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Dry Matter Accumulation and Partitioning in Wheat Genotypes as Affected by Sowing Date Mediated Heat Stress

Agriculture

KEYWORDS : Wheat, Dry matter, partitioning, Sowing date

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ABSTRACT

Dry matter accumulation and its partitioning to grain are important factors which directly or indirectly affects the grain yield. Heat stress during grain filling period of wheat negatively effects the dry matter production of wheat genotypes. Delay in sowing date significantly reduces the dry matter accumulation of wheat genotypes at anthesis as well as maturity. Grain yield was positively correlated with dry matter at maturity (r = 0.640 and r=0.584 timely and late sown respectively) indicating that plant dry matter is important for grain formation and grain filling in wheat genotypes. At maturity, timely sown genotypes had more percentage of dry matter partitioned to grain as compared to late sown genotypes. High yielding genotypes showed more dry matter accumulation in grain whereas low yielding genotypes retained much dry matter in stem, leaves and chaff. This reduction in dry matter accumulation in grain may be attributed to high temperature stress faced by late sown genotypes during their grain filling period.

Introduction

In India, wheat is grown mostly after harvesting of summer crops. Sowing wheat usually gets delayed beyond November due to late harvesting of rice, cotton etc. delay in sowing adversely affects the wheat growth due to high temperature during grain filling period. Exposure to high temperatures during grain development reduced the yield and yield attributing parameters. High temperature (< 31°C) can decrease the rate and duration of grain filling period in wheat [Stone *et al* 1995; Wardlaw and Moncur, 1995). Late sowing reduced the total duration of vegetative phase and decreased the dry matter accumulation in growth period (Dogiwal and Pannu 2003). The supply of assimilates to the developing grain originates both from direct transport of current assimilation to kernels, and from the remobilization of temporarily stored assimilates in vegetative plant parts (Gebbing *et al* 1999). The reserves deposited in vegetative plant parts before anthesis may buffer grain yield when conditions become adverse to photosynthesis and mineral uptake during grain filling (Tahir and Nakata 2005). In recent years, there has been an improved understanding of yield responses to alterations in assimilates availability during different phonological phases, as affected by sowing dates (Takahashi and Nakaseko 1993).

Different stresses, such as high temperature and water deficit limits the production of photoassimilates. For instance, a rise in temperature during the grain filling period of wheat negatively effects the dry matter production (Alvaro *et al*. 2008). Under such conditions, the contribution of pre-anthesis assimilates to grain may be crucial for maintaining yield of crop when harsh climatic conditions reduce photosynthesis, water, and mineral uptake (Arduini *et al*. 2006). The remobilization of assimilates originates from plant senescence, in which stored reserves from stems and leaves are translocated to the grain (Ercoli *et al*. 2008).

The hot and dry conditions during grain filling reduces the photosynthesis rate after anthesis which directly affects and limit the contribution of assimilates to the grain (Alvaro *et al*. 2008). Under these circumstances, dry matter accumulation before anthesis in vegetative parts and its remobilization to the grain during grain filling becomes particularly important. Earlier it was reported that delay in sowing reduces both shoot biomass and grain yield and N content as compared to the optimum sowing dates (Chatha *et al*.1999). These results indicated that the estimation of the amount of stem reserves accumulated and mobilized were dependent on environmental conditions (i.e. sowing date) genotype, and cultural practices. Therefore, the contribution of stored carbohydrates may become very important and predominant source of transported materials (Blum *et al*. 1994). There is very little information is available regarding the effect of sowing dates on the accumulation and translocation of assimilates into wheat grain. The objectives of this research were to study the effect of heat stress during grain filling period on status of dry matter accumulation and partitioning in wheat genotypes at two different sowing dates.

