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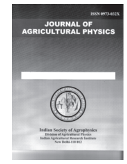

Research Article

Effect of High Temperature Stress on Biomass Partitioning in Wheat (*Triticum aestivum* L.) at Different Growth Stages

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ABSTRACT

Field experiments were conducted during 2013-14 and 2014-15 to characterise changes in biomass of each aerial component at different crop growth stages in wheat (*Triticum aestivum* L.) var. HD 2967 under the ambient and high temperature stress (ambient +3°C) conditions. High temperature stress significantly affected the growth of all aboveground parts and also the partitioning of dry-matter, at different crop growth stages. Partitioning of dry-matter to leaves was maximum (0.526) during the vegetative stage while in stem, the maximum value of 0.75 was recorded at panicle-initiation stage. The crop exposed to high temperature stress had higher partitioning coefficient to stem (0.53) than that to leaves (0.47) and the reverse was true under high temperature stress condition.

Key words: Biomass partitioning, High temperature stress, Wheat

Introduction

Globally, India is the second leading producer of wheat with a share of 13.2 % of the production during 2014-15. In the recent past, a considerable increase in temperature in both the global and local levels have been reported to affect its production (Valzadeh *et al*., 2015). Under global warming scenarios, two major avenues could be identified to improve the genetic potential of wheat viz., to increase the total biomass and the proportion of biomass partitioned into the sink i.e., the harvest index (Reynolds *et al*., 2012; Valluru *et al*., 2015).

Dry matter distribution at different developmental stages of the crop is useful to improve quantification of various parameters in crop growth simulation studies. The process of quantifying distribution of assimilates to various organs of plant, has been studied in wheat (e.g. Evers *et al*., 2010, Fletcher and Chenu, 2015), who considered the carbohydrate partitioning as 60% of dry weight.

Development in crop is linearly related to net assimilation rate (Stratonovitch and Semenov, 2015) and consequently to dry-matter production (Fletcher and Chenu, 2015). The present study investigates both these aspects, with an aim to characterise the distribution of biomass to various plant organs at different developmental stages, and precisely to the sink (grain yield) under high temperature stress conditions.

Materials and Methods

Field experiments were conducted during November-March, 2013-14 and 2014-15 at New Delhi (28°35 N and 77°12 E) in a sandy loam soil [Typic Haplaquept, pH 7.9, organic C 0.52%, and medium in available N (272.6 kg ha^{-1}), P (18.4 kg ha^{-1}) and K (191.6 kg ha^{-1})]. The experiment was laid out in a complete randomized design with two temperature levels, ambient and high

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temperature (ambient +3°C, using Free Air Temperature Increment –FATI facility) as treatments. Nitrogen (through urea) at 150 kg ha^{-1} in equal split at sowing, CRI and booting, and entire P @ 30 kg ha^{-1} as basal (through single superphosphate) as basal were applied. Samples were drawn at nine crop growth stages (Seedling, tiller initiation, active tillering, stem elongation, booting, ear emergence, flowering, dough development and harvest) in four replications from each treatment. The turgidity of samples was maintained until further processing in the laboratory, and then was separated into leaves, stems and panicles. The leaf sheath and the developing inflorescence before onset of heading were retained as part of the stem. The plant parts were dried at 70°C for 3 days and then weighed. The data for two consecutive years were pooled and analysed using SPSS version 16.0.

Crop Growth stages were expressed in Zadoks scale from 0 to 92. To calculate the partitioning coefficients of dry matter, new incremental biomass i.e., only increase in dry-matter of leaf, stem and panicle for the period between consecutive samplings were calculated (Keulen and Wolf, 1986). The relative fractions of incremental biomass, represented as the respective partitioning coefficients were computed. Total increase in dry weight of the aboveground plant was taken as the sum of the increase in weight (i.e., incremental biomass) of plant parts. Thus,

$$dWT = dWL + dWS + dWP$$

where dWT, dWL, dWS and dWP are total increase in dry weight of whole plant, leaf, stem and panicle between two consecutive samplings. From the above, the partitioning coefficients of dry matter of leaf, stem and panicle were derived as dWL/dWT, dWS/dWT and dWP/dWT. As the sum of the fractions of the partitioning coefficients of all the organs is 1.0, a cumulative presentation was preferred.

Growing degree days (GDD) were computed following Nuttonson (1955) by taking base temperature of 4°C. The sum of degree days for each phenophase was obtained as: GDD = (Daly minimum temperature + daily maximum temperature)/2 – base temperature.

Results and Discussion

Dry-matter partitioning at different growth stages

Total biomass was significantly different under ambient and high temperature stress condition (1124 and 868 g m^{-2} respectively) (Fig 1). Significant differences were also observed in the biomass partitioning under different developmental stages (Fig. 2a). Maximum biomass was partitioned to the leaves (0.62) during vegetative stage, to the stem (0.53) at flowering and to panicle (0.52) during post flowering stages. However under high temperature stress condition, the average biomass was 23.5% less at flowering than in ambient condition (Fig 2b). This indicated that growth in wheat was reduced under high temperature stress condition.

