Wheat sterility - identification of probable causes and solutions

M. Saifuzzaman[1], Q.A. Fattah[2], A.F.M. Maniruzzaman[3], M.S. Islam[4] and Craig Meisner[5]

[1] Senior Scientific Officer, Wheat Research Centre, Bangladesh Agricultural Research Institute, Gazipur 1701, Bangledesh Email wheatjoy@dhaka.net
[2] Professor, Department of Botany, University of Dhaka, Dhaka 1200, Bangladesh, e-mail: botany@du.bangla.net
[3] Ex-Director (Research), Bangladesh Agricultural Research Institute, Gazipur 1701, Bangledesh
[4] Director General, Bangladesh Agricultural Research Institute, Gazipur 1701, Bangledesh Email baridss@bttb.net.bd
[5] CIMMYT Agronomist NRG, P.O. Box 6057 Gulshan Dhaka 1212 Bangladesh
www.cimmyt.org/bangladesh/ Email c.meisner@cgiar.org

Abstract

The probable cause(s) of spikelet sterility of wheat and solution(s) thereof was investigated in a sub tropical environment. Experiment was conducted in a controlled environment, both in field and in greenhouse, simulating weather and soil conditions (high humidity and low light intensity due to dense fog and low soil boron) of the wheat sterility-prone areas of the country.

High humidity and low light intensity during Zadoks' 45 to 69 was mainly responsible for high spikelet sterility in wheat. Boron deficiency in soil and different soil type appeared to be less contributing factors in this regard. Boron concentration in the flag leaves and young spikes at booting increased with the soil applied boron but did not contribute to reduce the problem as and when there was high humidity and low light intensity prevails during certain plant developmental stages. Plants were found more sensitive to the environmental stress in Zadoks' 39 to 69 and Zadoks' 45 to 69 stages in 1993-94. It was confirmed in a precise trial the following year that a combination of high humidity and low light causes sterility more than the low light alone. This kind of environment was the most harmful during the eight-day period from Zadoks' 39 followed by that from Zadoks 45.

Media summary

High humidity and low light intensity during eight days period from Zadoks' 39 and 45 induce wheat sterility rather than soil boron under Bangladesh conditions.

Keywords

Environmental stress, Wheat sterility, High humidity, Low light intensity, Soil boron

Introduction

In recent decades, sporadic and/or massive occurrence of sterility in wheat is not a problem of Bangladesh alone, but it is a widespread problem in the subtropical wheat growing areas of Asia, where production has expanded since the 1960s. Problem areas so far identified include Orissa, Terai regions of West Bengal and Assam (Mandal 1994); Eastern Terai region and other parts of Nepal (Subedi and Budhathoki 1994); Northern Thailand (Rerkasem *et al*. 1989); and Heilongjiang (Li *et al*. 1978) and Yunnan (Yang 1992) provinces of China.

In the literature, a number of reasons have been put forwarded on the possible causes of sterility in wheat. Among them, deficiency of boron (B) in the soil causing failure in grain setting through male sterility (Rerkasem *et al*. 1989, Subedi and Budhathoki 1994); high humidity and low light intensity during the period between floret initiation and anthesis (Rawson 1996b); insufficient assimilate supply during the period between 17 and 9 days before anthesis (Fischer and Stockman 1980). Although several reasons have been put forward to explain the phenomenon of spikelet sterility in wheat in different countries by different scientists, the prime factors responsible for spikelet sterility in wheat in Bangladesh is yet unknown, though there was a preconceived idea that low soil boron in the sterility prone areas might be a major contributing factor in this regard (Saifuzzaman 1995). The present investigation is aimed to investigate probable cause(s) and solution(s) regarding the wheat sterility problem.

Methods

Experiments were carried out in pots in controlled conditions at Bangladesh Agricultural Research Institute (BARI) central station, Joydebpur, Gazipur, Bangladesh. In 1991-92 and 1992-93, the experimental treatments were (1) Control (a set of pots kept remain open throughout the plant developmental stages) and (2) Covered by thick white transparent polyethylene from 5 pm to 11 am of the next morning during plant developmental stage of Zadoks 45 to 69 (Zadoks *et al.* 1974) as environment; (1) 0.0 kg B ha^{-1} (control i.e., B not applied) and (2) 2.0 kg B ha^{-1} as boron. Three different soils are (1) Joydebpur (heavy textured clay, sterility did not occur in 1990-91), (2) Kaunia (light textured loam, sterility occurred in 1990-91) and (3) Birgonj (light textured loam, sterility occurred in 1990-91).

