Available online at www.ijpab.com

DOI: http://dx.doi.org/10.18782/2320-7051.2316

ISSN: 2320 – 7051

Int. J. Pure App. Biosci. **4 (4):** 179-184 (2016)

Research Article

International Journal of Pure & Applied Bioscience

OPEN ACCESS

Impact of Heat Stress on Yield and Yield Attributing Traits in Wheat (*Triticum aestivum* L.) Lines during Grain Growth Development

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Received: 15.06.2016 | Revised: 26.06.2016 | Accepted: 28.06.2016

ABSTRACT

A field study was conducted with seven wheat lines NDL-10-2, NDL-9-4, NDL-12-1, NDL-12-3, KO-307, NDL-12-2 and NDL-12-4 to assess heat stress effects on yield and yield related traits of wheat. Heat stress was induced by delayed sowing of 60 days from normal date of sowing so that grain filling stage of wheat could experience severe heat stress. Data related to no. of tillers, plant height, spike length, no. of grain per spike, grain yield per plant and test weight of wheat lines were taken in control and heat stress condition. On the basis of yield and yield attributing traits, three wheat lines NDL-10-2, NDL-9-4 and NDL-12-4 showed heat tolerant while NDL-12-1, NDL-12-3, KO-307 and NDL-12-2 appeared as susceptible under heat stress conditions.

Key words: *Heat Stress, Wheat, Grain, Yield*

INTRODUCTION

Wheat (*Triticum aestivum* L.) is a cereal of choice in most countries of the world. Constant efforts are therefore needed to boost its production to keep the pace with ever increasing population. High temperature stress during reproductive development resulting in a reduction in both individual kernel weight and kernel number[5,16]. In the other hand, late harvesting of previous crops like rice or maize, plant machine deficiency or continual rainfall caused late planting of wheat in many regions that has coincided reproductive stage of crop with high temperature[13]. Terminal heat stress during anthesis and grain filling period, accelerate maturity and significantly reduces grain size, and weight[9]. Exposure to higher than optimal temperatures reduces yield and decreases quality of cereals.

Cite this article: Kumar, N., Prasad, S., Dwivedi, R., Kumar, A., Yadav, R.K., Singh, M.P. and Yadav, S.S., Impact of Heat Stress on Yield and Yield Attributing Traits in Wheat (*Triticum aestivum* L.) Lines during Grain Growth Development, *Int. J. Pure App. Biosci.* **4(4):** 179-184 (2016). doi: http://dx.doi.org/10.18782/2320-7051.2316

Heat stress is an important constraint to wheat productivity affecting different growth stages specially an thesis and grain filling. It has already been established that heat stress can be a significant factor in reducing the yield and quality of wheat. Heat tolerance thus should be essential characteristic of wheat cultivars to be developed. Stay green is a trait that has been used to indicate heat tolerance in hot environment[1,8]. Photosynthetic rate is maximum at 20-22^{0}C and decreases abruptly at 30-32^{0}C[2,14]. Heat stress injuries of the photosynthetic apparatus during reproductive growth of wheat diminish source activity and sink capacity which results in reduced productivity[4].

Though, heat stress affects the metabolic pathways at every stage of life of wheat finally leading to yield reduction, the effect of high temperature is particularly severe during grain filling; these losses may be up to 40 % under severe stress[6]. Other effects of high temperatures are decreased grain weight, early senescence, shriveled grains, reduced starch accumulation, altered starch-lipid composition in grains, lower seed germination and loss of vigour[3].

Wheat experiences heat stress to varying degrees at different phenological stages, but heat stress during the reproductive phase is more harmful than during the vegetative phase due to the direct effect on grain number and dry weight[20]. End-of-season or ‘terminal’ heat stress is also likely to increase for wheat in the near future[12,17]. Hence the main focus is on responses to elevated temperatures during reproductive and grain-filling stages and processes that affect grain yield.

The average global temperature is reported to be increasing at a rate of 0.18 °C every decade[7]. Due to global warming and changes in the climate pattern, development of heat tolerant varieties and generation of improved prebreeding material seems to be the main focus of any breeding program in future[15]. However, due to complex nature of heat stress tolerance, the advanced techniques of molecular breeding and genetic engineering including MAS in combination with conventional breeding approaches can play a vital role in designing new wheat cultivars with enhanced heat tolerance.

