Addressing Wheat Sterility through Nutrient Management

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Introduction

Grain set failure or sterility in wheat is an important yield constraint in the rice-wheat system of South and Southeast Asian countries including Bangladesh occurring in some years but not in others . Wheat sterility was first observed in Brazil in 1962 (Da Silva and Da Andrade, 1980). Widespread sterility was observed in Nepal in 1964 when improved and high yielding wheat cultivars were introduced (Misra et al., 1992). Li et al. (1978) published the first report of large-scale wheat sterility describing 40,000 ha of wheat in Heilongjiang Province in North China.

In Bangladesh sterility was first noticed in the Mexican wheat variety, Tanori 71 in the Thakurgaon seed increase farm of the Bangladesh Agricultural development Corporation in the mid seventies (Saifuzzaman and Meisner, 1995). Since then, spikelet sterility has been observed sporadically in different areas of Bangladesh. In 1987 and 1988, spike sterility in farmers' fields was reported from two northern districts, Rangpur and Dinajpur. Soil analysis indicated low boron levels with almost all the varieties in the affected plots showing sterility to some extent. The percentage of sterility was 84, 82, 75, 24 and 12% in Kanchan, Akbar, Ananda, Barkat and Sonalika, respectively (Sufi and Meisner, 1996). Again sterility was observed in 1998-99 in Pakistani- and Indian-origin wheat varieties Inquilab and Raj-3027, respectively, specifically in greater Rangpur and Dinajpur districts. Survey results indicated that grains/spike were 0 in high sterility fields compared to 48.8 in non-sterility fields, while 0 and 2.43 were the lowest and highest grains/spikelet in surveyed wheat fields. Sterility percentage ranged from 27% to 100%. The survey results indicated that where sterility does occur, it severely decreases the crop yields. This phenomenon is a common occurrence in rice-wheat system areas of the South Asian countries and needs much attention to establish wheat and sustain production in non-traditional wheat growing areas.

Definition

The first symptom of sterility can be seen at anthesis where the florets remain open (gaping glumes) for longer than normal, giving the spikes a transparent appearance when viewed with the sun behind them (Li et al., 1978; Rerkasem et al.,1989). When such florets are examined during anthesis, the anthers and pollen appear poorly developed and shriveled (Li et al., 1978). Da Silva and da Andrade (1983) associated sterility with the abnormal development of the male reproductive organs and called the problem male sterility. Sterility at anthesis resulted in lower grain yield or lower grain set.

In a broad sense, a sterile floret or spike is one that has no grain at maturity. Terminology and relavent measurements are used by different scientist to define wheat sterility. Some of them are given in Table-1.

Photo 1: Wheat sterility symptom during anthesis

Table 1. Summary of some definitions of 'sterility', 'fertility' and 'grain set' in wheat (Source: Rerkasem, 1995)

Publication	Term used	Measure
Single 1964 Li *et al.*, 1978	fertility, grain set sterile ear partially sterile ear, fertile ear	grains/ear no grain in any floret any grain set in up to half of florets all florets filled
Morgan, 1980	% fertile florets	% florets with seed
Saini and Aspinall, 1981	% grain set	% florets with grain (those florets judged potentially fertile)
da Silva and da Andrade 1983	% chochamento (% male sterility)	% florets without grain
Sthapit, 1988 and Rerkasem *et al.*,1989	basal florets fertility (grains /F1 + F2)	average number of grains in two basal florets of 10 central spikelets
Sthapit and Subedi, 1990	% sterility	% florets without grains
Misra *et al.*,1992	% sterility	average sterility of 100 to 250 spikes felt by hand during grain filling, each graded as 100%, 75%, 50%, 25% or 0% sterile, by degree of absence of grain
Tandon and Naqvi, 1992	sterility	% florets with grain
Rerkasem and Loneragan, 1994	% sterility grain set (index)	visual rating of gaping glumes at anthesis % grain bearing in two basal florets of 10 central spikelets