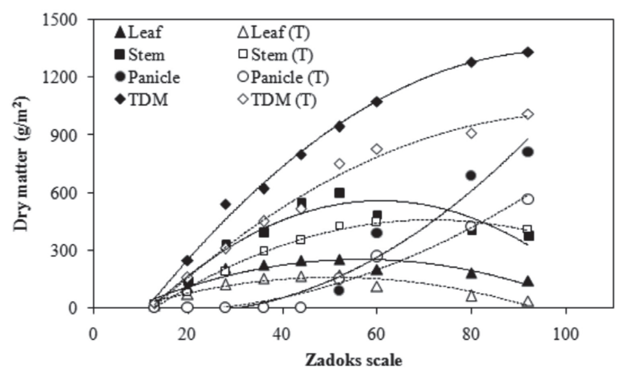

Fig. 1. Dry-matter accumulation in wheat crop grown under ambient and high temperature stress (T) conditions

Difference in leaf dry matter partitioning between active tillering and ear emergence stage was 0.17 in high temperature and 0.11 in ambient condition. Thus under high temperature condition, the leaf partitioning coefficient in wheat declined faster compared to the crop under ambient condition. At flowering, crop grown under ambient condition accumulated proportionately more biomass in leaves (252.67 g m^{-2}) than the high temperature stress condition, which accumulated 172.53 g m^{-2} of biomass in leaves. Even though the biomass decreased, the proportionate accumulation of straw increased under high temperature stress condition because

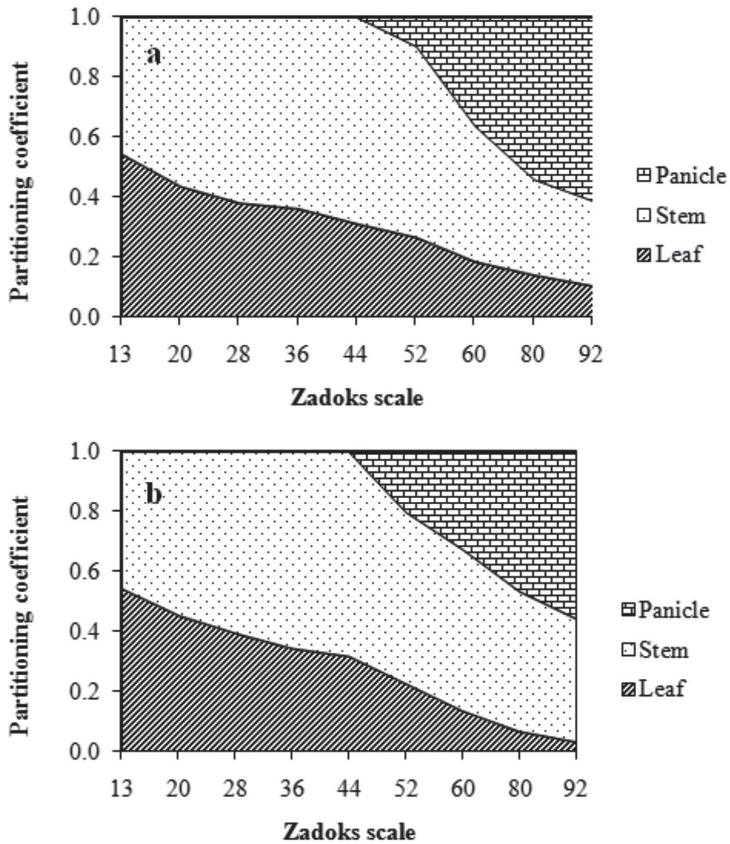

Fig. 2. Dry matter partitioning into different components of wheat crop grown under (a) ambient and (b) high temperature stress conditions

high temperature stress reduced the crop duration and had a reduced rate of translocation (Chenu, 2015).

Differences in crop duration and accumulated growing degree days

In our study, differences in GDD were not significant, although total duration of the crop significantly reduced under high temperature stress condition (Fig 3). In general, difference in the GDD between high and ambient temperature was recorded at post flowering growth stages, but no difference during pre-flowering could be observed. In pre-flowering stages, the differences in GDD between the two treatments were 5.5% and that in post flowering stage was 23.07%. Overall, the crop duration was significantly reduced by 14.8% under high temperature stress condition (Fig 4). Under high temperature stress the duration of the growth decreases but the rate of growth increases. However the increased rate

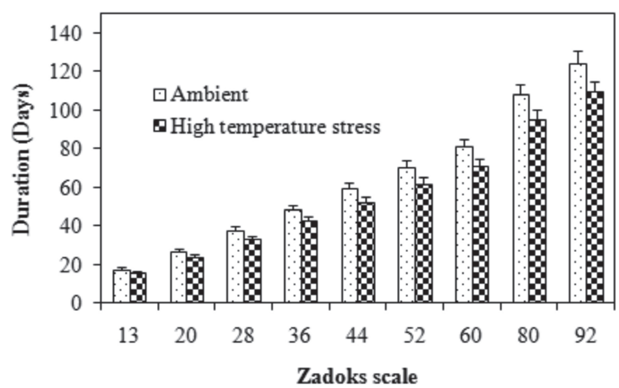

Fig. 3. Changes in duration (days) of the growth stages of wheat crop

of growth was not compensated by a reduction in duration of development; hence the dry matter reduced.