Material and Methods

This field study was conducted in experimental area of department of botany, Punjab Agricultural University, Ludhiana, during the 2012-13 growing season. Twenty genotypes consisting of various lines assembled by CIMMYT under generation challenge program with different trial names viz. QTLs POPS MAP, PT CAN II sq , CSIRO GCP and PBW 621 and HD 2967 (some Punjab cultivars which served as checks) were selected for present studies. Selected genotypes were tested under two different sowing date's i.e.29 November (Timely sown) and 29 December (late sown conditions). All the genotypes were planted in two replications, with a 7-row plot, row length of 1.5 m and 23 cm spacing between rows. Plants from 0.5 m row length of genotypes under timely and late sown plots were harvested at anthesis and physiological maturity. Samples collected at anthesis were separated into stem, leaf and ear fraction including all senescent leaves. The samples harvested at maturity were separated into stem, leaves, grain and chaff. The various plant parts were dried in oven at 60°C to constant weight and dry weight recorded. Dry matter partitioning was calculated as:

$$\text{Dry matter Partitioning coefficient} = \frac{\text{Dry matter in plant part}}{\text{Total plant dry matter}} \times 100$$

Results and Discussion

Total dry matter accumulation was adversely affected by delay in sowing date because heat stress reduces the dry matter production (Table 1). At anthesis, all genotypes showed significant reduction in dry matter accumulation with delay in sowing date. On an average more dry matter was produced by timely sown genotypes (33.10 q $acre^{-1}$) than late sown (21.0 q $acre^{-1}$). In overall this trait showed 38 % reduction due to heat stress. Genotypes also showed significant variation under both conditions. At SD1, G6 from Group I produced maximum dry matter whereas G13, G14 and G16 from Group II produced minimum. Whereas, under late sown conditions (SD2) maximum dry matter was observed in G4 and minimum in G11 and G18. Among check varieties PBW 621 produced more dry matter under both control and stressed condition than HD 2967.

Similar trend of total dry matter accumulation was found at maturity. At maturity this trait showed 37% total reduction with delay in sowing date. Overall genotypes of Group I, Group III and check varieties produced more dry matter as compared to genotypes of Group II. Highest value of dry matter was recorded in G32 and minimum in G12 in timely sown whereas during late sown maximum was recorded in G6 and minimum G11, G14 and G13. As reported earlier, temperature stress during the grain filling period of wheat has a negative effect on dry matter production (Alvaro *et al* 2008). Grain yield was positively correlated with dry matter at maturity (r = 0.640 and r=0.584 timely and late sown respectively) indicating that plant dry matter is important for grain formation and grain filling in wheat genotypes. It was suggested that one of the ways to achieve higher wheat yield increases under stress conditions is to keep improving dry matter translocation in grains, which may result from an enlargement of the source size (biomass) at anthesis or from increase in dry matter translocation efficiencies (Alvaro *et al*. 2008).

At both timely and late sown conditions, during anthesis more dry matter (Timely sown: 36 to 53% and late sown: 32 to 52%) was partitioned in stem followed by leaves and ear in all the varieties (Figure1). Dry matter partitioning in stem in genotypes of Group I, Group II and Group III ranged from 40 to 46 %, 39 to 45 % and 41 to 53% respectively under timely sown condition. Whereas during late sown condition all genotypes showed reduction in dry matter partitioning in stem.

At maturity all genotypes showed more dry matter partitioned in grain under both timely and late sown conditions (Figure 2). High yielding genotypes showed more dry matter accumulation in grain whereas low grain yielding genotypes retained much dry matter in stem, leaves and chaff. So, timely sown genotypes had more percentage of dry matter partitioned to grain as compared to late sown conditions. Dry matter partitioning in grain of timely sown genotypes ranged from 37 to 53% whereas during late sown condition only 26 to 46 % dry matter accumulated in grain and rest was retained in other plant parts. This reduction in dry matter accumulation in grain may be attributed to high temperature stress faced by late sown genotypes which reduces the grain filling period.