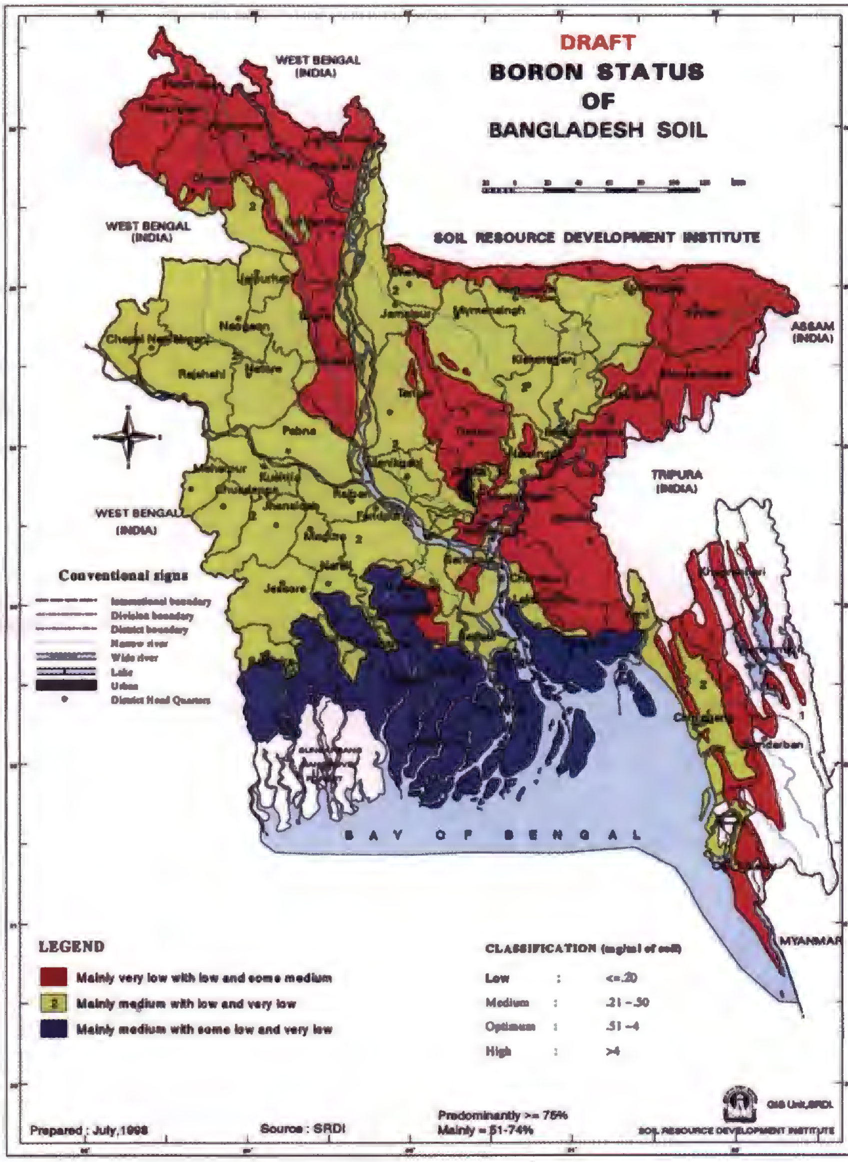
Causes of sterility

Research has shown that sterility in wheat can be caused by many environmental factors and in various combinations.

The soils of sterility-prone areas of Bangladesh are mostly sandy loam with a low pH (4.8 to 5.8). These soils are thus likely to be boron deficient (Palkovics and Gyori, 1984). The soils are also poor in organic matter, nitrogen and zinc (Jahiruddin, 1991). Boron (B) deficiency in soil has been well established as a cause of wheat sterility (Sigh et al.,1976; Subedi et al.,1993). Deficiency of copper has also been found to cause of sterility (Grendon, 1991) though the soils of Bangladesh generally have adequate Cu. Besides these nutrient deficiencies, environmental conditions can cause of sterility. These include high humidity and low light (Willey and Holliday, 1971), high temperature (Saini and Aspinall, 1982), low night temperature (Subedi et al.,1993), water stress (Saini and Asinall, 1981) and water logging (Saifuzzama and Meisner, 1995). Additionally, some genotypes are prone to sterility (Subedi et al.,1993). From the above citations and our own experiences, we summarize the causes of sterility are combinations of the following factors:

- Nutrient deficiency, particularly boron limitation and low organic matter.
- Low radiation (cloudy dull weather, fogs, mists).
- High humidity
- Low light
- High temperature
- Water logging or excess moist soil
- Genetic or varietal factors.

