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Review Article

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Variation of Thermal Environment and its Effect on Performance of Wheat (*Triticum aestivum* L.) Under Future Global Warming

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Abstract

High temperature during post-anthesis period has been found to decrease the yield and the yield attributing characters of Wheat (*Triticum aestivum* L.). While, High yield is correlated with low soil temperature between shoot elongation and beginning of heading. The increased carbon dioxide concentration is helpful in simulating the development of tiller buds. Carbon dioxide enriched wheat produced about twice the dry matter of control plants. Tillers and earhead numbers is also increased by carbon dioxide enrichment irrespective of N supply. Agroforestry can provide suitable microclimatic conditions for growth and development of wheat and also help to mitigate the hot weather and dry wind effects which are injurious to wheat plant at grain filling. Grain filling is not greatly affected by short shading period but increasing the length of period of shading brought about an accelerating yield reduction. The crop is most sensitive to shading at the time of rapid ear growth.

Keywords: Wheat (*Triticum aestivum* L.); Modified Thermal Environment; Agroforestry; Climate Change.

Introduction

Global circulation climate models predict an increase in mean ambient temperatures between 1.8 and 5.8^{0}C by the end of this century (IPCC, 2007). Future climates will also be affected by greater variability in temperature and increased frequency of heat waves (Pittock, 2003). In addition to the general warming, a predicted increase in the occurrence of heat waves is likely to result in further yield losses (Long and Ort 2010).Exposure to excessive temperatures during development reduce the yield of many in the tropics. Increasing global temperatures and increasingly frequent heat waves are likely to have similarly negative effects on natural systems. The heat stress is mainly encountered in combination with water deficit and excess load of radiation , it can be difficult to separate the effects of the three factors. The effect of heat stress on staple crops like wheat can be severe depending on the developmental stage of the plants. High temperatures shorten the duration of various phenophase, accelerating their development and thereby limiting the ability of the plant to accumulate the carbohydrate necessary for grain growth. Wheat is exposed to high temperatute in many arid countries mean day temperatures beyond threshold during much of the growing season and so heat stress can significantly reduce crop yield by accelerating plant senescence, diminishing seed number and seed weight. Therefore, it is very much needed to acess the impace of changing climatic condition on overall growth and yield of wheat.

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Effect of Shading on Wheat

The effect of light on growth inhibitor in wheat root was studied. It was found that a growth inhibitor was present in the acid fraction and its concentration was much higher in root tips grown in light than in thosegrown in darkness. Masuda (1962). Friend *et al.*

(1962) reported that the length of lemina increased with each increase in temperature, but the breadth and thickness decreased. The greatest area of individual leaves was formed at 20^{O}C. The greatest leaf area was also formed at 1000- 1750 f.c. Change in leaf shape under different environmental conditions were not directly related to change in leaf dry weight. Hsia and Wang (1964) studied the effect of light intensity on growth and development of wheat. In shaded plants (to 10 per cent of sunlight intensity) from sexual cell formation to flowering filled grain number / spike was markedly decreased, but weight / grain was increased. On shading from flowering to ripening number / spike was somewhat decreased and both weight / spike and weight / grain increased. There was a similar difference between the effects of shading from the first 10 days after flowering and for the following 10 days.

Pendleton and Weible (1965) conducted the shading studies (30, 60 and 90 per cent of shading) on winter wheat. It was concluded that all degrees and periods of shading adversely affected grain yield, which were reduced by 37, 70 and 99 per cent respectively, by the 3 degree of shading. Light was a critical factor during the heading stage, even slight restriction for short periods reduced yield. Wardlaw (1970) concluded that low yield which resulted from high temperature during the early period was caused by a reduction in seed set, which was partially compensated by increased grain size. In contrast high temperature during the later stages reduced the weight of individual grain. Low light at both stages of development significantly reduced grain weight per ear at maturity.