Conclusion

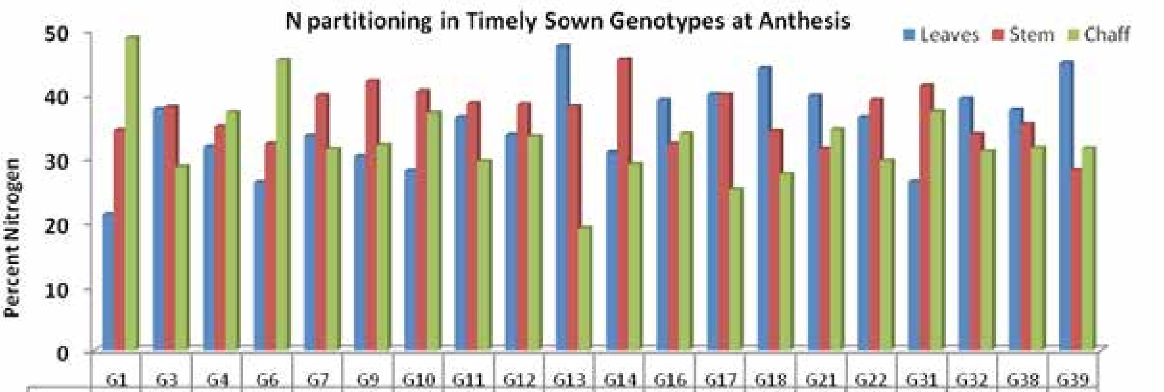
In wheat, high temperature stress is known to accelerate leaf senescence and adversely affects the grain filling period (Al-Khatib *et al* 1984). Assimilate transport from flag leaf to grain is substantially reduced by temperatures above 30^0C but there is no influence of temperature (from 1 to 50^0C) on translocation from the stem (Wardlaw 1974). This indicates that, in wheat, the effect of heat stress on assimilate translocation is indirect even though heat stress reduces the rate of assimilate transport from vegetative organs to grain. In our studies, poor dry matter partitioning to the grain in late sown genotypes may be due to sudden termination of grain filling and early onset of maturity caused by high temperature stress. Grain yield is generally simulated by assuming that the fraction of total above ground dry matter fairly partitioned to the grain. So lower yield of late sown genotypes may also be attributed to their low dry matter production as well as lesser partitioning of dry matter to the their grain. According to Ehdaie and Waines (2001) more grain yield was obtained with sowing the wheat crop on optimal date and with the genotypes that showed the highest post-heading accumulation of both dry matter and nitrogen and the best N remobilization efficiency.

Table 1: Effect of terminal heat stress on total dry matter accumulation (q acre^{-1}) of wheat genotypes at timely and late sown conditions.

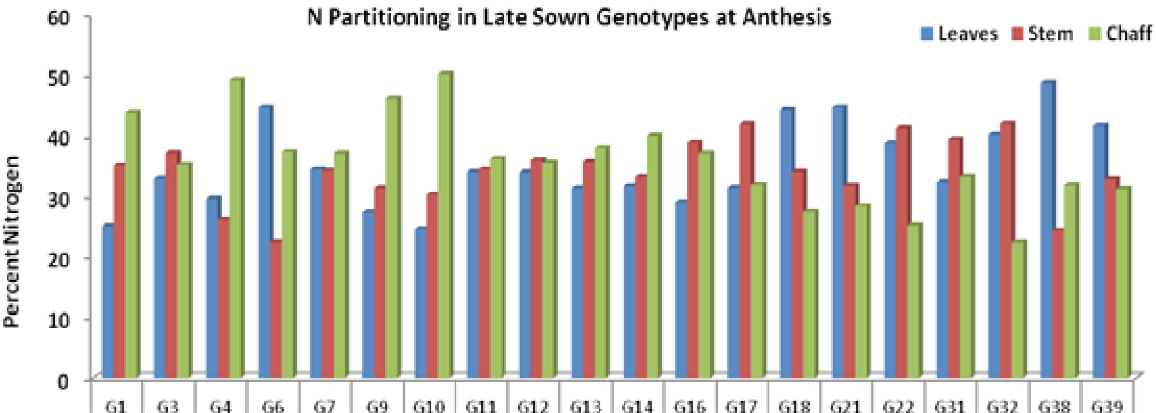
Groups	Genotype No.	Name of Genotypes	At Anthesis		At Maturity	
			Timely sown	Late sown	Timely sown	Late sown
GROUP I	G1	QTLs POPS MAP-I	29.89	18.43	65.16	38.84
	G3	QTLs POPS MAP-III	33.81	22.49	61.97	28.34
	G4	QTLs POPS MAP-IV	34.72	26.27	55.45	39.84
	G6	QTLs POPS MAP-VI	40.20	22.34	64.68	48.69
	G7	QTLs POPS MAP-VII	37.21	22.41	55.11	45.10
	G9	QTLs POPS MAP-IX	31.00	22.17	60.32	43.18
	G10	QTLs POPS MAP-X	34.63	23.74	66.43	40.97
GROUP II	G11	QTLs POPS MAP-XI	33.17	16.83	56.59	32.81
	G12	QTLs POPS MAP-XII	34.09	20.10	46.92	42.95
	G13	QTLs POPS MAP-XIII	26.72	18.22	54.80	33.77
	G14	QTLs POPS MAP-XIV	28.51	20.43	56.06	32.52
	G16	QTLs POPS MAP-XVI	25.06	21.80	50.26	35.82
	G17	QTLs POPS MAP-XVII	30.89	15.96	54.34	35.76
	G18	QTLs POPS MAP-XVIII	36.14	16.84	53.78	35.20
GROUP III	G21	PT CAN II sq-I	34.70	21.64	61.84	34.75
	G22	PT CAN II sq-II	37.79	23.62	61.54	41.24
	G31	PT CAN II sq-XI	34.33	21.31	63.47	40.24
	G32	PT CAN II sq-XII	34.19	20.50	68.24	37.37
GROUP IV	G38	PBW 621	33.00	23.52	62.98	40.32
	G39	HD 2967	32.56	21.36	64.52	41.45
Mean			33.13	21.00	59.22	38.46
LSD (0.05)			Genotypes= 1.56 Treatment= 0.495		Genotypes= 1.751 Treatment= 0.552	