H. M. Rawson (1995) reported that almost all major environmental variables have been linked with sterility, but boron is the primary factor while the others act as either modifiers of boron movement or contributors to sterility in their own right.



Factors about boron

- Boron is required by the reproductive organs in relatively large concentrations.
- Boron is required continuously for cell wall development by the generative organs during their growth

- Boron probably moves into the roots passively, in association with water fluxes. Only minor amounts move in the phloem.
- Boron moves within the plant almost exclusively in the transpiration stream.

The consequence of these factors is that any restrictions in plant transpiration rate at any time during the generative stage could lead to incomplete development of the sexual organs through limiting boron movement (Rerkasem, 1995).

Critical stage

Research suggests that the critical period possibly spans 6 to 10 days, between emergence of the second-to-last leaf legule and preheading. Most sterility occurs as a result of environmental factors limiting the movement of water into and through the plant during the critical 6 to 10 days between emergence of the second-to-last leaf legule and preheading and, by association, limiting the movement of boron into the generative regions (Rerkasem, 1995).

Soil factors limiting boron uptake

- Low boron concentrations in the soil, i.e. boron ranging between 0.12 and 0.38 mg/kg can result in sterility, but the degree depends on the location
- High pH or low pH which can prevent the roots from taking up the available boron

Environmental factors limiting transpiration and boron uptake

- High humidity or more correctly, low vapour pressure deficit (VPD) means that the air has a limited capacity to accept water vapour from the plant's leaves, so transpiration could be low even though the stomata are open
- Dew, fogs and mists. These make leaf to air VPD small.
- Low radiation, associated with cloud cover, mists and fog closes the stomata to a degree that depends on radiation level and thus limit transpiration

- Drought and low humidity cause stomata closure to conserve plant water
- Water logging causes stomata to close in wheat

Photo 2: Filled spikes with boron (Left) and unfilled spikes without boron (Right) in the field in 2005

Two main factors associated with wheat sterility

i. Boron levels in the soil
ii. Less transpiration during the critical phase hindering the uptake of boron though these factors are driven by many variables.

Response of wheat to boron

Researchers have conducted experiments to know the response of wheat to boron application. A few of the results are cited here.

Boron is an essential micronutrient for normal growth and development of plants. It plays a crucial role in fertilization in higher plants, but anthers appear to be particularly sensitive to B deficiency (Vasil, 1963). Cheng and Rerkasem (1992) found that in

B deficient wheat, the pollen does not accumulate starch and the nuclei, when present, are abnormal. Rerkasem (1993) found that the fertility of both male and female plants of the wheat florets appear to be affected by boron deficiency. From research in Nepal, Subedi et al. (1993) found that there was a significant reduction in percent sterility with the application of boron and that there was also a highly significant boron and genotype interaction (Fig. 1). Bodruzzaman et al. (2003) reported that the yield benefits due to application of 2 kg B/ha from borax and boric acid and 3 kg B/ha also from borax and boric acid were a 19%, 20%, 28% and 23% increase in yield over control, respectively (Fig.2). Four field trials were conducted in two agro-ecological regions of Bangladesh with an objective of examining the effect of B, Cu and Moon grain formation in wheat. From their experiments Jahiruddin et al (1992) reported that the use of boron caused a higher formation of grains (Fig. 6) resulting in higher

Photo 3: Sterile spikes (Left) and filled spikes (Right)

Photo 4: Sterility in the experimental field at maturirty without boron in 2005

grain yield compared to Cu, Mo or control treatment (Fig.-3). Again Jahiruddin et al (1995) reported that B had a marked influence on grain set and yield (Fig.-4). Bodruzzaman et al. (2002) stated that boron had tremendous effect on wheat grain yield in boron deficient soils (Fig. 7).