Effect of temperature change on wheat

Halsa and Weir (1974) studied the effect of temperature on spikelet number of wheat and found that temperature affected spikelet number. On providing increased total amount of illumination spikelet numbers were increased. Warrington *et al.* (1977) found the most important temperature effects during the ear development phase. Plants grown at low temperature at this time had long culms large flag leaves and more potentially fertile florets in each spikelet. The number of florets which produced harvestable grains and the weight of these grains at maturity, were affected by temperature during the grain growth stage. Closed relation was found between wheat and barley crop growth rates and radiation absorbed. It was reported that 2.2 g dry matter was produced per Maga Joule of radiant energy absorbed which was equivalent to a growth efficiency of approximately 3.9 percent. Gallagher and Biscoe (1978)

The increasing temperature from 21 / 16^{0}C to 30 / 25^{0}C, during the period of development from anthesis to maturity found to substantially reduce grain dry weight in wheat. Altering either the demand for photosynthate by grain removal or the supply of photosynthates by a defoliation and shading treatment, did not prevent the reduction in grain dry weight due to high temperature and this was a further indication that the temperature effect occured mainly within, or close to the grain itself and did not result from an effect on availability of photosynthate (Wardlaw et al. ,1980). Manogaran (1982) proved that factors most significantly associated with wheat yield were monthly and seasonal values of potential evapotranspiration, soil moisture deficit and precipitation. Climatic variables accounted for > 30 per cent of yield variance. Bhuller and Jenner (1983) observed that brief warming of ears of wheat cv. Sonora reduced total grain weight due to reduction in grain number, individual grain weight and water content of the grain. Amores-Vergara and Cartwright (1984) showed that when wheat cv. Sonoro 64 was exposed to high temperature during 6 developmental stages and compared with growth of controls at continuous high (27^{o}C) and continuous low (17^{o}C) temperatures, the time for sowing to maturity was reduced more by later exposure to high temperature, especially from anthesis to maturity.Timefeenko and Urusova (1984) determined the correlation between grain yield and different meteorological factors using several regression equations and showed that heat sum, photosynthetically activated radiation, number of sunshine hour and R.H. were not factors limiting yield of winter wheat in dry zone of North-Caucasus. Iizuka *et al.* (1987) studied the influence of air temperature on growth of wheat cv. Norin - 61 from 1972 until 1986. Photoperiod affected maturity date more than air temperature with little variance between years. Morrison (1988) studied about the profound effect of increased atmospheric CO_2 concentration on plant growth and discussed the interactions of increased CO_2 concentration with low light intensities, restricted water supply, low temperature and atmospheric pollutants in wheat, V*icia faba,* peas, *Liquidambar styraciflua,* soybean and okra. Caldiz and Sarandon (1988) grew wheat variety cv. Klein Toledo and Lapaz INTA that were and were not shaded with plastic grey mosquito mesh from seedling emergence until maximum spikelet number (M.S.N.), from MSN until maximum floret number stage (M.F.N.), from M.F.N. until anthesis, and from anthesis until grain maturity. Shading reduced final yield from 4.5 t / ha to a minimum of 2.65 t / ha with shading during development stages. Shading had no effect on 1000-grain weight or dry matter distribution between leaves, stems and ears. Shading did not decrease maximum spikelet number in either cv. but spikelet number / ear decreased 15 per cent in Lapaz INTA and was not affected in Klein Toledo during period between terminal spikelet and maximum floret number stages of development.

Tashiro and Wardlaw (1989) reported that grain weight at maturity of wheat cultivars Banks was reduced by about 5 per cent for each 1°C rise in daily mean-post anthesis temperature in the range from 17.7 to 32.7°C using grain weight at 17.7°C as the base. In both wheat and rice there was a reduction in the duration of grain growth with increasing temperature up to a mean of about 26.7°C. In this range wheat did not show compensating increase in rate of dry matter accumulation. Above 26.7°C, the rate of dry matter accumulation feel down and the duration of grain growth continued to decrease.

Dawson and Wardlaw (1989) confirmed that exposure to high temperature only during anthesis generally had a small effect on grain set, where as other showed a decrease. Al-Khatib and Paulsen (1990) grew wheat of ten genotypes from major world wheat producing regions under moderate (22 / 17°C day / night) and high (32 / 27°C day / night) temperatures for 2 weeks as seedlings or from anthesis to maturity and showed that high temperature reduced mean kernel weight 20 per cent and mean grain yield 23 per cent relative to the moderate temperature. Relative grain yield was strongly influenced by decreased duration of photosynthetic activity which ranged widely in 10 genotypes. Genotypes that were most tolerant of high temperature had stable rates and / or long duration of photosynthetic activity high kernel weights, and high harvest indices.