Figure 1: **Effect of terminal heat stress on Dry-matter par-**

titioning at anthesis in selected wheat genotypes at timely and late sown conditions

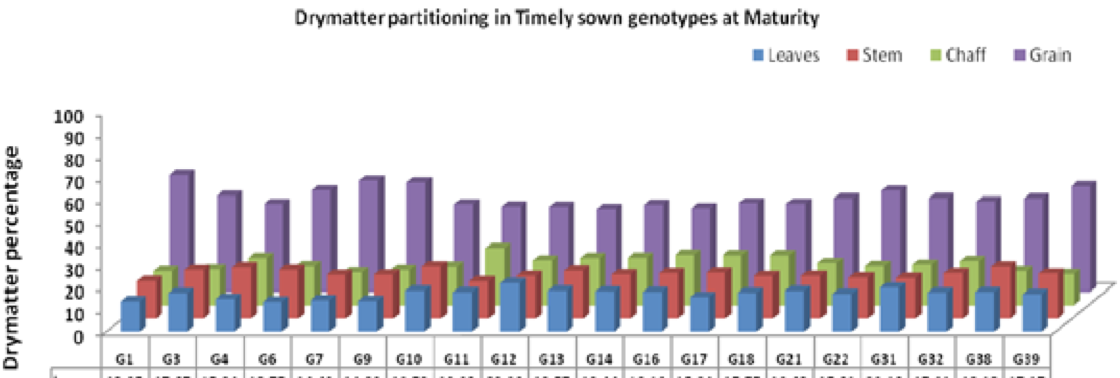


	G1	G3	G4	G6	G7	G9	G10	G11	G12	G13	G14	G16	G17	G18	G21	G22	G31	G32	G38	G39
Leaves	21.1	37.5	31.8	26.2	33.3	30.2	28.0	36.3	33.5	47.5	30.8	39.0	39.9	44.0	39.7	36.4	26.3	39.2	37.4	44.7
Stem	34.3	37.9	34.8	32.3	39.8	42.0	40.4	38.5	38.3	38.0	45.3	32.3	39.8	34.1	31.4	39.0	41.2	33.6	35.2	28.1
Chaff	48.7	28.6	37.0	45.2	31.3	32.0	37.0	29.4	33.3	19.0	28.9	33.8	25.0	27.4	34.4	29.5	37.1	31.0	31.6	31.5