Photo 5: Filled spikes in the experimental field at maturity with boron in 2005

There was no significant influence of boron on sterility in 1994-95 in Bangladesh due to humidity, light, temperature and rainfall during the important critical growth stages were not so adverse (Sifuzzaman1995). But significant difference was observed between genotypes during those years (Fig.-5). Low organic matter, low boron concentrations and low boron availability generally occur concurrently. Addition of organic matter can increase boron concentrations and reduce the risk of crusting, which can cause water logging. Also, the benefits of OM to soil structure and root growth are well documented. The On-Farm Research Division of the Bangladesh Agricultural Research Institute has many research sites in northern Bangladesh for which it makes and annually applies compost at the full-recommended rate. These fields have never exhibited sterility, despite growers' plots nearby having sterility.

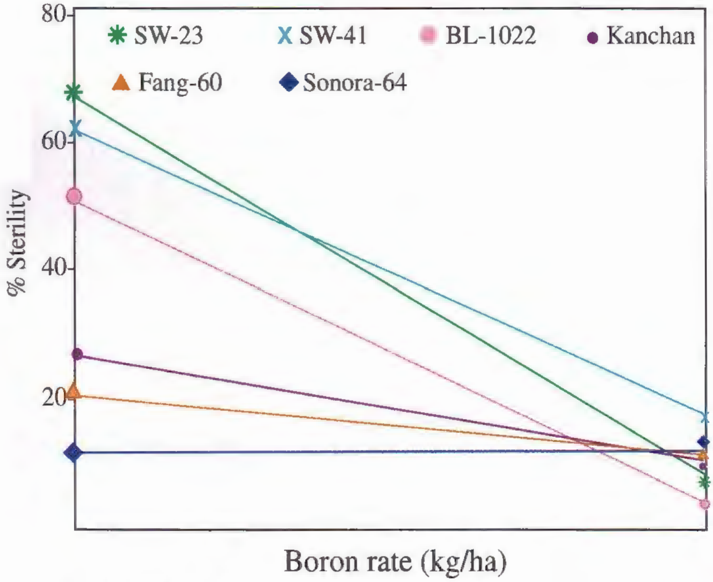


Fig. 1 Effect of boron on percentage strerility of six genotypes of wheat at Khairanitar (480m), Nepal, 1992-93