Tashiro and Wardlaw (1990) reported that grain sterility was increased by high temperature 2-3 day prior to anthesis in wheat cv. Bank and this response was enhanced by high humidity. Parthenocarpic grains were induced by high temperature between anthesis and 3 days after anthesis. High temperature, 6-10 d after anthesis resulted in notched, split and opaque grains.

In an experiment Hunt et al. (1990) grew winter habit cultivars in doors under 16-h photo period and at a day / night temperature 20 / 15⁰C and spring habit cultivars at temperature ranging from 15 / 15⁰C to 30 / 25⁰C. Grain filling duration of spring wheat ranged from 56.4 to 47.0 d at 15 / 15⁰C and from 23.8 to 18.1 d at 30 / 25⁰C. Grain number per spike decreased from 15 / 15⁰C to 30 / 25⁰C. Hocking and Meyer (1991) studied the effect of CO_2 enrichment and nitrogen stress on growth in wheat and maize and concluded that CO_2 enriched wheat produced about twice the dry matter of control plants at all levels of N supply. There was no effect of CO_2 enrichment on specific leaf weight. CO_2 enriched wheat plant accumulated more N than the control but the proportional increase in N content was not great as than in dry matter. CO_2 enrichment increased N-use efficiency by wheat.

Savin and Slafer (1991) studied the effects of shading on the yield of Argentinian wheat crop. It was found that an applied shading treatment of 50 per cent of incident radiation reduced biological yields, above ground dry matter and grain yield of field grown wheat. Mehra *et al.* (1991) reported that in wheat cv. Kalyan sona and HD 2428, high temperature during the Ist week after anthesis decreased grain number / spike but increased 1000 grain weight, while high temperature in the 2nd and 3rd weeks after anthesis decreased 1000 grain weight particularly in HD 2428.

Rawson and Zajac (1993) reported fewer spikelets production per leaf at short photopheriod. High temperature delayed spike emergence in wheat both in controlled environments and in field. Lombardo et al. (1993) conducted field trial on four wheat cv. and showed that effective filling period duration decreased and grain filling rate increased with increasing air temperature. Both were positively correlated with number of seed per spike and grain yield. Sun (1994) reported that seedling growth and dry weight and were higher in different day / night temperatures than in constant temperatures. The shoot : root ratio was lower with diurnal temperature variation. Lower night temperatures were advantageous to root growth.

Scheeren et al. (1995) reported that shading significantly reduced the yield components and increased number of sterile spikelets per spike. The reduction caused by excess soil water were less significant, mainly as a result of environmental conditions during the growing season. Wardlaw and Moncur (1995) reported that high temperature resulted in a considerable drop in kernel dry weight at maturity. The importance of rate of kernel filling in determining varietal responses to high temperature illustrated the need to isolate the effect of temperature on process in kernel during the linear phase of growth. Chaurasia *et al.* (1995) showed in a field trial that grain filling duration depended on temperature and rainfall during February and March, but rate of grain growth depended on PAR interception and canopy temperature.

Delayed planting of wheat reduced the plant height, days to heading, days to maturity and grain filling duration and ultimately showed the reduction in yield and yield components (Din & Singh, 2005).

To sustain wheat productivity under late planting, development of heat tolerant genotypes has been suggested. There is an average yield loss 1.7% per day, when sown beyond optimum time (Mohammadi, 2002).Grain filling duration contribute to the final yield of a plant that is a product of rate of grain filling and du-ration of the grain filling period. High temperature during grain-filling period may be with a degree of plant heat escape due to shortening of the grain filling duration by 0.4 day for each 1 °C increase in mean temperature from optimum temperature. (Tahir & Nakata, 2005).

Hays et al. (2007) reported that stress occurring after anthesis mostly has detrimental effects on wheat grain yield by hastening maturity, trigger premature senescence, shortening grain filling duration and reducing net assimilates and 1000 kernels weight. Heat stress during grain filling is responsible for shortening of grain growth period and improper grain filling affects over-all yield of wheat crop (Rane et al. 2007).

Conclusion

Excessive heat load affect the wheat crop during reproductive phase Under Mediterranean climate after anthesis. Modification of microclimatic conditions on field basis is not so easy. Introducing trees in the wheat field offers much scope for useful management of micro-climatic conditions for favourable purpose and thereby may also increase the yield as compared to monoculture. Therefore further research is needed to utilize the trees to optimize microclimatic conditions under global warming.

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