MATERIAL AND METHODS

An experiment was conducted with seven wheat lines NDL-10-2, NDL-9-4, NDL-12-1, NDL-12-3, KO-307, NDL-12-2 and NDL-12-4 at instructional farm of N.D. University of Agriculture and Technology, Kumarganj, Faizabad in rabi season 2015-16. Heat stress was given by delayed sowing of 60 days (15 January, 2015) from normal date of sowing (15 November, 2014) so that the reproductive phase of wheat could experience severe heat stress. General agronomical practices were adopted time to time as per need of the crop. The temperature at the time of grain filling stage varied from 35to 39.5^{0}C in delayed sown wheat crop. Plant height (cm) was recorded from ground surface of stem to the tip of stem of five randomly selected plants at grain filling stage and average out to plant height per plants. Number of tillers was counted from five randomly selected plants at reproductive stage and average out to tillers number per plant. Main spike of randomly five selected plant were recorded at maturity stage. Number of grain spike^{-1} were recorded by selecting main spike of five plants and average out to one as considered grains spike^{-1}. Weight of thousand grains of wheat were taken as test weight. Grain yield of randomly selected five plants were recorded after threshing separately to average out to get grain yield plant^{-1}.

RESULT AND DISCUSSION

Wheat lines showed the genetic diversity in plant height (fig. 1). The maximum plant height was recorded in NDL-12-1 (81.33 cm) while minimum in NDL-10-2 (63.66 cm) under control condition. Heat stress significantly reduced the plant height. The high reduction in plant height was recorded in NDL-9-4 (22.58%), NDL-12-3 (19.18%), NDL-10-2 (16.74%) and NDL-12-1 (16.35%) while low in NDL-12-2 (15.97%), NDL-12-4 (13.53%) and KO-307 (10.39%) under the heat stress condition. The reduction in plant height is due to fast phasic change and due to this, vegetative phase become short and reproductive come early[18].

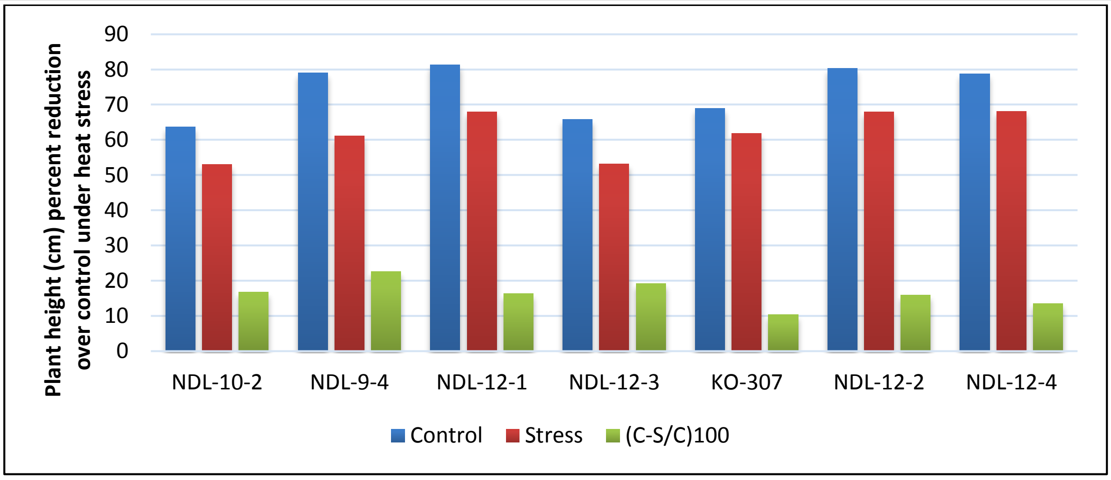

Fig. 1: Effect of heat stress on plant height (cm) of Wheat lines

Wheat lines showed significant variability in number of tillers per plant (fig. 2). Maximum no. of tillers recorded in NDL-12-3 (6), NDL-12-2 (5.33), Ko-307 (5.33) and NDL-12-1 (4.66), while minimum in NDL-10-2 (3.33) under control condition. Maximum no. of tillers recorded in Ko-307 (4.66) while minimum in NDL-10-2 (2.33) under stress condition. The high reduction in no. of tillers was recorded in NDL-12-3 (50%), NDL-12-2 (31.33%), NDL-12-4 (26.8%) and NDL-10-2 (30%) while low in NDL-9-4 (18%), NDL-12-1 (14.61%) and KO-307 (12.57%) under heat stress condition. The potential no. of tillers varies with genotype, particularly among flowering types, winter types having a greater number. Tillering does not end at any specific wheat development stage, but rather it is controlled by a no. of genetic and environment factors[11].