Source: Subedi *et al.*,1993

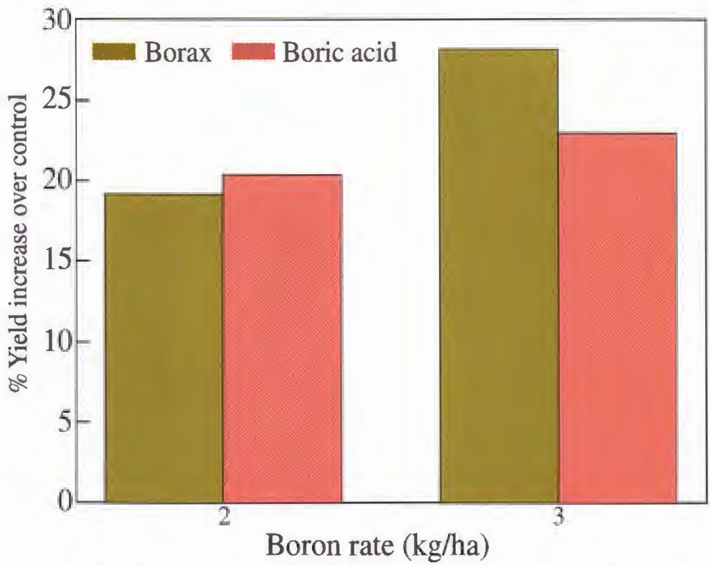


Fig. 2 Effect of boron sources on grain yield

Source:Bodruzzaman, et al., 2003

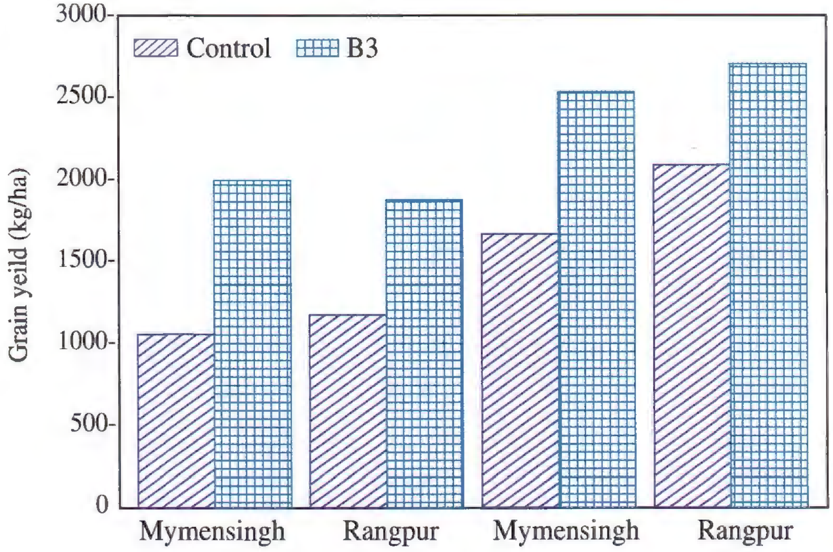


Fig. 3 Influence of boron on wheat grain yield
Source: Jahiruddin *et al.* 1992

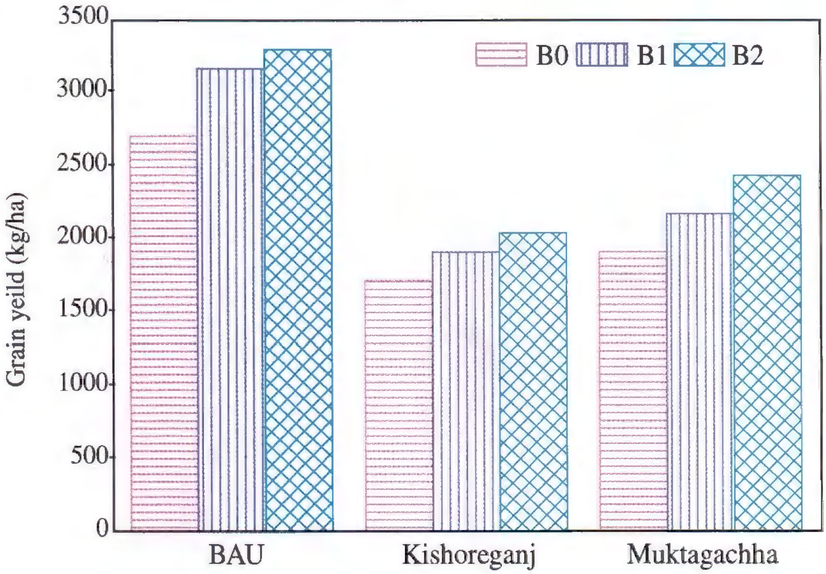


Fig. 4 Effect of boron on wheat
Source: Jahiruddin *et al.*, 1995

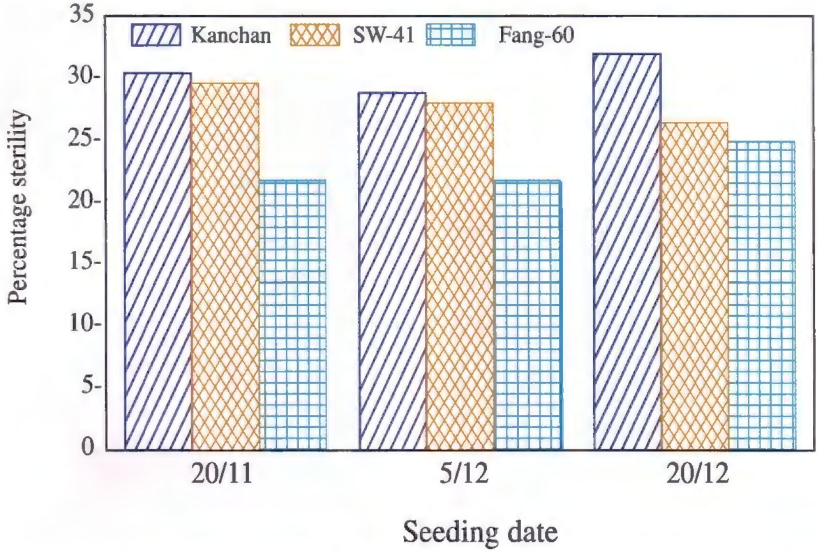


Fig. 5 Effects of genotypes and seeding date on percentage sterility, WRC, Dinajpur, 1994-95
Source: Saifuzzaman, 1995