In 1993-94, the experimental treatments are T_1 = control (pots kept outside the glasshouse i.e., in the field), T_2 = high humidity and low light (created in a controlled glass house) and T_3 = high humidity and low light (created by covering with thick double layered white markin cloth in the field). The environmental treatments were given G_1 = from Zadoks' 39 to 69, G_2 = from Zadoks' 45 to 69 and G_3 = from Zadoks' 60 to 69. In 1994-95**,** treatments are T_1 = control (pots kept outside i.e., on the field), T_2 = high humidity and low light (created by covering with thick double layered white markin cloth and water was poured and kept beneath the pots) and T_3 = low light (created by covering with thick double layered white markin cloth). Treatments were given G_1 = from Zadoks' 39 for eight days, G_2 = from Zadoks' 45 for eight days and G_3 = from Zadoks' 60 for eight days. The soil used in pot experiments of 1993-95 was collected from the experimental plots of Wheat Research Centre (WRC), Dinajpur where severe wheat sterility observed in 1992-93. Complete randomized design was followed and the percentage of sterility was determined in the following way:

$$\text{Sterility } (\%) = \frac{(a-b)}{b} \times 100$$

Where; a = average number of florets $spike^{-1}$
b = average number of grain set $spike^{-1}$

Soil and tissue boron were analyzed in the following way respectively:

Soil boron

Available boron in ppm was determined by hot water extracting using Azomethine-H as the colour development reagent (Handbook on reference methods for soil analysis 1980). Quantification is performed by atomic absorption spectroscopy. Available soil B in different soils was 0.07, 0.04, 0.05 and 0.0 ppm in case of Joydebpur, Kaunia, Birgonj and WRC soils, respectively.

Tissue boron

Flag leaves and young spikes were collected from each pot at booting stage. To avoid contamination, collected samples were first wrapped with white tissue paper and were kept in paper envelopes. Collected plant samples were oven dried at 70^0C for 48 hours, grounded in Willey mill and sieved through 1mm mesh. Dry ashing technique was used to extract boron from the ground plant samples and azomethine-H method was used to determine boron content in the extracted solution according to the procedure of Loshe (1982).

Results

Results presented in figure 1 clearly showed that simulated environment with high humidity and low light during Zadoks 45 to 69 (booting to anthesis completed) had prominent effect on the percentage of spikelet sterility in the wheat variety Kanchan in both the years of 1991-92 and 1992-93. Simulated environment (polyethylene covered) increased the sterility percentage by 75.1% in 1991-92 and 86.3% in 1992-93 as compared to natural (open) environmental conditions. Soils collected from previous year's sterility affected farmers' field of Kaunia and Birgonj, and non-sterility affected farmers' field of Joydebpur, also did not have any significant influence on the sterility percentage of the wheat variety Kanchan.

Application of boron at rate of 2.0 kg ha^{-1} did not show any influence on the spikelet sterility in both the years (Figure 1). Plant boron analysis indicated that the B concentration in the flag leaves and in the young spikes at booting was sufficient in case of without B and increased with B application (Figure 2). It could be noted here that 3.0 ppm B concentration in the flag leaves and 2.0 ppm B in the young spikes at booting were the critical levels according to Reuter and Robinson (1986).