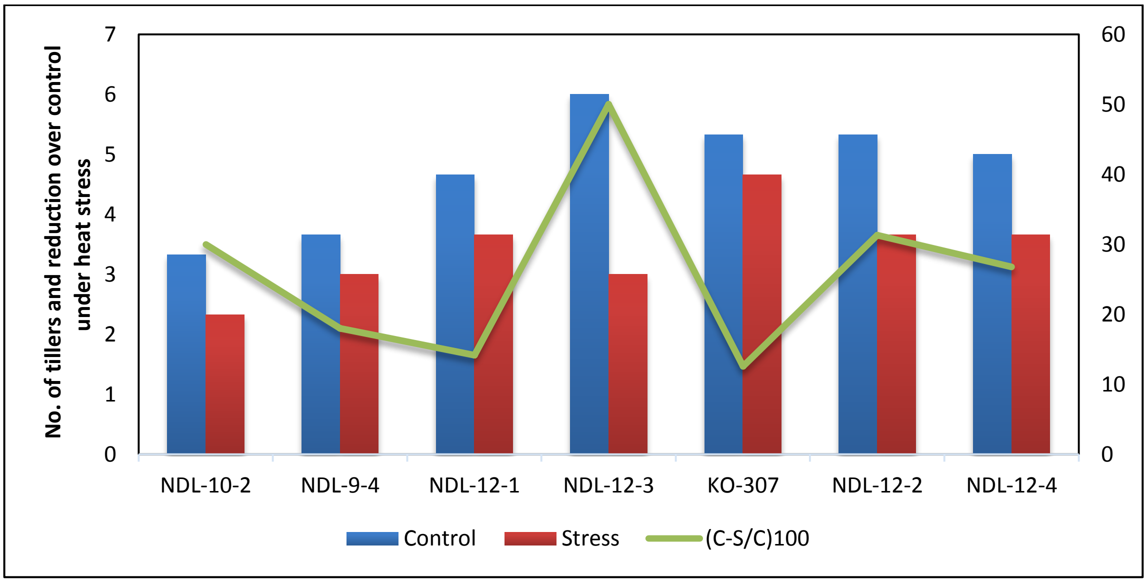

Fig. 2: Effect of heat stress on no. of tillers of wheat lines

The spike length (cm) varied under control and stress condition (fig. 3). The maximum spike length was recorded in NDL-9-4 (12.16 cm) while minimum in NDL-10-2 (9.83 cm) under control condition. The high reduction in spike length was recorded in NDL-12-3 (27.05%), NDL-10-2 (25.12%) and NDL-12-2 (20.6%) while low in NDL-12-4 (16.07%), NDL-9-4 (15.87%), NDL- 12-1 (15.16%) and KO-307 (10.8%) under the heat stress condition. Spike length has strong indirect influence on grain weight / plant through no. of spikelet / spike[10].