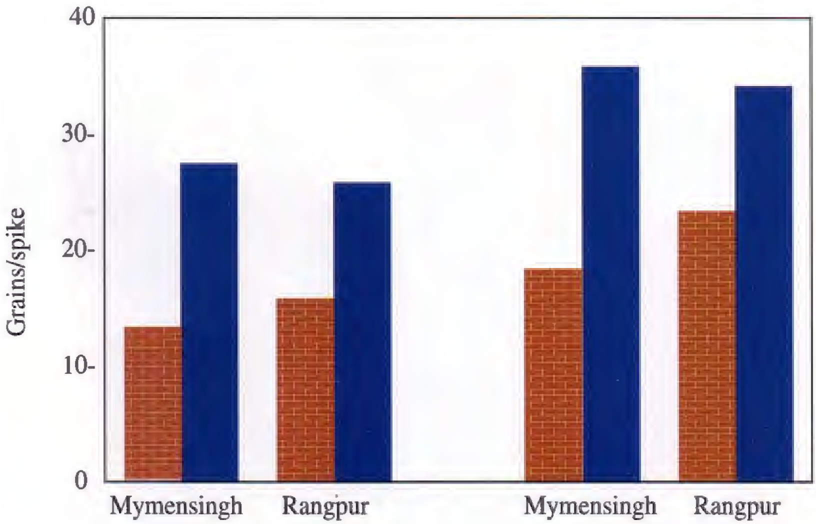


Fig. 6 Influence of bron on grains/ spike
Source: Jahiruddin *et al.* 1992

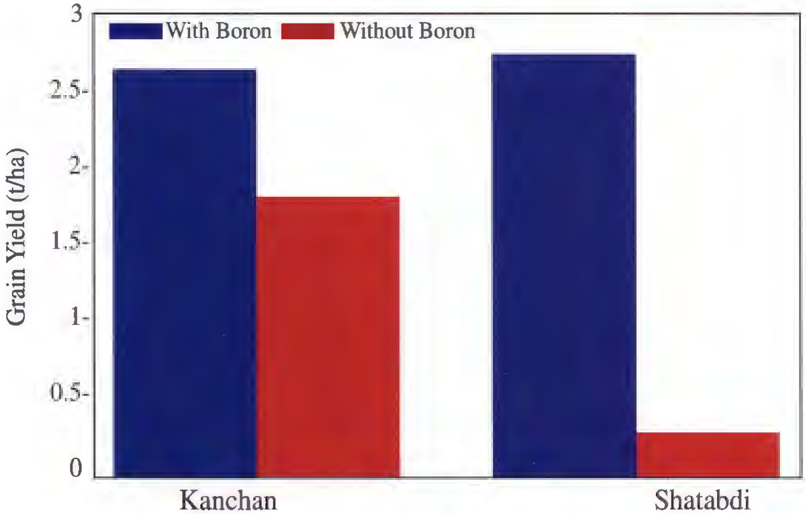


Fig. 7. Effect of boron on wheat yields in 2001-02
Source: Bodruzzaman et al., 2003

Photo 6: Sterility in the farmer's field without boron in 2005

Probable solutions proposed to reduce sterility

i. Use recommended dose of fertilizers with 1-2 kg boron/ha in B deficient soils
ii. Avoid water logging by controlling irrigation or by drainage immediately after rainfall especially during the critical stages 6 to 10 days between emergence of the second-to-last leaf legule and preheading
iii. Use farm yard manure (FYM) at the rate of 5-10 t/ha for optimum wheat production by reducing sterility through its enhancement of root development and supply of micronutrients
iv. Use boron efficient /sterility tolerant genotypes or cultivars

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