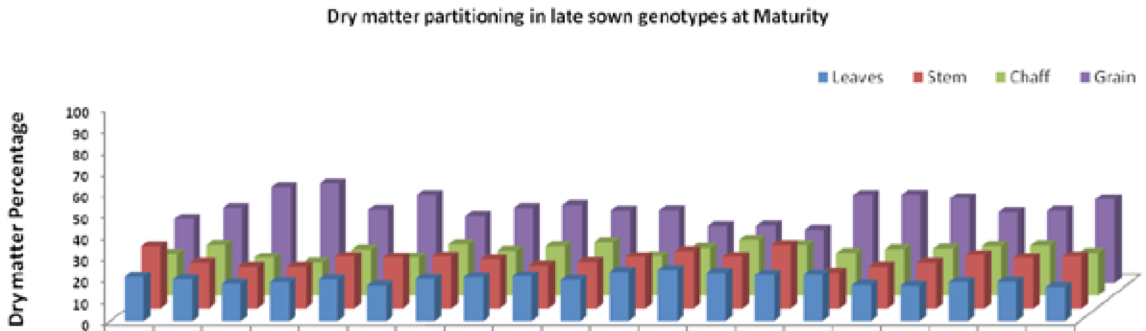


	G1	G3	G4	G6	G7	G9	G10	G11	G12	G13	G14	G16	G17	G18	G21	G22	G31	G32	G38	G39
Leaves	24.9	32.8	29.5	44.5	34.4	27.3	24.5	33.9	33.8	31.2	31.5	28.9	31.3	44.1	44.5	38.6	32.2	40.1	48.6	41.5
Stem	35.0	37.0	26.1	22.4	34.2	31.2	30.2	34.3	35.8	35.6	33.1	38.8	41.8	33.9	31.6	41.1	39.3	41.9	24.2	32.7
Chaff	43.7	35.2	49.1	37.2	36.9	46.0	50.1	36.1	35.4	37.8	39.8	37.0	31.8	27.4	28.2	25.1	33.1	22.3	31.7	31.1

Figure 2: Effect of terminal heat stress on dry matter partitioning at maturity in wheat genotypes at timely and late sown conditions



	G1	G3	G4	G6	G7	G9	G10	G11	G12	G13	G14	G16	G17	G18	G21	G22	G31	G32	G38	G39
Leaves	13.95	17.67	15.04	13.77	14.43	14.06	18.73	18.03	22.30	18.77	18.44	18.19	15.84	17.77	18.63	17.31	20.16	17.91	18.13	17.17
Stem	17.16	22.21	23.33	22.26	19.90	20.05	23.74	17.04	19.44	21.90	20.16	20.70	20.94	19.33	19.50	18.72	18.50	20.67	23.71	20.53
Chaff	15.63	16.37	21.57	17.78	15.03	16.09	17.53	26.03	20.49	21.56	21.69	23.00	22.79	22.77	19.27	17.88	18.62	20.23	15.61	14.24
Grain	53.26	43.75	40.06	46.20	50.65	49.80	39.99	38.89	38.76	37.77	39.71	38.11	40.42	40.12	42.60	46.09	42.73	41.18	42.55	48.06



	G1	G3	G4	G6	G7	G9	G10	G11	G12	G13	G14	G16	G17	G18	G21	G22	G31	G32	G38	G39
Leaves	20.99	19.70	17.62	18.36	19.59	16.79	19.88	20.76	21.15	19.40	23.15	24.07	22.69	21.76	21.87	17.12	16.62	18.35	18.54	16.12
Stem	29.16	21.36	19.60	19.54	24.33	23.98	24.41	23.00	20.10	21.73	24.19	26.39	24.23	29.65	16.74	19.63	21.41	25.05	23.78	24.49
Chaff	19.72	23.76	17.87	15.52	21.61	17.93	24.12	21.12	23.22	24.94	18.49	22.44	26.19	23.66	20.11	21.87	22.18	23.25	23.62	20.09
Grain	30.12	35.17	44.92	46.58	34.46	41.30	31.59	35.12	36.53	33.94	34.17	26.60	26.90	24.93	41.28	41.38	39.80	33.34	34.06	39.29

Genotypes

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