Effect of high temperature stress on incremental biomass partitioning

Partitioning of the newly synthesized biomass to essential plant organs is important to sustain

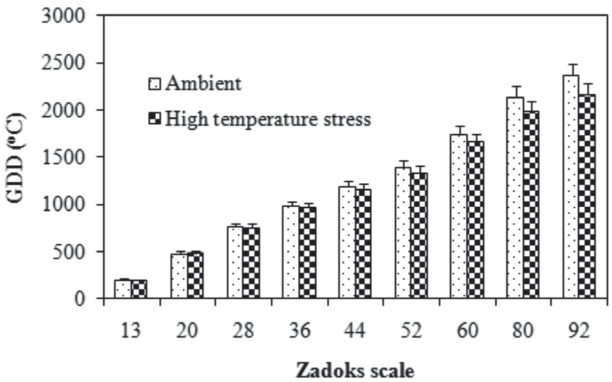

Fig. 4. Changes in accumulated Growing degree days (GDD) (°C) of wheat crop

the plant metabolic activities. Under ambient condition, initially the investment of new incremental biomass partitioning was in leaves, later in stems (during panicle initiation stage) and ultimately in storage organs (Fig. 5). The incremental biomass partitioning to leaf increased only up to active tillering stage (0.524), but it increased in the stem and reached a maximum (0.702) at panicle initiation stage and thereafter, there was a decline. Results are similar to Slewinski (2012), who reported the pattern of carbohydrate partitioning to different organs. In wheat, beyond the dough stage, there was no stem partitioning (Foulkes *et al*., 2010). Similar pattern was observed in partitioning coefficient up to dough stage of wheat and thereafter to panicle only. Thus, it attained a maximum of 1.0.

At high temperature stress condition, difference in the fraction of allocation in stems and leaves could be noted. Higher proportion (0.86) was observed in stems compared with the leaves (0.135), whereas under ambient condition, the proportion of allocation to leaves was higher (0.298). This shows that the high temperature stress shunts the growth of leaf organs (Stratonovitch and Semenov, 2015). Leaves had the major fraction of the new incremental biomass (0.53) at planting, but there were a continued reduction in leaf partition coefficient to 0.15 at flowering, because the plant actively photosynthesized at early growth stages, and the photosynthates are preferably used tor protein synthesis and formation of leaf-blades (Fletcher and Chenu, 2015). With the progress in plant growth, more assimilates were used for the production of culm plus sheath. However, under high temperature stress condition, higher proportion of new incremental biomass was invested on stems rather than on leaves.

Allocation of biomass is crucial before the economic products are formed (Valluru *et al*., 2015). In this study, only aboveground biomass partitioning was considered since the root biomass is not likely influenced by temperature stress (Stratonovitch and Semenov, 2015). There were differences among crop growth stages with respect to apportioning of incremental biomass and its rate over time and these can serve as useful tools to understandthe intrinsic nature of plant growth under different environmental conditions. The study will help to develop reliable quantitative model that would predict the effect of environment on crop growth.

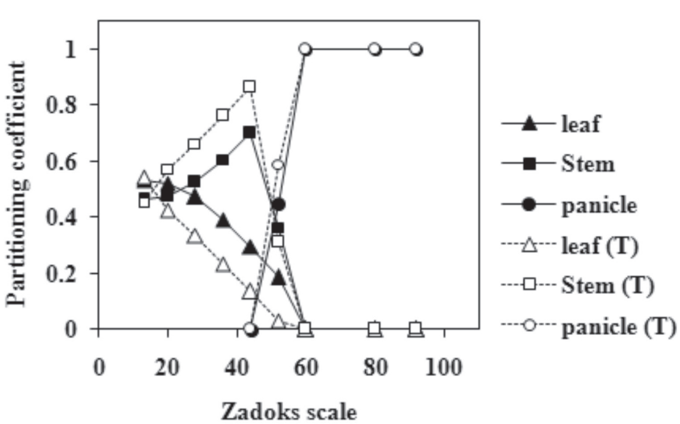

Fig. 5. Rate coefficient in dry-matter partitioning of wheat crop grow under ambient and high temperature stress (T) conditions

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