW 34'	6.44 (38.7)	5.08 (36.0)	5.76 (37.4)	2.92 (17.5)	1.93 (13.7)	2.42 15.6	4.98 (30.0)	4.62 (32.7)	4.80 (31.3)	2.29 (13.8)	2.50 (17.7)	2.39 (15.7)	16.6	14.1	15.4
'UP 2338'	6.37 (37.0)	5.11 (33.3)	5.74 (35.1)	2.96 (17.2)	1.98 (12.9)	2.47 (15.0)	6.14 (35.6)	5.77 (37.6)	5.95 (36.6)	1.76 (10.2)	2.48 (16.2)	2.12 (13.2)	17.2	15.3	16.3
'HD 2428'	5.51 (31.2)	4.89 (34.3)	5.20 (32.7)	3.44 (19.5)	2.40 (16.8)	2.92 (18.1)	6.65 (37.7)	4.72 (33.1)	5.68 (35.4)	2.06 (11.6)	2.26 (15.9)	2.16 (13.8)	17.6	14.3	16.0
'Raj 3765'	6.40 (39.0)	6.00 (41.5)	6.20 (40.2)	2.55 (15.6)	1.88 (13.0)	2.21 (14.3)	5.17 (31.5)	4.00 (27.6)	4.58 (29.6)	2.28 (13.9)	2.60 (18.0)	2.44 (15.9)	16.4	14.5	15.4
Mean	6.06 (35.4)	5.33 (36.5)	5.69 (35.9)	2.94 (17.1)	2.02 (13.9)	2.48 (15.5)	6.22 (36.0)	4.86 (33.2)	5.54 (34.6)	1.97 (11.6)	2.39 (16.4)	2.18 (14.0)	17.2	14.6	15.9
CD (P=0.05)															
Genotypes		0.59			0.27			0.63			0.35			NS	
Sowing dates		0.37			0.17			0.40			0.22			0.53	
Interaction		NS			NS			0.89			NS			NS	

* Including grains; Values in parantheses are per cent contribution

Table 3. Dry matter partitioning (g/plant) at physiological maturity in different wheat genotypes (pooled over 2 years)

Genotype	Stem weight			Leaf weight			Root weight			Spike weight*			Total dry weight			Grain yield (g/plant)		
	Normal sowing	Late sowing	Mean	Normal sowing	Late sowing	Mean	Normal sowing	Late sowing	Mean	Normal sowing	Late sowing	Mean	Normal sowing	Late sowing	Mean	Normal sowing	Late sowing	Mean
'PBW 343'	7.39	5.16	6.28	2.82	1.97	2.40	7.74	6.33	7.03	12.6	9.22	10.9	30.6	22.7	26.6	9.40	5.57	7.54
	(24.2)	(22.7)	(23.5)	(9.22)	(8.70)	(8.96)	(25.3)	(27.9)	(26.6)	(41.3)	(40.7)	(41.0)				(30.7)	(25.0)	(27.9)
'NIAW 34'	7.36	4.58	5.97	3.00	1.82	2.41	6.82	4.69	5.76	11.0	7.23	9.13	28.2	18.3	23.3	8.46	4.67	6.56
	(26.1)	(25.0)	(25.5)	(10.6)	(9.92)	(10.3)	(24.2)	(25.6)	(24.9)	(39.1)	(39.5)	(39.3)				(30.0)	(25.5)	(27.7)
'UP 2338'	5.96	4.84	5.40	2.39	2.11	2.25	5.63	4.67	5.15	8.59	5.93	7.26	22.6	17.5	20.1	5.79	3.94	4.86
	(26.4)	(27.6)	(27.0)	(10.6)	(12.0)	(11.3)	(24.9)	(26.6)	(25.8)	(38.1)	(33.8)	(35.9)				(25.6)	(22.4)	(24.0)
'HD 2428'	6.37	3.97	5.17	3.00	1.86	2.43	5.99	5.11	5.55	8.56	6.08	7.32	23.9	17.0	20.5	5.89	3.89	4.89
	(26.6)	(23.3)	(25.0)	(12.6)	(10.9)	(11.7)	(25.0)	(30.0)	(27.5)	(35.8)	(35.7)	(35.8)				(24.6)	(22.9)	(23.7)
'Raj 3765'	6.70	3.65	5.18	2.32	1.49	1.91	5.69	3.88	4.79	9.92	6.25	7.88	24.2	15.3	19.7	7.14	4.36	5.75
	(27.7)	(23.9)	(25.8)	(9.58)	(9.76)	(9.70)	(23.5)	(25.4)	(24.5)	(39.3)	(40.9)	(40.1)				(29.5)	(28.6)	(29.0)
Mean	6.76	4.44	5.60	2.71	1.85	2.28	6.37	4.94	5.65	10.1	6.94	8.50	25.9	18.2	22.0	7.33	4.51	5.92
	(26.2)	(24.5)	(25.5)	(10.5)	(10.3)	(10.4)	(24.6)	(27.1)	(25.9)	(38.7)	(38.1)	(38.4)				(28.1)	(24.9)	(26.5)
CD (P=0.05)																		
Genotypes		0.36			0.17			0.59			0.87			1.3			0.94	
Sowing dates		0.23			0.11			0.37			0.55			0.81			0.59	
Interaction		0.51			0.24			NS			NS			1.8			NS	

*Including grains; Values in parentheses are per cent contribution

15.5 and 14.0% of the total dry matter. As the plant growth advanced toward maturity, the per cent contribution of stems, roots and leaves to total dry matter decreased and of spikes increased consistently and attained the values of 38.4 of the total dry matter at physiological maturity (Table 3). Such a shift of dry matter accumulation in reproductive organs could be important for the survival of its own generation and proper support to the other biotic population. Similar results were reported by Farrar and Gunn (1998). The decreased weight of vegetative organs after anthesis under late sowing might be due to contribution of vegetative reserves to final grain grain yield. The greater contribution of pre-anthesis reserves to final yield under abnormal condition was also reported by Chaudhary *et al.* (1992). A significantly positive association of grain yield with total dry matter at harvest (r=0.98 and 0.89), stem weight (0.87 and 0.88), root weight, (0.90 and 0.69) and spike weight (0.99 and 0.98) under normal as well as late sowing indicated that higher biomass yield and its maximum partitioning into spikes brought about positive improvement in grain yield of wheat. Sarkar *et al.* (2001) emphasized that selection for high biomass yield should bring about positive improvement in grain yield of wheat under late planting.

It was concluded that higher biomass yield and its greater partitioning into roots and spikes resulted in higher grain yield of wheat. The genotypes, 'PBW 343' and 'NIAW 34' produced significantly higher biomass as well its better partitioning into different plant parts, which resulted in higher yield under normal as well as late- sown conditions.

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