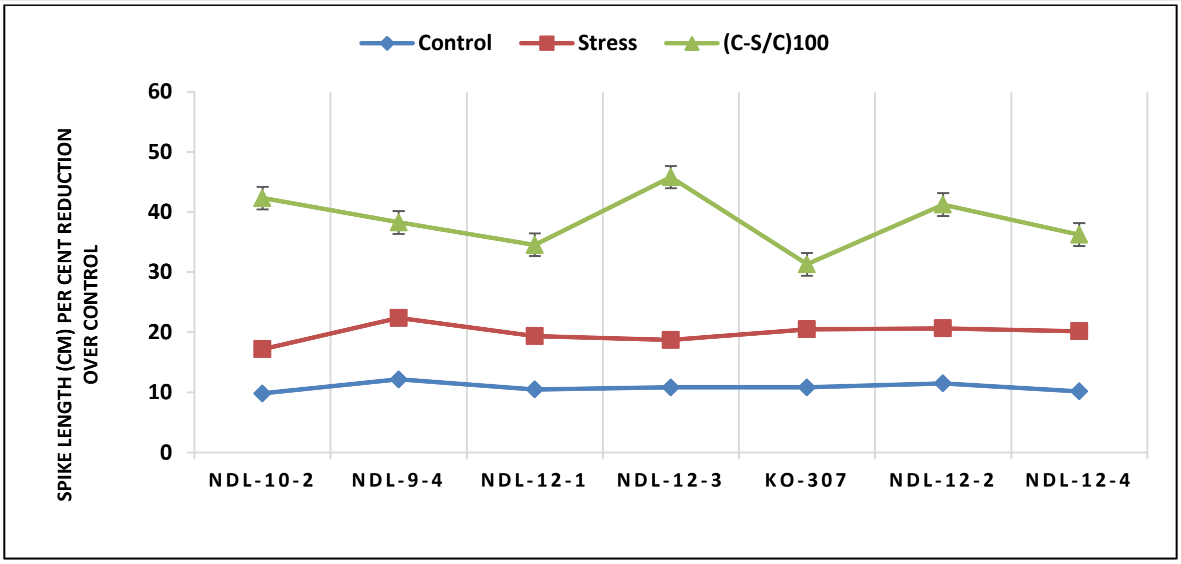

Fig. 3: Effect of heat stress on spike length (cm) of wheat lines

Wheat lines showed genetic variability in number of grains in main spike under control and stress condition (Fig. 4). High number of grains in main spike was noted in NDL-12-3 (65.33) and NDL-12-1 (57) while less number of grains recorded inNDL-9-4 (41) and NDL-12-3 (40).Heat stress reduction the grains in main spike irrespective of wheat lines. High reduction in number of grains in main spike was obtained in NDL-10-2 (47.03%), NDL-12-4 (45.02%), NDL-12-3 (38.77%) and NDL-12-1 (36.84%) while less in KO- 307 (31.57%), NDL-12-2 (27.22%) and NDL-9-4 (21.95%) under heat stress regions. Number of grains finally contribute the grain yield. High grain number per spike showed positive correlation with grain yield per plant in control and stress condition[10].

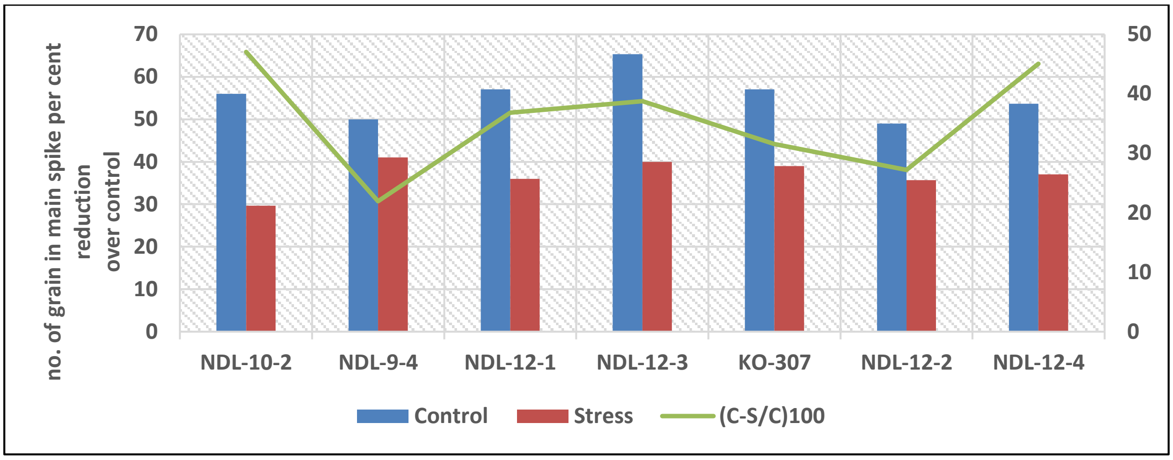

Fig. 4: Effect of heat stress on no. of grain in main spike of wheat lines

The recording of test weight (g) under control and stress condition (Fig. 5). The maximum test weight was recorded in NDL-10-2 (40.94 g) while minimum in NDL-12-2 (33.52 g) under control condition. Heat stress significantly reduced the maximum test weight NDL-12-4 (32.6 g) while minimum in NDL-12-3 (20.17 g). According to Hays et al[6]. (2007) stress occurring after anthesis often has detrimental effects on wheat grain yield by hastening maturity, triggering premature senescence, shortening grain filling duration and reducing net assimilates and 1000 kernels weight.