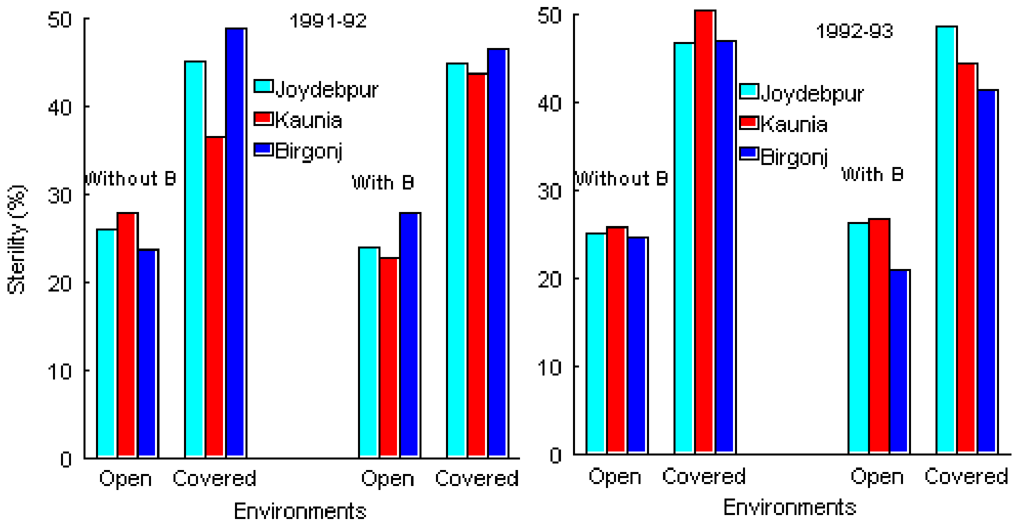

Figure 1. Effect of environment, boron (B) and soils (Joydepur, Kaunia, Birgonj) on the sterility (%) of wheat variety Kanchan in 1991-92 and 1992-93.

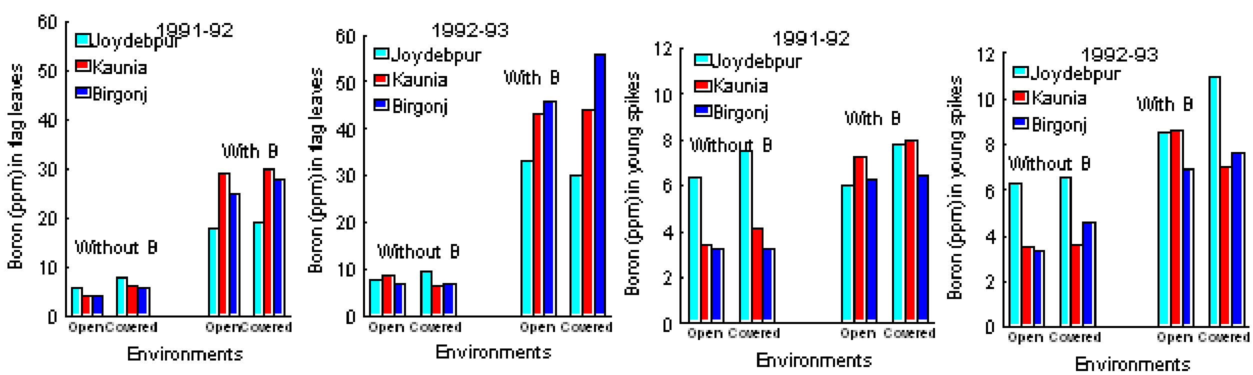

Figure 2. Effect of environment, boron and soils on the flag leaves and young spikes boron concentration (ppm) at booting of wheat variety Kanchan in two years.

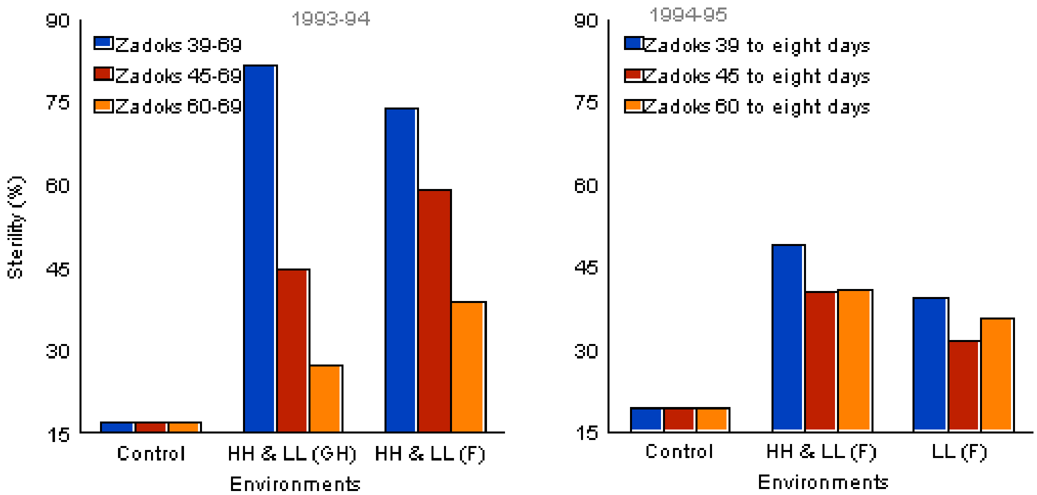

Figure 3. Effect of artificially created high humidity (HH) and low light (LL) in glasshouse (GH) and field (F) at different growth stages on the sterility (%) of wheat.