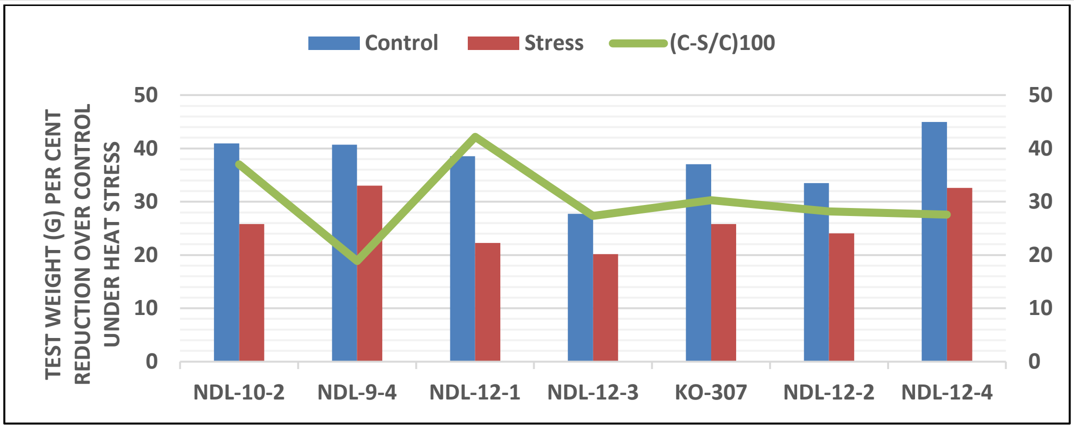

Fig. 5: Effect of heat stress on test weight (g) of wheat lines

The grain yield varied among wheat varieties in normal and heat stress condition (Fig. 6). NDL-12-3 showed maximum grain yield (8.25 g plant^{-1}) in control, but it per cent reduction (78.66%) was also high in heat stress environment. NDL-12-2 and NDL-12-4 showed less reduction of 34.09% and 35.82% respectively due to its generic level of heat tolerance. Grain yield is decided by mutagenic factors. It depends upon genetic potential and tolerance again stress in plants. Heat stress decreases the yield due to affecting growth and development processes, lowering the yield component potential and affecting the activity of key enzymes that contribute a lot during grain filling and development[19].

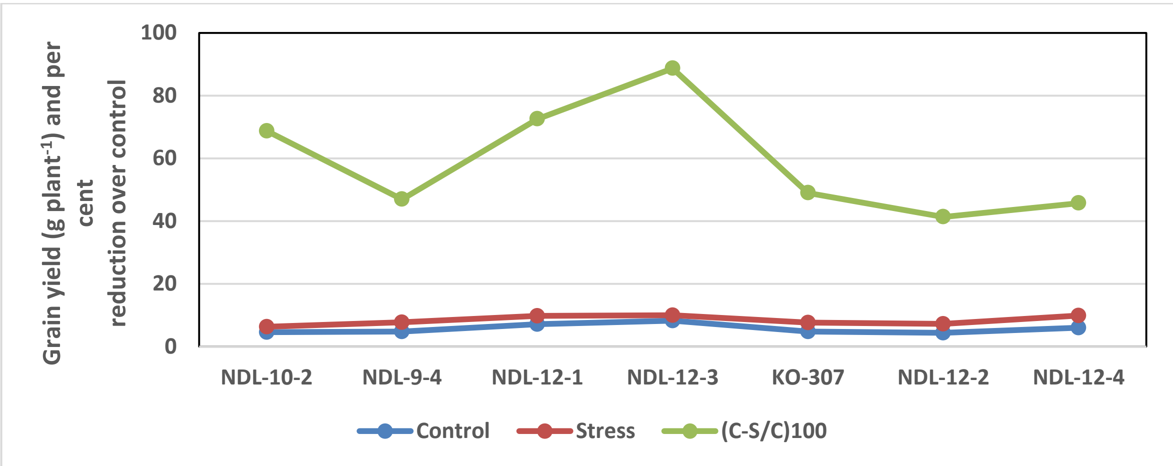

Fig. 6: Effect of heat stress on grain yield (g plant^{1}) of wheat lines

CONCLUSION

Heat stress significantly reduced growth and yield irrespective wheat lines. Under the late sowing, heat stress drastically No. of tillers, Plant height (cm), Spike length (cm), No. of grain in main spike, Grain yield per plant and Test weight in wheat lines. High per cent in NDL-12-1 (42.15%), NDL-10-2 (37%), KO-307 (30.26%). High percent reduction was noted in NDL-12-3 and NDL-12-1 in comparison to NDL-12-2 and NDL-12-4. Therefore, the lines which showed for per cent reduction in grain/sample also showed less reduction in grain yield.

Acknowledgement

Authors are very much thankful to UPCAR for providing grant during course of research.

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