In 1993-94, relatively highest sterility occurred due to artificially created high humidity (HH) and low light (LL) intensity in the field (F) followed by same environmental condition in the glass house (GH). In 1994-95, the highest sterility (%) was noticed due to high humidity and low light intensity followed by low light intensity alone only in field condition (Figure 3). Most sensitive stage in terms of sterility was found to be Zadoks' 39 to 69 (pre-booting to anthesis completed) in 1993-94 and Zadoks' 39 to eight days (pre-booting to 8 days) in 1994-95 (Figure 3). In both the years, spikelet sterility did not occur when there was no environmental stress though the soil was also from the sterility prone areas (from the sterility-affected field of Wheat Research Centre, Dinajpur in 1992-93) and soil B was below the critical level. The findings so far obtained regarding the influence of artificially simulated environments i.e., high humidity and low light intensity, supported the findings of Rawson *et al*. (1996b). Rawson (1996b) also reported that the critical period of up to one week in length, extending from the time of emergence of flag leaf tip to fully expanded flag leaf and the present findings are in accord with this.

Probable solutions

Development of sterility tolerant wheat genotypes through having well-developed stomata aperture which will keep on transpiration under high humidity and low light, and thereby help to gain more assimilates and/or essential nutrients like B are suggested. Genotypes with healthy root systems needs to be identified so that the plant gains access to more essential nutrients and water from the soil.

Conclusion

From the present investigations, it is evident that under Bangladeshi conditions, both environment and plant developmental stage at which environmental stresses occur play an important role in causing wheat spikelet sterility, more so than boron concentration in both soil and plant.

Reference

Fischer RA and Stockman YM (1980). Kernel number per spike in Wheat (*Triticum aestivum* L.): Responses to preanthesis shading. Aust. J. Plant Physiol. **7**: 169-180.

Handbook on reference methods for soil analysis (1980). The council on Soil Testing and Plant Analysis. Athens, Georgia.

Li WH, Kui MC, Chao WS, Jern HP, Li CR, Chu WJ and Wang CL (1978). Studies on causes of sterility of wheat. J. Northeastern Agric. College. 3: 1-19.

Loshe G (1982). Microanalytical azomethine-H method for boron determination in plant tissue. Commun. Soil Sci. Plant Anal. 13: 127-134.

Mandal AB (1994). Effect of boron on wheat (*Triticum aestivum*) varieties and on boron and nitrogen concentration of plant tissues. Indian J. Agric. Sci. 64: 783-784.

Rawson HM (1995). Parameters likely to be associated with sterility. p.9-43. *In* R. W. Bell and B. Rerkasem (ed.) Causes of Sterility in Wheat. Environmental Science Report 94/6.

Rawson HM (1996b). The developmental stage during which boron limitation causes sterility in wheat genotypes and the recovery of fertility. Aust. J. Plant Physiol. 23: 709-717.

Rerkasem B, Saunders DA and B. Dell. (1989). Grain set failure and boron deficiency in wheat in Thailand. J. Agric. 5(1): 1-10.

Reuter DJ and Robinson JB (1986). Plant Analysis. An Interpretation Manual. Inkata Press. Melbourne, Australia.

Saifuzzaman M (1995). Sterility in Wheat in Bangladesh. In: Bell RW and Rerkasem B. ed., Causes of Sterility in Wheat, pp. 57-72. Proceedings of a Workshop held at Chiang Mai, Thailand, 25-28 July 1994. Environmental Science Report 94/6, Murdoch University, Western Australia wheatjoy@dhaka.net.

Subedi KD and Budhathoki CB (1994). Wheat sterility problem in Nepal: research at Lumle Agricultural Research Centre. Seminar Paper No. 94/16. Pokhara, Nepal: Lumle Agricultural Research Centre.

Yang YH (1992). Wheat boron deficiency in Yunnan, China. p. 72-75. *In* C. E. Mann and B. Rerkasem (ed.) Boron Deficiency in Wheat. Wheat Special Report No. 11: CIMMYT, Mexico D. F.

Zadoks JC, Chang TT and Konzak CF (1974). A decimal code for the growth stages of cereals. Weed Res. 14: 415-421.